KENYATTA UNIVERSITY
SCHOOL OF AGRICULTURE AND ENTERPRISE DEVELOPMENT

1ST BIENNIAL INTERNATIONAL CONFERENCE PROCEEDINGS ON BRIDGING THE GAP BETWEEN SOCIETY, SCIENCE AND INDUSTRY

HELD BETWEEN 30TH NOVEMBER AND 5TH DECEMBER 2014 AT BUSINESS AND STUDENT SERVICES CENTER, KENYATTA UNIVERSITY

Edited by Waceke Wanjohi, George Kariuki, Maina Mwangi and Cyrus Gichaga

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PREFACE

Africa's greatest hope for development and freedom from poverty is closely linked to the performance of the agriculture sector. Agricultural higher education institutions (HEIs) have critical roles to play in developing well trained manpower to support a thriving agriculture sector that effectively addresses Africa's needs for food, employment, income and other benefits derived from agricultural activities. However, African HEIs face the common challenges of diminishing resources, diminishing interest in agriculture careers, weak linkages to industry and other stakeholders of the development process, and a constant need to remain relevant and responsive to the needs of society.

To extend efforts in addressing the challenges facing agriculture higher education institutions, the School of Agriculture and Enterprise Development (SAED) at Kenyatta University resolved to organise and host a Biennial Conference (every two years). This is an important forum for various stakeholders to share and exchange their knowledge and experiences, and a platform for developing networks between individuals and institutions, through which capacity and expertise can be shared to spur development.

This first conference was organised in collaboration with the Alliance for a Green Revolution in Africa (AGRA) and the Horticulture Association of Kenya (HAK), with support from the German Academic Exchange Foundation (DAAD). The conference brought together local and international Scholars, Researchers, representatives of public and private sector, development partners, Non-governmental organisations, and Community based organisations, industry and development practitioners, farmers associations and representatives, among others. The deliberations centred on innovative approaches for strengthening the interaction of academia, researchers and industry to more effectively address the needs of African small scale farmers, consumers and other members of society. Core to the theme of the conference was recognition of a need to develop a generation of agricultural researchers and agro-entrepreneurs with the knowledge and skills to tackle the challenges of the 21st Century.

This book presents the Proceedings of the 1st SAED Biennial International conference that was held from 30th November to 5th December, 2014 at Kenyatta University, Nairobi, Kenya.

It is therefore with great pleasure that we launch the Proceedings of the 1st School of Agriculture and Enterprise Development International Biennial Conference that was held in Kenyatta University, Nairobi, Kenya from 30th November to 5th December, 2014.

The five days Conference under the theme "Bridging the gap between the Society, Science and Industry" featured a rich mix of keynote addresses, technical papers and poster presentations, exhibitions, plenary panel discussions and field excursion.

The organizing committee members representing Kenyatta University, AGRA, the University of Nairobi, Horticulture Association of Kenya, DAAD, Kenya Agricultural and Livestock Research Organization and other stakeholders worked tirelessly to ensure the success of the conference. The commitment, diversity of ideas and resources contributed by the various stakeholders in the committee significantly increased the quality of deliberations and eased the task of organizing the conference. The opportunity to host celebrated Pan-African and global scholars, the next generation of young researchers, policy makers and opinion shapers, innovators and industry practitioners was a great motivation to deliver a high quality conference.

The committee greatly thanks Kenyatta University Management, Conference Organizers, Collaborators, Sponsors, Participants, Government of Kenya and all other stakeholders for their valuable contributions towards the success of the forum. We particularly thank the then Cabinet Secretary for Ministry of Agriculture, Livestock and Fisheries Hon. Felix Koskei for officially opening the conference. We are delighted to have worked together to organize this conference successfully.

ACKNOWLEDGEMENT

WELCOME REMARKS BY PROF. WACEKE WANJOHI DURING THE CONFERENCE OPENING CEREMONY

Distinguished Guests Ladies and gentlemen,

On behalf of our partners, I wish to warmly welcome you all to this international conference on "*Bridging the gap between society, science and industry* at Kenyatta University, Nairobi Kenya.

This conference is jointly organized by Kenyatta University's School of Agriculture and Enterprise Development, African Green Revolution on Agriculture (AGRA), Horticultural Association of Kenya (HAK) and University of Nairobi. When we commenced the planning of our Inaugural Biennial International conference early in the year, least did we know that AGRA jointly with University of Nairobi had also plans to hold an African Green Revolution Student Led Conference where young scientists who have trained under their soil health program could get an opportunity to share their research breakthroughs with a wider audience. At the same time some of my colleagues in the School had worn a bid to host the 14th HAK Annual Conference. This conference is therefore three conferences blended into one. For me it's a dream come true, a dream I have had since I became Dean of this young (6 years old) school four years ago and I am therefore very excited to see this conference become reality. I wish to express my deep appreciation and thanks to the co- organizers for the immense role and significant contribution they have made towards the success of this conference. To our partners, I wish welcome you again to join us in 2016 when we shall organize our second biennual International conference.

The theme of this conference *"Bridging the gap between society, science and industry"* seeks to find viable ways of reducing the gaps between these three interdependent sectors for the benefit of all. The "how" the three can interact optimally, effectively and efficiently to address major concerns such as achieving equitable development, food security, nutrition and sustainable agriculture has remained elusive for a long time. It is because of this that we have brought together agricultural scientists, civil society, policy makers and practitioners in the various agricultural sectors to deliberate on this question. Bridging this gap will partly depend on attracting, resourcing and building the capacity of talented, system thinking, young agricultural scientists who are technologically versatile to innovatively transform agriculture in the continent. Creating an enabling policy environment will be critical. It because of this belief that this conference has dedicated plenary sessions to discuss issues related to youth in agribusiness and policy and partnership. As we consider this, the focus must be on the needs of small scale farms in diverse ecosystems and to areas with the greatest needs. This means improving rural livelihoods, empowering marginalized stakeholders, sustaining natural resources, enhancing multiple benefits provided by ecosystems, considering diverse forms of knowledge, and providing fair market access for farm products.

The objectives of this conference are to;

i.   Share experiences and learn lessons on capacity building, agricultural research and policy initiatives being implemented in different countries of the world. This will be achieved through four key topics to be discussed in the plenary session by speakers and discussants drawn from three different continents (Africa, North America and Europe).

ii.   Network and collaborate- I am very happy with the excellent collaboration that took place

prior to and during the planning of this conference among the co- organizers and it can only get better. In this conference we have participants from 17 countries in three different continents, the opportunities therefore to establish new networks and collaboration and/or strengthen the existing ones are many.

iii.   Identify knowledge and capacity gaps that could be considered in future resource allocation, training and research priority setting activities. As a training Institution and as organizations funding capacity building initiatives in Africa; we are looking forward to receiving your contributions and feedback as we seek to continually improve training and research in agriculture. I am very optimistic that you'll not only help identify knowledge and capacity gaps in this areas but you'll also generously share with us workable solutions and opportunities that we can exploit in addressing these gaps, based on your vast experiences.

In this conference, the young upcoming Agricultural Scientists and entrepreneurs who are the future and hope for Africa will have an excellent opportunity to present their research findings and share experiences in agribusiness and obtain feedback from a wider multigenerational, highly experienced International Community. Their experiences will be further enriched as they learn and share lessons and experiences among themselves. Interaction with various speakers and panel discussants from different parts of the world with diverse experiences will further enhance their experience. In this conference, therefore a unique opportunity is provided to build capacity of a New Generation of Scientists and entrepreneurs in agriculture and each of us has a role to play. The bringing together of various industry players as exhibitors further exposes our young scientists and contributes to our effort to bridge the gap between Society, Science and Industry.

The programme for the week is very exciting with broad based topics for plenary discussions, parallel sessions on different sub themes, exhibitions and side events by different organizations and excursions and it's our hope that you'll find the sessions interesting.

We wish to thank our chief guest, distinguished key note speakers and panel discussants for availing themselves to play this very significant role. We also wish to thank all the exhibitors, side event organizers and all the organizations and individuals who supported us in one way or the other to ensure this conference is successful. We wish to single out and appreciate the valuable support given by Prof Olive Mugenda, the Vice Chancellor of Kenyatta University, Dr Agnes Kalibata, the President of Agriculture Green Revolution in Africa (AGRA); Prof Hartmut Stuetzel of University of Leibniz in Hannover, Germany and the Director, German Academic Exchange Program. We acknowledge the immense work done by the Conference Organizing Committee and our colleagues in AGRA, the School of Agriculture and HAK.

Prof. Waceke Wanjohi,
Dean, School of Agriculture and Enterprise Development
Kenyatta University

REMARKS BY THE VICE CHANCELLOR PROF OLIVE MUGENDA DURING THE OFFICIAL CONFERENCE OPENING CEREMONY

Our Chief Guest, Cabinet Secretary, Ministry of Agriculture, Livestock and Fisheries Mr. Felix Koskei
Guests from other countries in Africa and other parts of the world,
Ladies and gentlemen,
Good morning:

It gives me great pleasure to welcome you to Kenyatta University for the the Conference on "Building a new generation of agricultural scientists". This event incorporates three separate conferences that is the 1st International biennial conference of KU School of Agriculture, the 1st student led conference by the Alliance for a Green Revolution in Africa (AGRA), and the 14th Annual Symposium of the Horticulture Association of Kenya (HAK). It is a great honor for us to host this event. I wish to register my appreciation to all who have worked hard in research and helped to prepare the students attending this conference, even as they develop their future careers and contribute to the development of our diverse countries.

Our Chief Guest, this conference comes at a time when our country and indeed the whole of Africa is transitioning through a phase of rapid development that is full of hope, yet facing numerous challenges. I am confident we have with us here today part of the new generation of researchers and agri-entrepreneurs that is well prepared to sustainably address the challenges of food insecurity and malnutrition. This conference has representatives of various sectors including universities, private companies, public institutions, development funding organizations and civil society, among others. Although we are from different countries, am sure most of the challenges we face are common. Thus, this forum presents an excellent opportunity to exchange knowledge, experiences and good practices from different parts of the Africa and other parts of the world.

Although the School of Agriculture and Enterprise Development is one of the youngest schools in Kenyatta University, it's one of the fastest growing in terms of programs and enrolment. The school's main thrust is "entrepreneurship" and rapid growth is underpinned by strong linkages that have culminated in this year's conference being held here. One of the key themes of this conference is on "Building capacity and making research relevant to societal needs". It is well recognized that increasing student populations and low investment in capacity development are among the factors hindering high quality training and research in many African institutions. At Kenyatta University, we are investing substantially to strengthen the capacity and quality of our teaching and research programmes in all our schools, agriculture included. Chief Guest, I am pleased to report that we have recently successfully completed very rigorous external audit of some of our programmes in the School of Agriculture. Last week, we opened a new laboratory complex in which we have assigned the school of agriculture additional space for practicals. Earlier in the year, we established a School of Agriculture teaching farm which we are stocking with various types of livestock and equipment and other facilities to give our students a well rounded learning experience. Further, to ensure our students gain exposure and start acquiring relevant work experience, Kenyatta University has pioneered an innovative Student Work Induction Programme (SWIP) that has enabled the university to partner with relevant industry for the benefit of students. Since Kenya's economy is agriculture based, we are optimistic students in the School of Agriculture will be among the major beneficiaries of the SWIP. These achievements would not be possible without the support of the government and many development partners, some represented here today. Indeed the school of agriculture at Kenyatta university is recognized regionally and has been training students from neighboring countries of Ethiopia, Sudan, Rwanda, Mozambique, DR Congo, and from as far as Sierra Leone. We are most grateful for your support.

At the same time I would like to point out we still have many outstanding needs. Chief Guest, the number of students in the school of agriculture has increased rapidly within a short time. We therefore would like to develop a school of agriculture facility to host the various departments and teaching programmes, more laboratories, offices and specialized agriculture teaching resources. While we are making effort, our resources are inadequate, I would like to appeal for assistance from the government and other funding agencies represented here to enable us develop and adequately equip the proposed facility. Furthermore, we have a plan to establish a model commercial dairy farm that will generate income for the university while providing an important training resource for the university and other stakeholders. We would like to seek the governments and other organizations support and partnership in this undertaking.

Our Chief Guest, ladies and gentlemen, as we participate in this important conference, I urge our researchers and other stakeholders from different organizations and countries to do more to increase the quality of learning and competitiveness of our graduates. We owe it to the future generations to ensure we lay a strong foundation for the path they will tread on. I congratulate everyone that has made this day possible and welcome all of you to Kenyatta University.

I wish you successful deliberations over the four days of the conference.

Thank you.

Prof. Olive Mugenda,
Vice Chancellor, Kenyatta University

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1.1.0 EXPLOITATION OF THE FERTILIZER EQUIVALENCY VALUE AND NUTRIENT USE EFFICIENCIES OF SOYBEAN RESIDUES OPTIMIZED WITH N FERTILIZER IN EASTERN UGANDA

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Abstract
Organic resources are an important component of tropical agriculture particularly, if the nutrients are recycled. Soybeans of recent have become dominant in the maize cropping systems of Eastern Uganda. However, there is limited use of soybean residues for soil fertility replenishment. Linking the nutrient content of the residues to its fertilizer equivalency value is paramount for sustainable agricultural productivity. Researcher managed on-farm experiments were carried out in 2011B and 2012A to establish the fertilizer equivalency value of soybean residues and its agronomic nitrogen use efficiencies with and without N fertilizer. The design was a RCBD with a 3x4 factorial treatment in two agro ecological zones (AEZs); the Lake Victoria crescent and South-eastern Lake Kyoga basin, in Namayingo and Tororo districts respectively. The treatments were; sole soybean residue at 0, 2 and 4tha^{-1} in combination with N fertilizer at 0, 30, 60 and120kgha^{-1}N in form of urea, with four and three replicates in Namayingo and Tororo districts respectively. The results indicate that agronomic nitrogen use efficiency (AEN) was generally <10kg grain kgN^{-1} with combined application of nutrient inputs, it was higher (12.9 kg grain kgN^{-1}) with sole 2tha^{-1} of soybean residues at both sites. The fertilizer equivalency value of 2tha^{-1} soybean residue was 28kghaN^{-1} in form of N fertilizer and the 4tha^{-1} residue was equivalent to 32kghaN^{-1}. Soybean residue was found to be appropriate in enhancing both maize yield and environmental quality since its application enables a farmer to forego 28kghaN^{-1} and 32kghaN^{-1} respectively, in form of mineral N fertilizer.

Key Words: Agronomic nitrogen use efficiency, Fertilizer equivalency value, Soybean residues

Introduction

Organic materials are readily available to smallholder farmers as compared to the inorganic fertilizers (Kimetu *et al.*, 2004b; Mutua, 2012) and become an important component of tropical agriculture (Chivenge *et al.*, 2009; Valbuena *et al.*, 2012) if they are re-used from the soil to crops, animals and human beings (Schröder, 2005).

Often, farmers develop various options for use of organic materials depending on the prevailing farming systems. For instance in the maize mixed farming system, use of crop residues are more for livestock feeding than applied as mulch on soils, influencing their availability for soil fertility improvement (Valbuena *et al.*, 2012).

Of recent, crops like soybeans have become dominant in the maize based cropping systems, but the use of the residues for soil fertility enhancement is limited. This could be possibly due to lack of knowledge on the nutrient content (Wortmann and Kaizzi, 1998) of such law quality organic materials that fall in the second category of the organic decision tree. These organic materials have <2.5%N content that are either incorporated into the soil in combination with N fertilizers or high quality organic materials (Palm *et al.*, 2001).

Linking the nutrient content of such organic materials to their fertilizer equivalency values and also establishing the appropriate levels/rates is vital to guide optimization of soybean residues under the integrated soil fertility management approach (Palm *et al.*, 1997). This helps to develop options for using locally available resources to improve soil fertility and consequently crop yields (Palm *et al.*, 1997).

In addition, research indicates that nutrient content of some organic materials such as swine manure, and other high quality organic materials such as *tithonia diversifolia, senna spectabilis* and *calliandra calothyrsus* commonly used by resource –poor farmers have been linked to their fertilizer equivalency values (Kimetu *et al.*, 2004a).

However, the fertilizer equivalency value of soybean residues (specific amount of soybean residue that can have a similar effect on crop yield as compared to a given quantity of inorganic fertilizer or the amount of N fertilizer applied to obtain the same yield as that of the organic matter) have not been established. It is hence paramount to popularize use of crop residues mostly, soybean residues among smallholder farmers with an established fertilizer equivalence value (Schröder, 2005). The specific objectives of the study were to establish the fertilizer equivalence value of soybean residues and the agronomic nitrogen use efficiencies of the residues with and without N fertilizer.

Materials and methods

The study was conducted in two villages of Namayuge and Nyemnyemi in Namayingo and Tororo districts respectively, representing the Lake Victoria Crescent and South and Eastern Lake Kyoga basin agro ecological zones of Uganda (Wortmann and Eledu, 1999). The two sites have almost similar climatic conditions, with a bimodal rainfall pattern, sub-humid climate and total annual rain-fall of greater than 1200mm. However, there is variation in altitude. Namayingo lies at an altitude of 1,174m above sea level and Tororo 1,075m above seas level (Wortmann and Eledu, 1999).

Experiment establishment

Soil sampling, preparation and analysis
Soil samples were taken from five farmer fields at Namayuge and Nyemnyemi villages in Namayingo and Tororo districts respectively. Random soil samples were taken from five spots at 0-20cm depth in each farmer's field to obtain composite samples of approximately 0.5kg. The composite samples were air-dried, ground and sieved through 2mm and then subjected to analyses of pH, SOC, Total N, extractable P, exchangeable bases and texture following the methods by Okalebo *et al*., (2002) at Makerere University's Soil and Plant analytical Laboratory. Soil pH was measured in a soil water solution at a ratio of 1:2.5, Organic matter was determined by potassium dichromate wet acid oxidation method, total N by Kjeldhal digestion, extractable P by Bray P1 method, exchangeable bases from an ammonium acetate extract by flame photometry (K^+, Na^+) and atomic absorption spectrophotometry (Ca^{2+}, Mg^{2+}); and particle size distribution (texture) using the Bouyoucos (hydrometer) method.

Soybean residue sampling, preparation and analysis
Soybean residues from each farmer's homestead were bulked and by quarter sampling, composite soybean residue samples were collected, oven-dried at 70°C, ground to pass a 0.5mm sieve and analyzed for total N, P and K. Total N and P were analyzed from micro-Kjeldhal digests with H_2SO_4 and H_2O_2 by steam distillation and titration with hydrochloric acid for N. Total K was analyzed by atomic absorption spectrophotometry.

The experiments were conducted over two seasons (2011B and 2012A) in the two study sites, with residual effects of applied nutrient inputs evaluated in 2012A. In 2011B, the fields were ox-ploughed and harrowed and later plot sizes of 5mx5m demarcated. In the subsequent season of 2012A, land preparation was done on plot basis using a hand hoe. The experiments were replanted in the same plots without any nutrient input additions since the 2012A season focused on the residual effects of the treatments applied in 2011B season.

The experiment was set in a randomized complete block design with a 3×4 factorial treatment structure. The treatments included 0, 2 and 4tha^{-1} soybean residue, 0, 30, 60 and 120kgha^{-1}N in form of urea and combinations of (2t;30, 2t;60, 2t;120kg ha^{-1}N$^)$ and 4 tha^{-1} of soybean residue (4t;30, 4t;60, 4t;120kgha^{-1}N) respectively, as shown below;

Table 1: Illustration of the treatment structure

N fertilizer rates (kghaN^{-1})	soybean residue rates (tha^{-1})		
	0	2	4
0		2t;0N	4t;0N
30		2t;30N	4t;30N
60		2t;60N	4t;60N
120		2t;120N	4t;120N

In the experiments, farms were replicates in each of the sites (4 in Namayingo and 3 in Tororo). The difference in the number of replicates between the sites is due to insufficiency of the residues at Tororo sites since some farmers had burnt all their residues after grain harvest. The moisture content of the residues was determined and the quantity of the residues applied on dry matter basis. The soybean residues were spread uniformly in each of the plots and worked into the soil using a hand hoe. The test crop was *DH04* maize hybrid planted between 2nd to 5th/September/2011 in Tororo and 6th to 11th/September/2011 in Namayingo, at a recommended spacing of 75cmx50cm at both sites. The planting of maize in 2012A was done between 4th to 6th/March/2012 in Tororo and 7th to 9th/March/ 2012 in Namayingo. The Kenyan origin hybrid maize variety was planted due to its tolerance to *striga* weed.

All agronomic management practices including weeding were done twice on average, depending on weed intensity. The nitrogen and potassium fertilizers were split applied following farmers' practice. The first splits were applied at planting, at the rates of 15kgha^{-1}N, 30kgha^{-1}N and 60kgha^{-1}N and 15kgha^{-1}K. The remaining half rates were applied five weeks after planting and phosphorus fertilizer (TSP) was basal applied in all the plots in the first season at a rate of 45kgha^{-1}P.

Data collection and Analysis
Maize was harvested at physiological maturity from the three inner rows of each plot that consisted of a 2.25m×4m sampling area where, the standing plants were counted and cut at ground level. Total above ground biomass samples were taken for oven drying to Makerere University soil and plant analytical laboratory. All the plant sub samples (both maize grain and stover) were oven-dried at 70°C, ground to pass a 0.5mm sieve and analyzed for total N using the standard kjeldahl method (Okalebo *et al*., 2002) . The oven dry weight was used to adjust the grain and stover yields to 12% moisture content on a hectare basis.

The response curves method (Schröder, 2005) was used to determine the fertilizer equivalence value of soybean residues. The rates of soybean residue were 0; 2000 and 4000 kgha^{-1} applied with and without 0, 30, 60 and 120kgha^{-1}N fertilizer. The method entails comparison of marketable yield of a test crop (maize) having received a specified amount of organic materials in this case soybean residue-N with a marketable yield of a response curve from a similar test crop (maize) having received incremental rates of mineral N fertilizer.

The fertilizer equivalence value of soybean residues is determined by constructing mineral N response curves for soybean residue and N fertilizer and the difference in the economic optimum rates is the measure of the fertilizer equivalent value of the soybean residue. The agronomic nitrogen use efficiency (AE) was determined by methods described by (Cassman *et al.*, 2002).

AE= Grain yield (Fertilized plot) ─ (Grain yield control plot) ÷N rate……………Equation 1

All the data collected were subjected to analysis of variance using the GENSTAT 14th window computer package. The interactions in site, treatment and season (site × treatment ×season) for all above ground biomass were considered. Where significant differences occurred, means were separated using Fisher' Protected Least Significant Difference (Lsd) at 5% probability levels (Gomez and Gomez, 1984).

Results
The soils at both Namayingo and Tororo experimental sites were moderately acidic, rich in exchangeable bases and had low levels of soil organic carbon and extractable Bray-1P (Table 1). However, there was soil textural difference between the sites with a loam textural class in Namayingo and sandy loam in Tororo. Soybean residue quality showed significant (p<0.001) difference in percent total N between the two sites (Table 2), even when residues of Maksoy 1N soybean variety were used at both study sites.

The total daily cumulative rainfall for Tororo district in the two subsequent seasons was almost similar (Figure 1); (419mm and 447mm). However, total rain fall for the two seasons (866mm) was below the annual rainfall amount of >1200mm the area normally receives. In Namayingo district, there was a seasonal difference in the amount of rainfall received between 2011B, and 2012A seasons (543mm and 605mm respectively). Total rainfall amount for the two seasons was (1,148mm) close to the >1200mm annual rainfall the area normally receives.
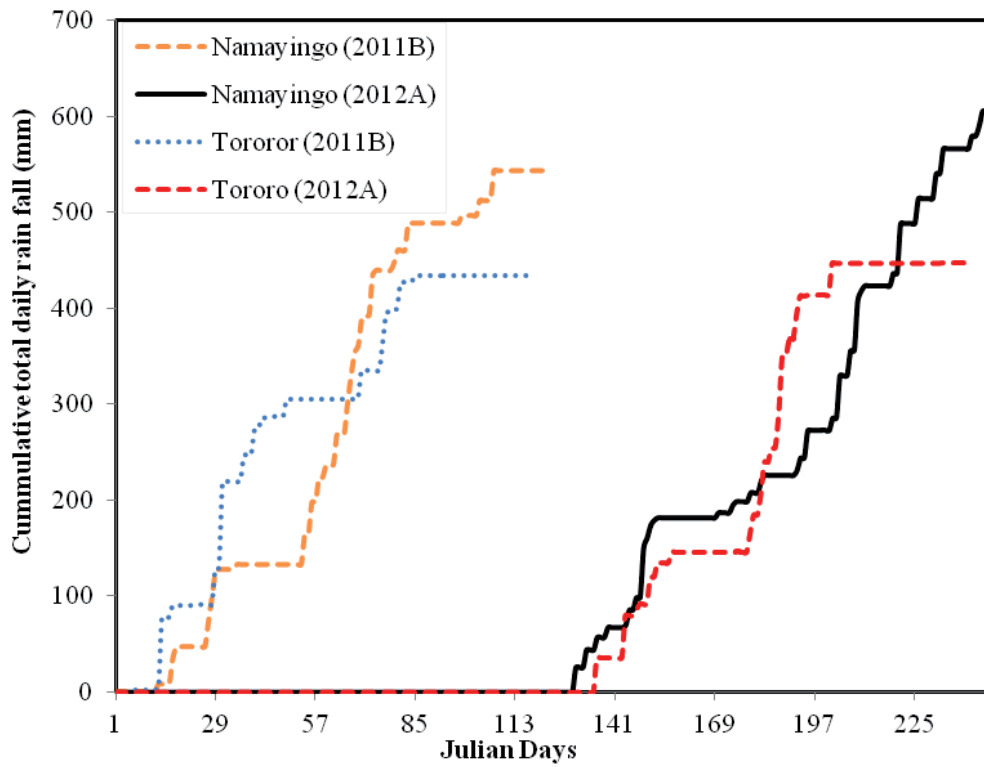
Figure 1: Cumulative daily rainfall received in the study areas during experimentation for two consecutive seasons

Table 2: Initial soil characteristics of fields in the study areas

Site	pH(H₂O)	g kg^{-1}	mg kg^{-1}	ExchBases (CmolCkg^{-1})				Texture (gkg^{-1})		
		SOC	Bray 1 P	K	Na	Ca	Mg	sand	silt	clay
Namayingo	5.81	18±0.3	2.8±0.5	0.5±0.1	0.8±0.02	7.5±0.4	3.1±0.4	42±4.7	33±30.7	25±8.5
Tororo	5.78	10±0.5	1.0±8.7	0.5±0.1	0.8±0.03	5.6±0.1	2.1±0.1	73±4.6	12±2.0	15±3.1
Critical values	**5.5**	**30**	**15**	**0.4**	**0.2**	**0.44**	**0.4**	**Na**	**Na**	**Na**

Na= Not available; {Values include means and standard deviations (M±SD)}

Table 3: Chemical characteristics of soybean residues used in experimental fields

Site	% Total		
	N	P	K
Namayingo (*n*=5)	1.1±0.3	0.5±0.4	1.1±0.4
Tororo (*n*=5)	0.6±0.1	0.6±0.3	1.0±0.1

{Values include means and standard deviations (M±SD)

Fertilizer equivalence value of soybean residues

The fertilizer equivalency value of 2tha[-1] soybean residue indicated an equivalent of 28kgha[-1] N fertilizer, a higher amount compared to18kgN obtained from soybean residue. The 4tha[-1] soybean residue resulted in an equivalent of 32kgha[-1]N, lower than the 36kgN obtained from soybean residue. Fertilizer equivalence values were 52% and 59% respectively (Figure 2).
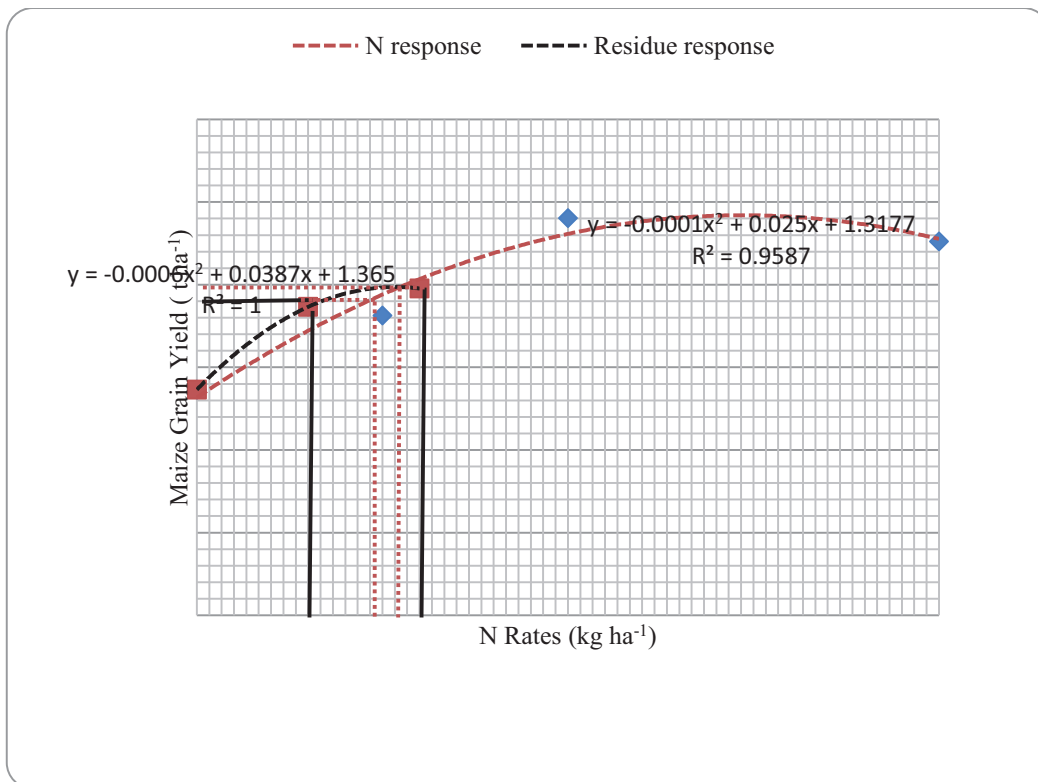
Figure 2: Estimation of fertilizer equivalent value of soybean residues**.**

(Calculated from yields of 2 seasons, 2tha[-1] soybean residue=18kgN and 4tha[-1]=36kgN)

Grain yield and agronomic nitrogen use efficiencies of the nutrient inputs in Namayingo and Tororo districts

In general, agronomic nitrogen use efficiency (AEN) declined at both sites with increase in nutrient input rates, apart from sole N and soybean residue at 60kgha[-1]N and 2tha[-1], respectively, where high AEN were obtained (Table 4).

Table 4: Grain yield and agronomic use efficiency of the nutrient inputs in Namayingo and Tororo districts

Treatment	Grain Yield t ha^{-1}		AEN kg kg^{-1}	
	Namayingo	Tororo	Namayingo	Tororo
0	1.63	1.02	0	0
30	2.12	1.41	7.7	5.8
60	3.03	1.57	10.9	4.0
120	2.43	2.04	3.2	3.7
18	2.12	1.52	12.9	12.7
36	2.36	1.47	9.5	5.6
48	2.38	1.76	7.4	6.9
78	2.80	1.98	7.1	5.5
138	2.91	2.19	4.4	3.7
66	2.25	1.82	4.5	5.4
96	2.74	2.29	5.5	5.9
156	2.78	2.46	3.6	4.0
LSD (p<0.05) treatment*site	0.89			3.5

(N rates) = 0, 30, 60,120kg ha^{-1} (2t h^{-1} soybean residues=18kgN and 4t ha^{-1}soybean residues= 36kgN) based on the nitrogen content of soybean residues, 2t+N= 48, 78 and 138 and 4t+N=66, 96 and 156.

Application of 2tha^{-1} soybean residue resulted in highest AEN (12.9 and 12.7kg grain kg^{-1}N) for both Namayingo and Tororo respectively. There was a decline in AEN with combined application of soybean residue and N fertilizer. It was generally <10kg grain kg^{-1}N at both sites.

Discussions

Fertilizer equivalence value of soybean residues
The fertilizer equivalency value of 4tha^{-1} soybean residue, an equivalent of 32kgha^{-1}N, lower than the 36kgN (Figure 2) obtained from soybean residue could be as a result of temporal immobilization of N fertilizer by the soybean residue that reduced potential loss of N fertilizer thereby, requiring a lower amount of N fertilizer to obtain the same yield. A similar finding has been reported by (Vanlauwe *et al.*, 2002).

While the 2t ha^{-1} soybean residue, an equivalent of 28kgha^{-1}N fertilizer, a higher amount compared to18kgN obtained from soybean residue could be attributed to the immediate nutrient

release as a result of mineralization, hence increasing the risk of N losses through runoff and leaching and consequently high N fertilizer quantity required to achieve the same yield.

This is in confirmation with the findings by Palm *et al.*, (2001) that combined application of medium to low quality organic materials with N fertilizer results to immediate nutrient supply for crop uptake. However, due to poor synchrony between nutrient supply and crop demand, losses may occur through run off and leaching (Vanlauwe *et al.*, 2001).

In addition, the percent fertilizer equivalence (%FE) values were 52% and 59% respectively, below 100%, attributable to the low quality of the soybean residues that could have caused poor synchrony between nutrient supply and crop demand which could have resulted in nutrient losses (Kimetu *et al.*, 2004a).

Agronomic nitrogen use efficiencies of the applied nutrient inputs

The decline in AEN between the two sites with combined application of soybean residue and N fertilizer (Table 4) could be probably attributed to the quality of the soybean residues used and the inherent fertility status of the experimental sites. This is because greater yield responses and AEN are expected from addition of high quality materials than with low quality organic materials which depress crop yields (Chivenge *et al.*, 2011).

Also, the responsiveness of the soils also affects crop yield responses and agronomic nitrogen use efficiencies (AEN). Higher yield responses and AEN are possible on responsive than on fertile, unresponsive and poor, less responsive soils fields due to better soil physical and chemical conditions (Kihara, 2011), as the initial soil status of the experimental units indicate slightly poor physical and chemical conditions (Table 2).

On the other hand, AEN was higher with application of sole soybean residues (Table 4) probably due to the low N rates from the residues applied that is, (2tha^{-1} gave an equivalent of 18kgN and 4tha^{-1}, an equivalent of 36kgN) which could have resulted to greater AEN since it is normally highest at the lower parts of the response curve. The finding is in agreement with Kaizzi *et al.*, (2012) that agronomic nitrogen use efficiencies are highest at low input rates due to substantial yield responses.

Conclusions

Fertilizer equivalency value of an organic material is influenced by the rate /level of the material applied. Application of 4tha^{-1} soybean residues resulted in a yield comparable to 32kgha^{-1} N and the 2t ha^{-1} soybean residue, an equivalent of 28kgha^{-1}N fertilizer are potentials N sources from soybean residues to enhance maize yields.

This ensures proper residue management practices since it gives an insight of its nutrient composition and the appropriate rates, that may later lead to drastic reductions in the use of costly mineral fertilizers, nutrient surpluses and consequently improved crop yields in order to ensure food security and environmental safety (Schröder, 2005).

The agronomic nitrogen use efficiency (AEN) of soybean residues combined with N fertilizer is lower than that from sole residue application contrary to other research findings that combined application of N fertilizer with organic materials results to higher yields and AEN. The quality of the organic material combined with N fertilizer plays a key role in either increasing or depressing both crop yields and AEN.

Recommendations

Application of soybean residues at varied rate of 2tha^{-1} and 4tha^{-1} is recommended to enhance maize yields for smallholder famers since the use of the rates improved maize yields comparable to 28kgha^{-1}N and 32kgha^{-1} N fertilizer, which could later lead to drastic reductions in the use of costly mineral fertilizers.

Given the inherent fertility status of the soils in the experimental sites and the low quality nature of the soybean residues, improving the agronomic nitrogen use efficiencies of the nutrient inputs requires initial extensive reinvestment in building up soil organic carbon levels.

References

Alley, M. M. and Vanlauwe, B. (2009). The Role of Fertilizers in Integraded Plant Nutrient Management. International fertilizer industry association.

Cassman, K. G., Dobermann, A. and Walters, D. T. (2002). Agroecosystems, nitrogen-use efficiency, and nitrogen management. AMBIO: A Journal of the Human Environment 31(2): 132-140.

Chivenge, P., Vanlauwe, B., Gentile, R., Wangechi, H., Mugendi, D., Van Kessel, C. and Six, J. (2009). Organic and mineral input management to enhance crop productivity in Central Kenya. Agronomy Journal 101(5): 1266-1275.

Chivenge, P., Vanlauwe, B. and Six, J. (2011). Does the combined application of organic and mineral nutrient sources influence maize productivity? A meta-analysis. Plant and soil 342(1-2): 1-30.

Gomez, K. A. and Gomez, A. A. (1984). Statistical procedures for agricultural research. Wiley.

Kaizzi, K. C., Byalebeka, J., Semalulu, O., Alou, I., Zimwanguyizza, W., Nansamba, A., Musinguzi, P., Ebanyat, P., Hyuha, T. and Wortmann, C. S. (2012). Maize response to fertilizer and nitrogen use efficiency in Uganda. Agronomy journal 104(1): 73-82.

Kimetu, J., Mugendi, D., Palm, C., Mutuo, P., Gachengo, C., Bationo, A., Nandwa, S. and Kungu, J. (2004a). Nitrogen fertilizer equivalencies of organics of differing quality and optimum combination with inorganic nitrogen source in Central Kenya. Nutrient cycling in Agroecosystems 68(2): 127-135.

Kimetu, J., Mugendi, D. N., Palm, C. A., Mutuo, P., Gachengo, C. N., Bationo, A., Nandwa, S. and Kungu, J. (2004b). Nitrogen fertilizer equivalencies of organics of differing quality

and optimum combination with inorganic nitrogen source in Central Kenya. Nutrient Cycling in Agroecosystems 68(2): 127-135.

Mutua, K. J. (2012).Nitrogen fertilizer equivalency values for organic materials of contrasting qualities based on maize performance at Kabete, Kenya.

Palm, C. A., Gachengo, C. N., Delve, R. J., Cadisch, G. and Giller, K. E. (2001). Organic inputs for soil fertility management in tropical agroecosystems: application of an organic resource database. Agriculture, ecosystems and environment 83(1): 27-42.

Palm, C. A., Myers, R. J. and Nandwa, S. M. (1997). Combined use of organic and inorganic nutrient sources for soil fertility maintenance and replenishment. Replenishing soil fertility in Africa (replenishingsoi): 193-217.

Roberts, T. L. (2009). Improving nutrient use efficiency. Turkish Journal of Agriculture and Forestry 32(3): 177-182.

Schröder, J. (2005). Revisiting the agronomic benefits of manure: a correct assessment and exploitation of its fertilizer value spares the environment. Bioresource Technology 96(2): 253-261.

Valbuena, D., Erenstein, O., Homann-Kee Tui, S., Abdoulaye, T., Claessens, L., Duncan, A. J., Gérard, B., Rufino, M. C., Teufel, N. and van Rooyen, A. (2012). Conservation Agriculture in mixed crop–livestock systems: Scoping crop residue trade-offs in Sub-Saharan Africa and South Asia. Field Crops Research 132: 175-184.

Vanlauwe, B., Aihou, K., Aman, S., Iwuafor, E. N., Tossah, B., Diels, J., Sanginga, N., Lyasse, O., Merckx, R. and Deckers, J. (2001). Maize yield as affected by organic inputs and urea in the West African moist savanna. Agronomy journal 93(6): 1191-1199.

Vanlauwe, B., Palm, C., Murwira, H. and Merckx, R. (2002). Organic resource management in sub-Saharan Africa: validation of a residue quality-driven decision support system. Agronomie 22(7-8): 839-846.

Wortmann, C. S. and Eledu, C. S. (1999). An Agroecological zonation for Uganda: methodology and spatial information.

Wortmann, C. S. and Kaizzi, C. (1998). Nutrient balances and expected effects of alternative practices in farming systems of Uganda. Agriculture, ecosystems and environment 71(1): 115-129.

1.1.1 NARROWING MAIZE YIELD GAPS UNDER RAIN-FED CONDITIONS IN TANZANIA: EFFECT OF SMALL NITROGEN DOSE

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Abstract

The wide gap between potential and actual yields of maize in Tanzania, due low productivity is the major constraint to improvement of food security and livelihood of farmers. The objective of this study was to evaluate the potential of the use of small amount of nitrogen fertilizer as a measure to reduce maize yield gap under rain fed conditions. Field experiments were conducted at Sokoine University of Agriculture, Morogoro during the dry and rainy seasons of 2012/2013 using Maize cultivar PIONEER PHB 3253. The nitrogen fertilizer application rates were 0 (control), 15 (low N dose) and 80 kg N ha^{-1} (recommended rate). Three water application regimes were non water stressed, water stress up to 50% anthesis and water stress from 50% anthesis up to grain filling. The treatments were applied in a completely randomized block design, in factorial layout for the dry season experiment. Nitrogen treatments were repeated during the 2012/2013 rain season under rain-fed conditions. Both experiments were replicated three times. In a dry season experiment, the water application regimes significantly (P≤0.05) increase biomass at both 50% and harvest maturity stages. Total tissue N content decreased under non-stressed water regime relative to water-stressed treatments. The interaction between irrigation and nitrogen interaction significantly (P≤0.05) affected grain yield. Application of recommended N rate did not result into yield increase when water was limiting. In the rainy season experiment, the recommended N rate resulted in highest biomass at end of juvenile (1 t ha^{-1}), 50% anthesis (7.7 t ha^{-1}) and harvest maturity stages (13.1 t ha^{-1}). Total tissue N content and grain yield increased significantly with increase in N application rates during the rainy season. Under water stress conditions, low N dose produced an extra 1000 kg ha^{-1} grain yield over absolute control treatment. Under water stress conditions, recommended N rate a 54% reduction of yield gap was observed, which could not sufficiently reduce yield gap. However, under adequate soil moisture conditions, recommended N rate attained up to 26% yield gap, suggesting that it would be beneficial to apply nitrogen fertilizer when water is not limiting to close the yield gap. Small nitrogen doses can be an effective strategy towards narrowing yield gaps for resource poor farmers especially in drought prone areas. Further study should be done to extend the results beyond experimental site to test and validate the approach under farmers' paradigms.

Keywords: potential yield, water stress, soil fertility, Maize, Tanzania,

Introduction

Low soil nutrients and water availability to crop are among the major constraints to crop productivity in the world (Hengsdijk and Langeveld, 2009). As a result yields of major food crops have been low and stagnated in most developing countries including Tanzania. Observed increased in food production in Tanzania has mainly been due to expansion of agricultural land (FAO, 2014), which is not sustainable due to loss of biodiversity and potential land degradation (Cassman *et al*., 2002; van Ittersum *et al*., 2013). In Tanzania, the number of chronically hungry people rose from 28.8% in 1992 to 33% in 2013 (FAO, 2014), suggesting that food supply has not matched with the demand. Moreover, despite 2.6% annual population growth rate between 1988 and 2002 in Morogoro Region, (United Republic of Tanzania - URT, 2013) maize yields declined from 2.1 tons ha^{-1} in 1994/95 season to 1.0 tons ha^{-1} in 2007/08 season (URT, 2012). Thus sustainable agricultural intensification through soil fertility and water management to increase food productivity per unit area without degrading the environment is inevitable to attain food security (Inter Academy Council, 2004; New Partnership for Africa's Development - NEPAD, 2003; The Montpellier Panel, 2013).

One of major challenges for food security is how to improve productivity under current crop land. Under rain fed conditions, maize, like any other crop faces periods of water stress at certain stages during its growth cycle, reducing possibility of attaining its potential growth and yield. Cognisant of rainfall pattern and associated risk of crop failure due to unreliable precipitation, farmers may be reluctant to invest in inputs and land management (Barron *et al*., 2003; de Fraiture *et al*., 2009).

Maize grain yield varies with levels of soil fertility and fertilizer use. One of the most limiting nutrients for crop growth and yield is nitrogen. Yin *et al.* (2014) indicated that nitrogen was the main factor for determining maize grain yield followed by water availability while phosphorus played a relatively minor role in semi-arid conditions of Northeast China. This is because N is naturally low in soils with low soil organic matter and is subject to losses through leaching, immobilization, mobilization and oil erosion (Brady and Weil, 2008). If soil fertility is well managed, rain fed dependent crop production turns out to be productive and substantial productivity improvement can be realized (Kalhapure *et al*., 2013). However, it is reported that up to 89% of fields under annual crops do not receive any kind of fertilizer in Morogoro region because of high fertilizer costs (URT 2012).

In semi-arid southern Zimbabwe, as low as 8.5 kg N ha-1, in combination with 3 t ha-1, maize yield increased from 1.26 t ha^{-1} (control) to 2.5 t ha^{-1} when there was good seasonal rains (Ncube et al., 2007). Tittonell *et al*. (2008) reported that fertilizer addition (30 kg P ha^{-1} + 90 kg N ha^{-1}) under rain fed conditions could increase maize yield yields and hence bridge the yield gap in Western Kenya. The question is how much yield gain is possible if a small nitrogen dose or recommended nitrogen rate is applied onto a maize crop under low and high seasonal precipitation? It is this set of scenarios which is not well documented not only in the study area, but also in Tanzania. With uncertain seasonal rainfall and high fertilizer costs, some farmers may not to apply any fertilizer at all. Consequently, maize yields will be low, even with good seasonal rains. Thus there is a need to investigate the importance of these growth resources as means of reducing maize yield gap. Low N rates could be an option for fertilizer management, for enhancing productivity under uncertain, rain fed conditions. This study will contribute to effective prioritization and allocation of resources needed to enhance maize productivity in small

scale farming environments. Moreover, the results from the yield gaps study may be important inputs into economic models that assess food security and land use.

Thus the aim of this work was to demonstrate the use of low dose of nitrogen fertilizer as a measure to reduce maize yield gap under rain fed conditions. Specifically, the aimed at: (i) determining the effects of low dose of nitrogen dose on growth and yield of maize at varying levels soil moisture availability, and, (ii) evaluating the effects of nitrogen fertilization on reducing maize yield gap.

Materials and methods

Description of the study area
Studies were conducted at the Crop Museum, located within the main campus of Sokoine University of Agriculture (SUA) Morogoro, Tanzania (6.85°S, 37.65°E). The area has a sub humid climate with mean annual temperature of 24°C and *iso-hyperthermic* mean annual soil temperature. The soils are highly weathered and classified as Utisols (USDA Taxonomy) or Acrisols (FAO-UNESCO soil classification) with *Ustic* soil moisture regime (Msanya *et al*., 2003).

Soil Sampling and analysis
One week before sowing, composite soil samples were collected from the experimental site using regular grid method (Paetz and Wilke, 2005) for physical and chemical characterisation. Samples were collected from depths of 10, 40 and 65 cm and from depths of 10, 30, 50 and 75 cm during the dry and rainy season respectively. Nine spots were randomly chosen for each sampling depth. The samples were composited on a clean plastic sheet, air-dried, and ground to pass through 2-mm sieve for analysis at Soil Science laboratory at SUA. The samples were later analysed for texture, organic carbon (OC), total nitrogen content, soil pH, available phosphorus and exchangeable potassium contents. Soil texture was determined using Bouyoucos hydrometer method; OC was analysed following the Walkley-Black method (Motsara and Roy, 2008); total soil N was analysed using modified Kjeldahl procedure (Wilke, 2005); Soil pH was measured by a glass electrode using soil to water ratio of 1:2. Available P was extracted using the Bray 1 method and determined by spectrophotometric procedure (Wilke, 2005). Exchangeable potassium was extracted using neutral, 1.0 M ammonium acetate and estimated using a flame photometer.

Field experimental design
Two field experiments were conducted, one during the dry season of 2012, and another during rainy season of 2013, The dry season experiment was conducted from July to October and consisted of three levels of nitrogen application; 0, 15 and 80 Kg N ha^{-1} and three levels of water application; non-stressed (full irrigation), water-stressed to 50% anthesis and water-stressed between 50% anthesis to grain filling. The treatments were arranged in a completely randomized block design in a factorial layout. Irrigation water was applied via furrows along the crop rows and a flow meter was installed to measure water volume per application. The water application regimes reflect regular rainfall trends in the area. The rainfall pattern in the area is that the rains may be low in the beginning of season and increase or cease during critical growth stages. It may also increase during grain filling. Irrigation regimes were based on daily plant requirement for non-stressed treatments (Figure 1). In non-stressed irrigation regime, up to 434 mm of irrigation

water was applied. In water-stressed crop up to 50% anthesis, 202 mm of water was applied and in a water-stressed between 50% anthesis and grain filling treatment, 309 mm of water was applied.

The rainy season experiment was conducted from March to July in a completely randomized block with three replicates. Nitrogen application rates were similar to the dry season experiment no irrigation. During the rainy season experiment the total rainfall received was 250 mm for the growing season (Figure 2). The precipitation was uniform during the period of linear crop growth. Up to 97% of seasonal rains was received within 60 days after sowing, the remaining of which was received after wards during grain maturation.

In both experiments phosphorus, as triple super phosphate (TSP) fertilizer was broadcasted uniformly to all experimental plots at the rate of 30 kg P ha^{-1} during sowing. Low dose of nitrogen (15 kg N ha^{-1}) was applied using Urea fertiliser banded about 5 cm around of the plant, 28 days after sowing (DAS), The recommended N rate was applied in splits of 40 kg N ha^{-1} at 10 and 45 DAS. The choice of application rates was based on practice of small holder farmers, who either apply very little or do not apply fertilisers at all.
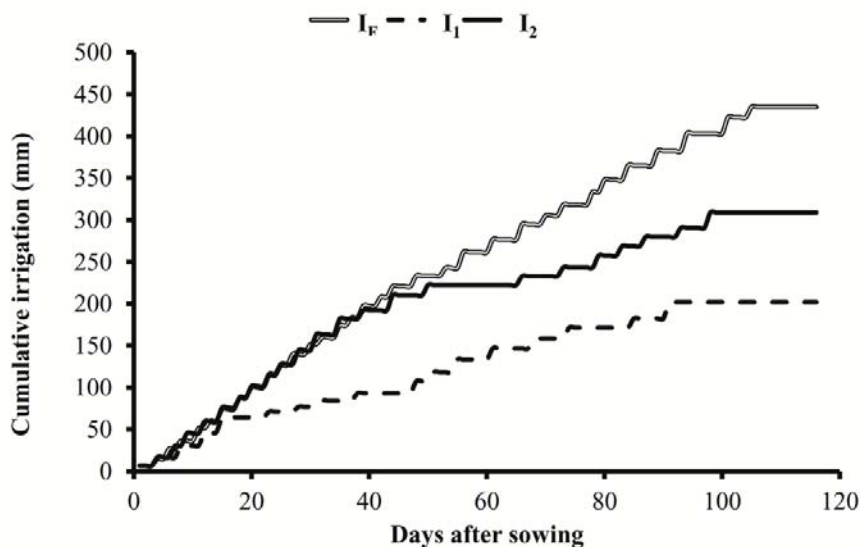
Figure 1: Cumulative water application in three irrigation treatments (I_F = non-stressed; I_1 = water stress between crop establishment and 50% anthesis; I_2 = water stress between anthesis and grain filling).

Maize cultivar used in this study was *PIONEER PHB 3253* and plant population was 44,000 plants ha^{-1}. *PIONEER PHB 3253* is a hybrid maize cultivar with white and hard flint kernels, adapted to low and medium altitude (Lyimo *et al.*, 2014). It is high yielding, resource intensive crop cultivar especially a hybrid which needs more water and more fertilizer. The plot size during dry season experiment was 20.8 m^2 (4.0 x 5.2) with six rows and 10 plants per row while in the rainy season experiment, the plot size was 18.9 m^2 (5.25 x 3.6 m) with 5 rows and 10 plants per row.

Data Collection

Plant sampling was done at three growth stages; during end of juvenile stage, 50% anthesis and harvest maturity. End of juvenile stage refers to the pre-induction stage when the plant is not sensitive to photoperiod (Ritchie, 1993). This is the stage shortly before flower initiation when the final leaf number is determined. At each sampling stage, four plants were cut just above the ground for dry biomass measurements. Yield components; grain number/ear, individual weight and tops weight were recorded at harvesting. Also, shoots were separated from the kernels, sheaths and cobs and oven dried at 70 °C until a constant weight was attained. A subsample from each component was ground separately and analysed for total N concentration (g N/g dry matter) using Kjeldahl wet digestion method (Motsara and Roy, 2008). Nitrogen content values from each component were averaged to determine overall plant N content.
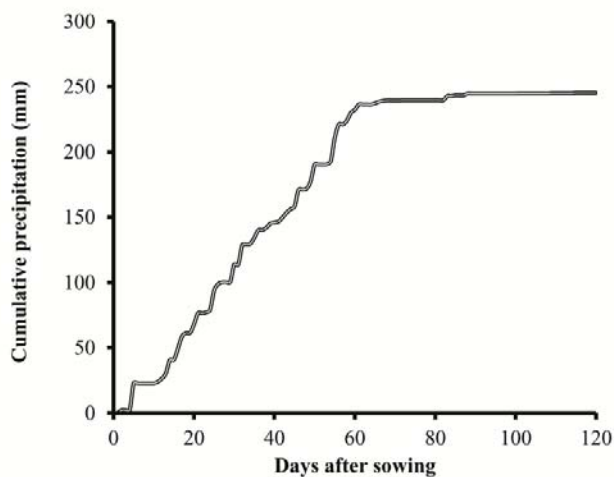
Figure 2: Cumulative precipitation for the March-June 2013 rain-fed experiment at Sokoine University of Agriculture Crop Museum site, Morogoro, Tanzania.

Plant samples were prepared as in the dry season experiment for determination of above-ground biomass, yield and yield components and tissue nitrogen content. Yield gap was calculated as the difference between potential yield and actual yield obtained from nitrogen treatments for both dry and rainy season experiments and irrigation regime treatments for dry season experiment. The yields for *PIONEER 3253PHB* reported in previous work by Mourice *et al*. (2014) was considered to be the potential yield because, water and nutrients were adequately supplied and all growth limiting and growth reducing factors were sufficiently controlled.

Statistical analysis

Inferential statistical analyses (analysis of variance) were conducted using GENSTAT v.14 software (VSN International, UK). Least significant difference (LSD) was used to compare means and where applicable, mean ranking was done using the Turkeys test at 5% significance level.

Results

The experimental site had a soil pH of 5.7 which is moderately strong acid, with medium soil organic C of 1.7 to 1.8%, and low total N (0.04 to 0.14 %) (Table 1, Table2). The available P ranged from 7.7 to 8.3 mg kg^{-1} while exchangeable K is high (0.7 cmol (+) kg^{-1}) (Table 1 and 2). All the measured soil fertility parameters decreased with depth. The textural class of surface soil is sandy clay and clay content increased with depth, which is not expected to limit maize growth and yield. Generally the fertility status of the experimental site is low due to acidic pH, low N, and P.

Table 2: Soil physical and chemical properties of the experimental site during the dry season (July-October 2012) one week prior to planting

| Depth (cm) | Soil texture | | | | OC (%) | Total N (%) | pH (H20) | P$_{BRAY}$ (mg/kg) | K$_{exch.}$ (cmol (+)/kg) |
	Clay (%)	Silt (%)	Sand (%)	Textural Class					
10	46	8	46	SC	1.7	0.11	5.7	7.7	0.69
30	47	9	44	SC	1.1	0.08	5.3	5.4	0.22
50	60	9	31	C	0.7	0.05	5.5	4.8	0.10
75	68	9	23	C	0.5	0.05	5.4	4.9	0.06

SC = Sand Clay, C = Clay, OC = Organic carbon, N = Nitrogen, P = Phosphorus, Kexch. = Exchangeable Potassium,

Table 3: Soil physical and chemical properties of the experimental site during the rainy season (March –June 2013)

| Depth (cm) | Soil texture | | | Textural Class | OC (%) | Total N (%) | pH (H20) | P$_{BRAY}$ (mg/kg) | K$_{exch.}$ (cmol (+)/kg) |
	Clay (%)	Silt (%)	Sand (%)						
10	48	10	42	SC	1.8	0.14	5.7	8.3	0.72
40	63	9	28	C	0.9	0.10	5.4	6.1	0.44
65	63	9	28	C	0.5	0.04	5.2	4.4	0.25

SC = Sand Clay, C = Clay, OC = Organic carbon, N = Nitrogen, P = Phosphorus, Kexch. = Exchangeable Potassium

Dry season experiment

Maturity was recorded earlier in crop grown under moisture stress compared to fully watered and mild stressed crop. Likewise, leaf senescence started earlier in water stressed crops than in those fully watered. Consequently, water application stopped earlier in stressed than in fully watered crop. Pic *et al*. (2002) reported that mild water stress accelerated leaf senescence by 15 days in peas (*Pisum sativum* L.) as compared to fully watered plants. Thus, irrigation continued depending on presence of green leaves and vice versa.

Effects of water regimes and Nitrogen levels on maize plant biomass

There were no significant effects of water supply on above ground biomass of the plants at the end of juvenile stage, but the effects were significant ($P<0.05$) at both 50% anthesis and harvest maturity stages. Generally, the above ground biomass was the lowest in water-stressed to 50% anthesis and highest in non-stressed irrigation regimes for all growth stages. Nitrogen levels significantly affected the above ground biomass for all growth stages. However, there was no significant irrigation x nitrogen treatment interaction effects on biomass for all growth stages.

Effects of water regimes and Nitrogen levels on tissue N content

There was significant effect of irrigation regimes ($P<0.05$) on total tissue nitrogen content of the plants. Total tissue N was high in water-stressed to 50% anthesis and low in non-stressed treatments. The N levels effect was highly significant ($P<0.001$). The total tissue N was low in N15 (3.8%) and high in N80 (5.6%) treatments. However, there was no significant irrigation regime x nitrogen levels interaction for total tissue N content.

Effects of water regimes and N levels on grain yield

Interaction between irrigation and applied nitrogen levels had significant effects on maize grain yield ($P<0.05$) (Figure 3). Low grain yields were recorded where nitrogen was not applied, regardless of irrigation regime. High grain yields were obtained in crops supplied with the highest Nitrogen level (80 kg N ha^{-1}), also regardless of the irrigation regimes. Highest grain yield of 4.7 t ha^{-1}, was recorded in a crop grown under highest level of nitrogen without moisture stress. It is evident that nitrogen played a profound role in increasing grain yield in every irrigation regime.

Rain season experiment

Effects of Nitrogen levels on maize plant biomass

During the rainy season, nitrogen levels significantly ($P<0.05$) affected above ground biomass at all growth stages (Table 3). Low above ground biomass during the dry season could be due to low air humidity during dry season as a result of increased wind speed and temperature. Low humidity and higher temperature increases evapotranspiration and respiration hence water loss is high and some assimilates are allocated for respiration process, unlike in rainy season where air humidity are normally high and temperatures are cool. The above ground biomass was significantly ($P<0.5$) higher (1000 to 13088 kg ha^{-1}) at recommended N rate than in control treatment (612 to 6320 kg ha^{-1}) (Table 3).

Effects of applied nitrogen levels on tissue N and maize grain yield

The effect of nitrogen fertilization on total tissue nitrogen content was highly significant in the rainy season. Total tissue N ranged from 2.8% to 5.8% with lowest total tissue N in control and highest in recommended N rate treatments (Table 3). Grain yield, increased significantly with increase in nitrogen levels. Grain yield increased by 65% and 240% in a low dose and recommended N rate respectively, over control (Table 3).

Yield gap analysis

From the previous work by Mourice *et al*. (2014) the potential yield for the maize cultivar *PIONEEER PHB 3253* (6318 Kg ha^{-1}) was used in this study. Under WATER-STRESSED TO 50% ANTHESIS treatment, maize yield gap declined from 74% at control nitrogen application to 54% at recommended N rate (Table 4). When the crop was water stressed between 50% anthesis and grain filling, the maize yield gap declined from 73% at control N to 43% at recommended N rate. Furthermore, at non-stressed water regime, the level of yield gap was higher than in water-stressed to 50% anthesis water regime at control N. However, the yield gap declined with increase in nitrogen levels to a minimum of 26% at recommended N rate when there was no moisture stress (Table 4).
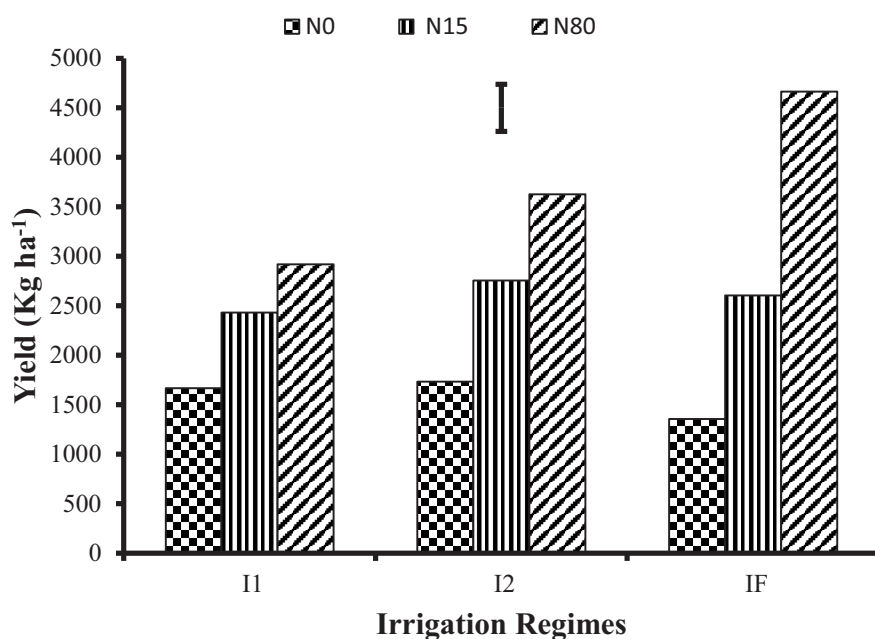
Figure 3. Effects of irrigation regimes and nitrogen levels on grain yield of maize grown during the dry season in Morogoro region, Tanzania. Vertical bar indicated the least significant difference (LSD)

Table 3: Effects of nitrogen levels on above ground biomass, tissue nitrogen content and grain yield of maize grown during the rainy season in Morogoro region Tanzania

| Treatment | Biomass (Kg ha^{-1}) | | | Total tissue N Content (%) | Grain yield (Kg ha^{-1}) |
	Juvenile stage	50% anthesis	Harvest maturity		
N0	612b	3663 c	6320 c	2.8 b	1533 c
N15	622 b	6369 b	10525 b	3.6 b	2527 b
N80	1000 a	7738 a	13088a	5.8 a	5198 a
Significance	*	***	***	***	***
LSD (5%)	**231**	**612**	**1593**	**0.8**	**365**
CV (%)	**4.7**	**4.6**	**7.0**	**8.7**	**5.2**

Means followed by the same letter within the same column are not significantly different ($P \leq$ 0.05).

*, **, *** = Significant F values at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$ respectively; NS: not significant.

Table 4: Maize yield gap under three water regimes and three nitrogen levels.

	N0	N15	N80
Potential yield (Kg ha^{-1})	6318	6318	6318
Observed yield in I_1 (Kg ha^{-1})	1667	2432	2920
Yield gap in I_1 (%)	74	61	54
Observed in I_2 (Kg ha^{-1})	1732	2754	3627
Yield gap in I_2 (%)	73	56	43
Observed yield in I_F (Kg ha^{-1})	1355	2605	4664
Yield gap in I_F (%)	79	59	26

Discussion

Fertility status of the soil determines yield and response of crops to fertilizer and water management. The site used for this study can be characterized as less fertile due to its low nitrogen, low phosphorus and marginal organic carbon content in the top soil. The soil is acidic, a characteristic of highly weathered soils found at the study site and surrounding areas. The fertility status of the study site suggests the need for soil fertility amendments using non-acidifying nitrogenous and phosphorus fertilizers for optimum crop production (Msanya *et al.*, 2003).

Plant nutrient and water supply improves crop productivity. Plant biomass development reflects the varied responses to water and nutrient availability. Lack of significant irrigation regime effects on above ground biomass towards the end of juvenile stage is because all treatments received similar water application at early stage up to 21 DAS. Water availability affects plants' ability to fix carbon dioxide through photosynthesis. When water is limiting, stomatal pores beneath leaf surface close to limit water loss but simultaneously restricting carbon dioxide entry into the leaf system for photosynthesis to take place. That is why plants under water stress have low biomass than those under sufficient water supply (Eck, 1986). Cakir (2004) reported that vegetative and yield parameters are significantly affected by water shortage during the sensitive tasseling and cob formation. This is in agreement with the effects of stressing maize plants up to 50% anthesis on vegetative biomass and yield in this study.

Nitrogen fertilization has an effect on biomass as early as 14 days after sowing as evidenced by the differences in biomass between nitrogen treatments. This suggests that sufficient nitrogen availability at the beginning of crop growth (starter N) provides a good head start to crop development. Early crop establishment leads to better competition against weeds and may result into strong root system for enhanced water acquisition and utilization, unlike in non-fertilized plants (Radma and Dagash, 2013). The canopy size which translates into photosynthesizing surface is different between fertilized and non-fertilized crop plants. Nitrogen deficiency in soil causes small maize leaf size and less carbon fixation as compared to sufficiently fertilized plants (Paponov and Engels, 2003).

Significant irrigation and N fertilizer level interaction shows that the two factors influence yield responses differently. Applying large amounts of fertilizer when moisture is limited may not be economically justified because eventually low yields would be realized. Although at any given irrigation regime higher N rate gave higher grain yield than low N rate, the grain yield obtained under recommended N rate and water stress was not statistically different from the yield under low N dose and water stressed from anthesis to grain filling . Results of this study suggest that plant biomass accumulation depend on availability of both water and nutrient. Where water is not sufficient, nutrients alone may not offset the lack of it and vice versa. This is because water uptake depends on the size of evaporative surface (crop canopy size) which in turn depends on the level of nutrients available in the soil (Pandey *et al*., 2000).

At all application rates of nitrogen, grain yields were similar for all water stressed treatments suggesting that water stress imposed after critical growth stage has no significant effect on final grain yield. The reason to this could be that within 45-50 days after sowing; the plant should have accumulated the requisite biomass for grain formation and filling even when water stress occurs afterwards. This may also be extended to the rain fed experiment, in which case crop plants would proceed to maturity even when rains decline just after grain filling stage without affecting grain yield. Although grain yield increases with nitrogen levels, it is important to consider the amount of available water, either from rain or irrigation. In situation where water is limiting, it may be not be justifiable to apply the whole recommended fertilizer package, because there would be little gain with respect to the fertilizer cost and attainable yield. But rather, a low nitrogen dose (e.g. 15 Kg N ha^{-1}) would result into better yield gains than absolute control. Under high rainfall environments, high or recommended nitrogen fertilizer rate is very important to take the advantage of readily available soil water to enhance farm productivity, as evidenced from the non-stressed irrigation regime and high nitrogen dose in this study.

There is a sharp contrast between using and not using nitrogen fertilizer as regards to the magnitude of the yield gap. Applying low doses of nitrogen reduced the maize gap to 59%, suggesting that there is approximately 1000 kg ha^{-1} grain yield increment with only 15 kg N ha^{-1} fertilizer input. Extra 1000 kg ha^{-1} of maize grain from same piece of land would make a difference in terms of improved food security and livelihood at household level even when the cost of fertilizer is deducted.

The advantage of using small nitrogen doze may be extended even to semi-arid areas, for example parts of Dodoma region where seasonal rains range between 250-300 mm (International Union for Conservation of Nature (IUCN) 2010). In such conditions, adding a small nitrogen dose would result into approximately 760 kg ha^{-1} yield gain over non fertilized crop, which would also make a difference to a resource poor farmer in terms of food security and income. Ncube *et al*. (2007) reported substantial yield gains by about 100% when small nitrogen dose of 8.5 kg N ha^{-1} in combination with 3 tons ha^{-1} of cattle manure was applied in semi-arid southern Zimbabwe. However, small scale, resource poor farmers may not afford large quantities of manure. Livestock keeping which would be the source of farmyard manures is done extensively and away from villages and arable lands thus the accessibility of manure becomes difficult. Transport of manure from *bomas* to maize fields means extra costs including labour (Kaliba *et al*., 2000).

In limited soil water availability, using large quantities of nitrogen fertilizer may not be justified. This is because plant growth rate and hence high water demand caused by nutrient availability

cannot be satisfied by low available water as a result of insufficient rains. A reduction of yield gap by 54% can be attained, which perhaps is not economical as well. In environments with low to medium seasonal rains, low nitrogen dose would also be beneficial, as there would be approximately 1000 kg ha^{-1} grain yield increase over non fertilized farm fields. Also using more fertilizer under this kind of environment would not be beneficial either, because yield gap reduction would only be 44%. Kaliba *et al*. (2000) pointed out that rainfall availability was among the key factors to adoption of fertilizer use in maize production. In environments with high seasonal rainfall, two scenarios are possible depending on resource endowment of the farmer. For resource poor farmer, applying low dose of nitrogen would still be beneficial since the yield gain is approximately 1300 kg ha^{-1} over unfertilized crop. On the other hand, more endowed farmers, who can afford high fertilizer rates would still benefit from it because yield gap reduction would be 26%. Lobell *et al*. (2009) pointed out that yield may not exceed 80% of the potential because this yield level may approximate an economic optimum of major cropping systems.

Conclusion

This study explains the importance of nitrogen use as a strategy towards narrowing maize yield gaps, especially in areas characterised with low and/or unreliable rainfall and low soil nitrogen for crop production. For resource poor farmers, low dose of nitrogen fertilizer applied after crop establishment may make a substantial contribution to the food security over non-fertilized crop production. This approach can work well in environments with low seasonal rains because yield gain is higher than when high nitrogen quantities are applied in water scarce environment. Under moderate to high rainfall environment, low dose of nitrogen would still be beneficial for resource poor farmers, although higher nitrogen rates may give higher grain yields, if farmers can afford fertilizer costs.

The limitation of this study is that the yield gap narrowing strategy was evaluated at a plot scale. Considering heterogeneity in soil nutrients, soil organic matter content, available water capacity and weather variations in space and time, further study is needed to investigate the necessary response of small nitrogen doses as a strategy in bridging the maize yield gaps in multiple fields and many seasons especially under farmer's management. A crop modeling approach may work well for as long as model calibration and key model inputs data are ascertained.

References

Barron, J., Rockström, J. Gichuki, F. and Hatibu, N. (2003). Dry spell analysis and maize yields for two semi-arid locations in East Africa. Agricultural and Forest Meteorology, 117, 23–37.

Brady, N. C. and Weil, R. R. (2008). *The Nature and Properties of Soils* (14th edition.). Pearson Prentice Hall, New Jersey. 975pp.

Cakir, R. (2004). Effect of water stress at different development stages on vegetative and reproductive growth of corn. Field Crops Research, 89, 1–16.

Cassman, K.G., Dobermann, A.R. and Walters, D T. (2002) Agroecosystems, Nitrogen-use Efficiency, and Nitrogen Management. Ambio, 31 (2):132-140.

de Fraiture, C., Karlberg, L. and Rockström, J. (2009). Can Rainfed Agriculture Feed the World? An Assessment of Potentials and Risk. In: Wani, S. P., Rockström, J. and Oweis, T. (Eds.). Rainfed Agriculture: Unlocking the Potential. CAB International, Wallingford, UK. Pp 124-132.

Eck, H.V. (1986). Effects of water deficits on yield, yield components and water use efficiency of irrigated corn. Agronomy Journal, 78: 1035-1040.

FAO (2014). Hunger Portal. http://www.fao.org/hunger/en/. June, 23rd 2014.

Hengsdijk, H. and Langeveld, J.W.A. (2009). Yield trends and yield gap analysis of major crops in the world. Wageningen University, the Netherlands, pp 170.

Inter-Academy Council (2004). Realizing the Promise and Potential of African Agriculture. http://www.interacademycouncil.net/24026/AfricanAgriculture.aspx. June, 08, 2014.

International Union for Conservation of Nature (IUCN) (2010). The Wami Basin: A Situation Analysis., Eastern and Southern Africa Programme, Nairobi, Kenya. Pp 92 pp.

Inter Academy Council (2004). Realizing the Promise and Potential of African Agriculture. Inter Academy Council. Via website: http://www.interacademycouncil.net/24026/AfricanAgriculture.aspx. Accessed on 12 June, 2014.

Kalhapure, A.H., Shete, B.T. and Dhonde, M.B. (2013). Integrated Nutrient Management in Maize (*Zea mays* L.) for increasing Production with Sustainability. International Journal of Agriculture and Food Science Technology, 4(3): 195-206.

Kaliba, A.R.M., Verkuijl, H. and Mwangi, W. (2000). Factors Affecting Adoption of Improved Maize Seeds and Use of Inorganic Fertilizer for Maize Production in the Intermediate and Lowland Zones of Tanzania. Journal of Agricultural and Applied Economics, 32(1): 35-47.

Lobell, D.B., Cassman, K.G., and Field, C.B. (2009). Crop Yield Gaps: Their Importance, Magnitudes, and Causes. Annual Review of Environment and Resources, 34: 179–204.

Lyimo, S., Mduruma, Z. and De Groote, H. (2014). The use of improved maize varieties in Tanzania. African Journal of Agricultural Research, 9(7): 643-657.

Motsara, M.R. and Roy, N. (2008). Guide to laboratory establishment for plant nutrient analysis. FAO Fertilizer and Plant Nutrition Bulletin No. 19. Rome, Italy. pp 204.

Mourice, S.K., Rweyemamu, C.L, Tumbo, S.D. and Amuri, N. (2014). Maize cultivar specific parameters for Decision Support System for Agrotechnology Transfer (DSSAT) application in Tanzania. American Journal of Plant Science, 5: 821-833.

Msanya, B.M., Kaaya, A.K., Araki, S., Otsuka, H. and Nyadzi, G.I. (2003). Pedological Characteristics, General Fertility and Classification of Some Benchmark Soils of Morogoro District, Tanzania. African Journal of Science and Technology, 4(2): 101-112.

Ncube, B., Dimes, J. P., Twomlow, S. J., Mupangwa, W. and Giller K. E. (2007). Raising the productivity of smallholder farms under semi-arid conditions by use of small doses of manure and nitrogen: a case of participatory research. Nutrient Cycling in Agroecosystems, 77: 53–67.

New Partnership for Africa's Development (2003). Comprehensive Africa Agriculture Development Program (CAADP). NEPAD, Midrand, South Africa, pp 102.

Paetz, A. and Wilke, B.-M. (2005) Soil Sampling and Storage. In: Margesin, R. and Schinner, F., (Eds.) Manual for Soil Analysis – Monitoring and Assessing Soil Bioremediation. Springer-Verlag, Berlin, pp. 1-45.

Pandey, R.K., Maranville, J.W. and Chetima, M.M. (2000). Deficit irrigation and nitrogen effects on maize in a Sahelian environment II. Shoot growth, nitrogen uptake and water extraction. Agricultural Water Management, 46: 15-27.

Pic, E., Teyssendier de la Serve, B., Tardieu, F. and Turc, O. (2002). Leaf Senescence Induced by Mild Water Deficit Follows the Same Sequence of Macroscopic, Biochemical, and Molecular Events as Monocarpic Senescence in Pea. Plant Physiology, 128 (1): 236-246.

Paponov, I A. and Engels, C. (2003). Effect of nitrogen supply on leaf traits related to photosynthesis during grain filling in two maize genotypes with different N efficiency. Journal of Plant Nutrition and Soil Science, 166, (6), 756–763.

Radma, I. A. M. and Dagash, Y. M. I. (2013). Effect of Different Nitrogen and Weeding Levels on Yield of Five Maize cultivars under Irrigation. Universal Journal of Agricultural Research, 1(4): 119-125.

Ritchie, J.T. (1993). Genetic specific data for crop modeling. In: de Vries, F.P., Teng, P and Metselaar, K. (Eds.). Systems Approaches for Sustainable Agricultural Development. Kluwer, Dodrecht, the Netherlands, pp 77-94.

The Montpellier Panel, (2013). Sustainable Intensification: A New Paradigm for African Agriculture.ImperialCollege,London. https://workspace.imperial.ac.uk/africanagriculturaldevelopment/Public/Montpellier. Accessed, January,10th, 2014.

Tittonell, P., Vanlauwe, B., Corbeels, M. and Giller, K.E. (2008). Yield gaps, nutrient use efficiencies and response to fertilisers by maize across heterogeneous smallholder farms of western Kenya. Plant and Soil, 313:19–37.

United Republic of Tanzania (2012). National sample census of Agriculture 2007/2008 Vol. 5e: Morogoro regional report. National Bureau of Statistics, Dar es Salaam. Pp 95.

United Republic of Tanzania (2013). 2012 Population and Housing census: Population Distribution by Administrative Areas. National Bureau of Statistics, Dar es Salaam.

van Ittersum, M.K., Cassman, K.G., Grassini, P., Wolf, J., Tittonell, P. and Hochman, Z. (2013). Yield Gap Analysis with Local to Global Relevance- A Review. Field Crops Research, 143: 4-17.

Wilke,] B.-M. (2005). Determination of Chemical and Physical Soil Properties. In: Margesin, R. and Schinner, F., (Eds.), Manual for Soil Analysis – Monitoring and Assessing Soil Bioremediation. Springer-Verlag, Berlin, pp. 46-96.

Yin, G., Gu. J., Zhang, F., Hao, L., Cong, P. and Liu, Z. (2014) Maize Yield Response to Water Supply and Fertilizer Input in a Semi-Arid Environment of Northeast China. PLoS ONE 9(1): e86099. doi:10.1371/journal.pone.0086099.

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1.1.2 EFFECTS OF INORGANIC AND ORGANIC FERTILIZERS ON GROWTH AND YIELD OF MAIZE (*ZEA MAYS* L.) IN LICHINGA – MOZAMBIQUE

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Abstract

Improving maize production with intensification can be done with optimized application of fertilizer, especially inorganic fertilizer. However, inorganic fertilizers are costly and the resource poor farmers lack credit and/or are unable to save sufficient cash from one cropping season to purchase fertilizers and organic inputs are often proposed as alternatives to inorganic fertilizers and the use of inorganic fertilizer for long periods cause decreased soil fertility that is unsuitable for sustainable of maize production. A field experiment was conducted in Lichinga Research Station (Mozambique) to assess the effect of chicken manure and inorganic fertilizer on growth and yield production of maize and soybean. Six fertilizer treatments were applied in a randomized complete block design (RCBD) with three replications Results were subjected to ANOVA and the least significant differences (LSD) was used to separate the means. Results indicate significant differences among treatments with sole application of chicken manure and in combination with inorganic fertilizer increasing the cob and grain weight/plant, and hundred seed weight compared to the control. This study demonstrates that the use of organic materials alone or combined with inorganic fertilizer has potential to address the low soil fertility problem in farmers' fields and raise yields of maize production.

Keywords: Chicken manure, Inorganic fertilizer, soybean, maize, yields.

Introduction

Maize (*Zea mays* L.,) is an important cereal crop grown in Mozambique. Maize ranks among the world's three most important cereals and is a major staple food in many developing countries. The greatest potential for maize production can only be fully realized with adequate fertilizer application (Norman *et al.*, 1976). Nutrient depletion is complicated by the low inherent nutrient status of many soils in Africa, and is a major factor in decreasing agricultural productivity since the 1960's (Sanchez *et al.*, 1997). Most of the cultivated soils in Mozambique have organic matter of below 2 % and on the other hand, addition of organic matter is very low. Efforts by extension officers to sensitize farmers on the use of fertilizers have not been very successful. Although the farmers are receptive, they lack the necessary purchasing power.

The level of inorganic fertilizer use in most African countries is very low due to cost, availability, lack of credit, and low grain prices resulting from limited market options (Kadi *et al.*, 1990). Inorganic fertilizers alone cannot guarantee long-term productivity on many soils since they are not effective in maintaining the soil organic matter stock; hence inputs of organic materials are needed to SOM levels. Efficient use of both organic and inorganic fertilizer is required to optimize crop yield to meet the food needs of a growing population and minimize soil degradation (Bationo and Buerkert, 2001). Efforts to use various sources of organic manure in order to address soil fertility problems are widely documented. These studies have included the possible use of chicken manure as a source of animal nutrients, supply of organic matter and in ameliorating soil acidity. A suitable combination of organic and inorganic sources of nutrients is necessary for sustainable crop yields. Hegde (1998) reported that the use of costly chemical fertilizers can be minimized or replaced by the use of locally available organic manures.

Furthermore, integrated use of organic and inorganic manures sustains the productivity of soil and crops in an integrated cropping system. This approach restores and sustains soil health and productivity in the long run, besides meeting the nutritional needs of crops (Satyajeet *et al*., 2007). Nambiar (1997) reported that integrated use of organic manure and chemical fertilizers would be promising not only in providing greater stability in production, but also maintaining better soil fertility status. Nutrients contained in organic manures are released more slowly and are stored for a longer time in the soil, thereby ensuring a long residual effect (Sharma and Mittra, 1991).

Chicken manure, when properly handled, is the most valuable of all manures produced by livestock (Charles and James, 1995) and incidentally, poultry farming is becoming a popular and fast growing enterprise in Mozambique, which implies increase in the volume of daily generated wastes, which vegetable maize growers can put to better use on their farmlands.

The objectives of this research were to determine the maize grain yield response to chicken manure application alone and in combination with inorganic fertilizer.

Materials and Methods

Experimental Site

The experiment was conducted during raining season of 2013 at Agronomic Research Area, Lichinga Research Station - Mozambique. Lichinga Research Station is located in Lichinga district to the west of the Niassa province and lies 12º 30′ to 13º 27′ S; 34°50' to 35°30' E. The site receives unimodal rainfall between November and April ranging from 900 to 2000 mm per annum (MAE, 2005). The agricultural production is predominantly rainfed (MAE, 2005). The soils are ferralsols according to FAO, (2006) soil classification system.

Experimental Design and Treatments

The trial were laid out in a completely randomized block design (CRBD) replicated three times. The treatments were:

Treatment	Chicken Manure (kg ha^{-1})	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
1. No fertilizer;	0	0	0	0
2. NPK	0	100	60	30
3. PK	0	0	60	30
4. NP	0	100	0	30
5. NP	0	100	60	0
6. Chicken manure	5000	0	0	0
7. N-P-K + Chicken manure	5000	100	60	30

Chicken manure and NPK fertilizer were applied along the furrows and mixed with soil to avoid direct contact with the seeds. Fertilizer was hand applied at those rates:

1. Urea was applied 217.4 kg ha^{-1} to reach 100 kg of N per ha equivalent to 4.17(kg/plot);
2. Superphosphate was applied at 600 kg ha^{-1} to reach 60 kg of P per ha equivalent to 11.52 (kg/plot);
3. K_2SO_4 was applied at 62.5 kg ha^{-1} to reach 30 kg of K per ha equivalent to 1.2 kg of k per plot;
4. Chicken manure was applied at rate of 5000 kg ha^{-1} equivalent to 96 kg per plot.

Land preparation was done prior to the start of the rains. Plots (21) measuring 12mx8m were used with a path of 2m between the replications and 1m between the plots. Planting was at the onset of the rains in December 2013. The spacing of maize (variety Matuba) was 80 cm x 30 cm. Two seeds of maize (variety Matuba) in monocropping system were sown per hill and later thinned to one plant per hill two weeks after emergence in order to achieve plant density of 64 plants of maize per plot. The maize was harvested at maturity. Data regarding 100-grain weight, Biomass and grain yield were recorded. The maize grain yield and biomass was weighed from the net harvest of 2 m^2 and converted into tons ha^{-1}.

Statistical analysis

Data were subjected to analysis of variance (ANOVA) using GENSTAT statistical package (Lane and Payne, 1997). Where F was significant means were separated using least significant difference (LSD) and results reported at $P \leq 0.05$ level of confidence.

Results and discussions

Hundred seed weight

The maize hundred grains weight (g) recorded are presented in figure 1. The results indicated that hundred grains weight was not significantly affected by chicken manure and NPK fertilizer treatment ($P < 0.05$). Dispite no statically significant difference, higher maize hundred grains (20.95g) was recorded in sole application of chicken manure. This may be attributed to the supply of enough nutrients in chicken manure compared to other treatments.
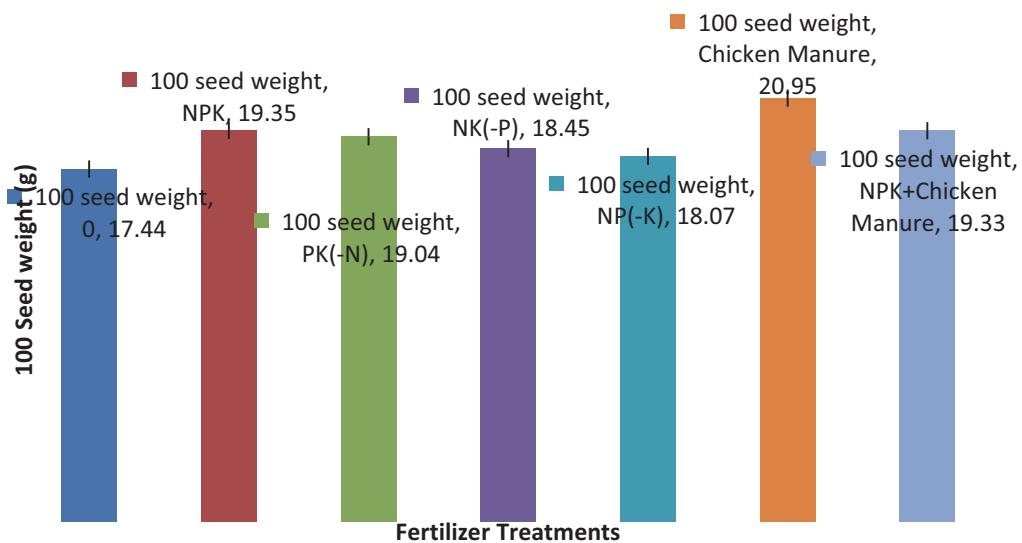
Figure 1. Hundred seed weight of maize (g).

Biomass Production

The biomass during the cropping season following the application of treatments is presented in figure 2. The maize biomass was increased by the fertilizer treatments. The results showed that the applied fertilizer treatments increased significantly maize biomass production ($P < 0.05$) compared to control. The control plots that had no fertilizers application gave the lowest biomass value of 1.42 t ha^{-1} while the highest values of 4.53 t ha^{-1} were obtained from chicken manure (5 ton ha^{-1}) + NPK (100 kg ha^{-1} + 60 kg ha^{-1} + 30 kg ha^{-1}). This may be due to an increase in the leaf area, which may have promoted photosynthate production to enhance high biomass production in the combined treatments. The results support the fact that combining organic and inorganic fertilizers increases nutrients availability to maize crop (Berga *et al.*, 2001). These findings are consistent with studies conducted by Achieng *et al.* (2010), Makinde *et al.* (2010) and Xiaonbin *et al.* (2001), who reported an increase of maize stover yield when farmyard manure was combined with inorganic fertilizers.
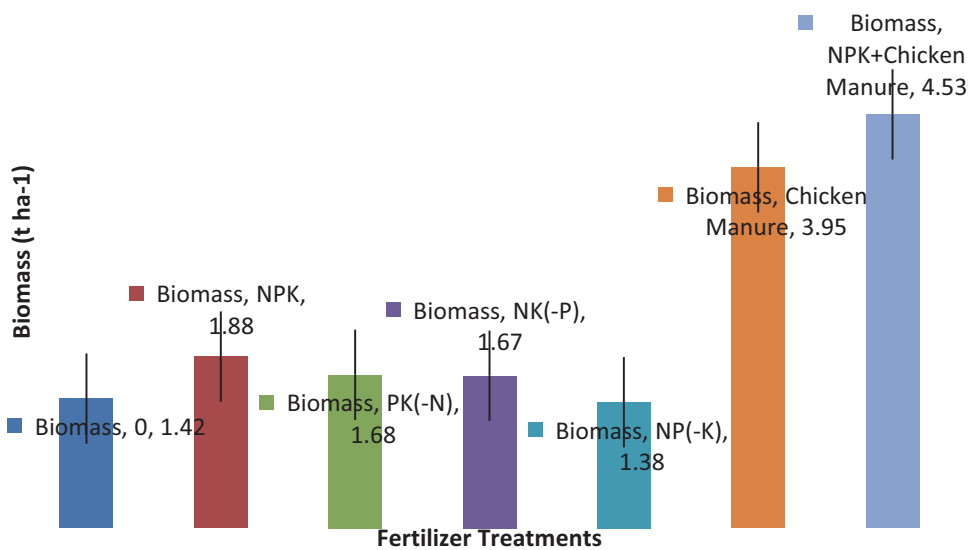
Figure 2. Biomass production of maize (t ha^{-1})

Total maize grain yield

The results of maize grain yield (t ha^{-1}) are presented in figure 3. The maize grain yield was not influenced significantly by manure and NPK fertilizer treatment ($P < 0.05$). Combined application of chicken manure and NPK fertilizer increased maize grain yield. Higher maize grain yield were recorded in plots treated with chicken manure (5 ton ha^{-1}) + NPK (100 kg ha^{-1} + 60 kg ha^{-1} + 30 kg ha^{-1}) of 3.43 t ha^{-1}. At sole application of cow manure (5 ton ha-1), and sole NPK (100 kg ha-1), total maize grain yield was reduced by 5 and 8%, respectively. The lowest grain yields were recorded in control plots at 1.73 ton ha^{-1}. The results show that the plots treated with combined chicken manure (5 ton ha^{-1}) + NPK (100 kg ha^{-1} + 60 kg ha^{-1} + 30 kg ha^{-1}) could be a likely alternative for improving crop yield in the study area. It can be associated to the better utilization of the available resources by maize at combined chicken manure and NPK fertilizer. Smaling *et al.* (1992), Palm *et al.* (1997) and Bationo *et al.* (2004) have observed that the combined use of organic and inorganic fertilizers results in higher yields than either source used alone.

There was generally no significant response to N, P and K fertilizer suppression. This implies that nutrients were available during the season of application to fully nourish a maize crop.
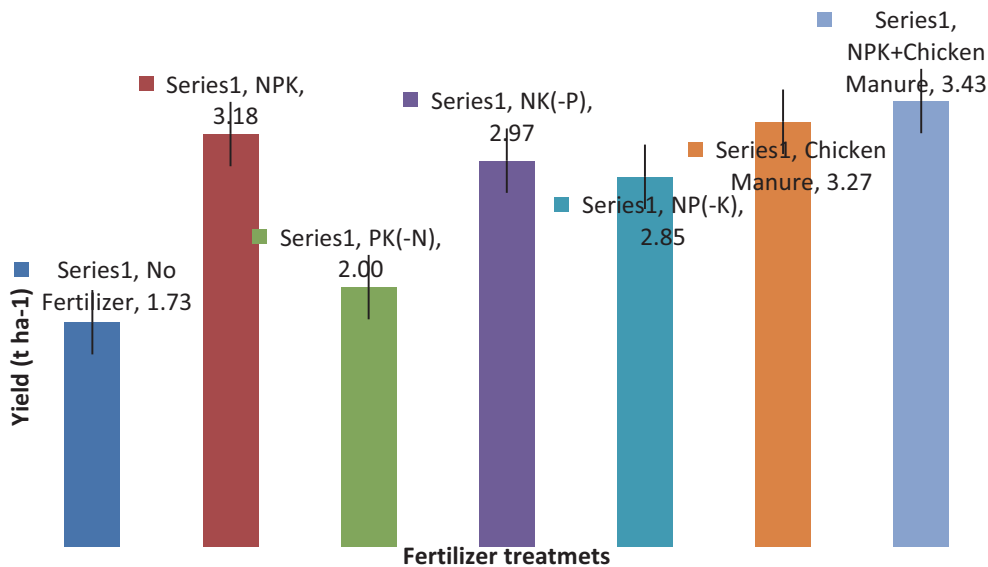
Figure 3. Maize yield (t ha^{-1})

Generally, the wide gaps between the grain yields of maize produced on the control plots and on the treatments supplied with chicken manure alone or together with NPK fertilizers in this study are expected to attract the attention of the farmers and help them to have a better understanding about the value of chicken manure in sustaining maize production.

Conclusions and recommendations

Results demonstrate that combination of chicken manure and NPK fertilizers significantly increased the yield of maize over application of chicken manure or NPK alone. Optimum yield of the maize was achieved at a combination of chicken manure (5 ton ha^{-1}) + NPK (100 kg ha^{-1} + 60 kg ha^{-1} + 30 kg ha^{-1}), hence farmers need to adopt this production system to increase yields. The study recommends that farmers with limited resources may fertilize maize with chicken manure at the rate of (5 t ha^{-1}) together with NPK (100 kg ha^{-1}) in the study area of Lichinga. As a long-term strategy in the future, locally available sources of organic fertilizers should be used on a continuous basis for replenishing the degraded physicochemical properties of the soils in the region.

Acknowledgements

References

Achieng, J. O., Ouma, G., Odhiambo, G. and Muyekho, F. 2010. Effect of farmyard manure and inorganic fertilizers on maize production on Alfisols and Ultisols in Kakamega, Western Kenya. Kakamega, Kenya. Agriculture and Biology Journal Of North America.

Bationo, A., Nandwa, S. M., Kimetu J. M., Kinyangi J. M., Bado, B. V., Lompo, F., Kimani, S., Kihanda, F. and Koala S. 2004. Sustainable intensification of crop-livestock systems through manure management in eastern and western Africa: lessons learned and emerging research opportunities. In: Williams TO, Tarawali SA, Hiernaux P, Ferna´ndezRivera S (eds) Sustainable crop-livestock production for improved livelihoods and natural resource management in West Africa. International Livestock Research Institute and Technical Centre for Agricultural and Rural Cooperation proceedings. Ibadan, Nigeria pp 173–198.

Bationo A, Buerkert A (2001). Soil organic carbon management for sustainable land use in Sudano-Sahelian West Africa. Nutri. Cycling Agroecosyst. 61:131-142.

Charles CM and James OD (1995). The value and use of poultry manures as fertilizer. Circular No.244. Alabama State University, U.S.A., p.6.

FAO (Food and Agriculture Organization). 2006. Guidelines for soil description. Fourth Edition. Rome. Food and Agriculture Organization (FAO). Pp 97.

Hegde, D. M., 1998. Integrated nutrient management for production sustainability of oil seeds: A review. Journal of oil seeds Research, 15: 1 - 17.

Kadi M, Lowenberg-Deboer J, Reddy KC, Abdoulaye B. (1990). Sustainable millet cowpea technologies for semi-arid Niger. Indian J. Dryland Agric. Res. Develop. 4:95 -98.

MAE (Minesterio da Administratração Estatal). 2005a. Perfil Do Distrito de Lichinga. Maputo : Minesterio da Administratração Estatal.

Makinde, E. A. and Ayoola, O. T. 2010. Growth, Yield and NPK Uptake by Maize with complementary organic and inorganic fertilizers. Ibadan, Nigeria: *African Journal of Food, Agriculture, Nutrition and Development*.

Nambiar, K.K.M.. 1997. Soil health and organic matter: Changing scenario. Proc. Nat. ACAD. Sci. India Spl. Issue pp 141-160.

Norman, D. W., P. Beeden, W. J. Kroeker, D. H. Pryor, H. M. Hays and B. Huizinga.1976. The feasibility of improved sole crop maize production technology forthe small-scale farmer in the northern guinea Savannah zone of Nigeria. Samaru Miscellaneous paper 59.

Palm, C. A., Myers, R. J. and Nandwa, S. M. 1997. Combined use of organic and inorganic nutrient sources for soil fertility maintenance and replenishment. USA: Agronomy and Soil Science Society of America. Pp. 196-217.

Sanchez PA, Shepherd KD, Soule MJ, Place FM, Buresh RJ, Izac AMN, Mokwunye AU, Kwesiga RK, Ndiritu CG, Woomer PL. (1997). Soil fertility replenishment in Africa: An investment in natural resource capital. In Buresh RJ, Sanchez PA, Calhoun F (eds.) Replenishing Soil Fertility in Africa. Soil Sci. Soc. Amer. Special Publication Number 51, Madison, WI. pp.1–46.

Satyajeet, R. K., Nanwal and Yadav, V. K. 2007. Effect of integrated nutrient management in nitrogen, phosphorus and potassium concentration, uptake and productivity in pearl millet. Journal of Maharastra Agricultural Universities, 32: 186 - 188.

Sharma, A. R. and B. N. Mittra.1991. Effect of different rates of application of organic and nitrogen fertilizers in a rice-based cropping system. Journal Agricultural Science (Cambridge) 117:313 - 318.

Smaling, E., Nandwa, S., Prestele, H., Roetter, R. and Muchena, F. 1992. Yield response of maize to fertilizers and manure under different agro-ecological conditions in Kenya. Agriculture, Ecosystems and Environment 41: 241-252.

Syers J.K. Managing soils for long-term productivity. Philosophical Transactions of the Royal Society of London. Series B, In: Biological Sciences. 1997;352:1011-1021.

Xiaonbin, W., Dianxiong, C. and Jingqing, Z. 2001. Land application of organic and inorganic fertilizer for corn in dry land farming Region of North China. China: Sustaining the Global Farm. Selected papers from the 10th International Soil Conservation Organization Meeting held May 24-29, 1999. at Purdue University and the *United States Department of Agriculture* - Agricultural Research Service *(USDA*-ARS). National Soil Erosion Research Laboratory. Pp. 419-422.

1.1.3 EFFECTS OF THE COMMERCIAL CHEMICAL PRODUCT TEPROSYN ON GROWTH AND YIELDS OF MAIZE GROWN ON AN ULTISOL IN MOROGORO, TANZANIA

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Abstract

A study was conducted under greenhouse and field conditions at Sokoine University of Agriculture to evaluate the effects of Teprosyn, a seed coating product, on growth and yields of maize SITUKA variety grown on an Ultisol. The study soil had medium organic matter, low available phosphorous and very low extractable zinc; hence the soil was of medium fertility status and moderately suitable for maize production. In each study, the Teprosyn product was evaluated in the randomized completely block design (RCBD) with three replications. Six treatments, namely: i.control (without Teprosyn product and P-fertilizer), ii. Teprosyn product alone at manufacturer's recommended rate, iii. Teprosyn product alone at double rate, iv. Teprosyn product + 10 kg P/ha P-fertilizer, v.10 kg P/ha P-fertilizer and vi.20 kg P/ha P-fertilizer, were used in both studies. In the greenhouse, Teprosyn did not result in any significantly (P=0.05) difference in maize growth or biomass yields relative to those in the control. However, Teprosyn in combination with P-fertilizer (at half recommended rate) resulted in significant (P=0.05) increase in growth parameters and biomass yields. Teprosyn increased biomass yields from 0.96 (Control) to 1.89 (K_2HPO_4 at 20 kg P ha^{-1}). In the field, Teprosyn had no effect on maize growth or did not increase maize biomass yields at tasseling. The Teprosyn, either alone or in combination with P-fertilizer (at half recommended rate) did not produce significant (P=0.05) differences in maize grain yields than from those in the control. However, grain yields increased significantly (P=0.05) from 2059 kgha^{-1} (Control) to 3386 kgha^{-1}

(YaraMila Cereal at 20 kg P ha^{-1}). Therefore, these findings indicate that Teprosyn product was of low quality to meet the needs of the plants, unless external sources of N, P and Zn are supplemented to enhance maize growth and yields in P-deficient soils.

Key words: Teprosyn, seed coating, Maize, ISFM, Soil fertility, commercial products

Introduction

Low soil fertility and high nutrient mining are the main factors limiting crop production in Sub-Saharan Africa (Adu-Gyamfi *et al*., 2007). Some soil fertility management technologies being pursued to address low soil fertility in Tanzania include use of organic soil amendments (e.g., crop residues, animal manures, agroforestry tree pruning) and inorganic resources (fertilizers, agro-minerals), improved fallows (Kwesiga *et al.*, 1994) and commercial chemical products containing micro- and macro-nutrients (Woomer, 2012).

Kaya *et al*. (2006), as cited by Pholo (2009), reported that treating seeds with commercial chemical products containing micro and macro-nutrients improved germination and seedling establishment of wheat, soybean, sunflower and maize. Van der Watt (2005) also proposed that treating seeds with a variety of commercial chemical products which consist of mixtures of macro-and micro-elements has proved to play a pivotal role in plant morphological and physiological growth through early seedling establishment, establishing strong root systems during seedling growth and early development of wheat, soybean, sunflower and maize. Improvement of plant growth may be due to, among others, the presence of phosphorous (P) which plays a role in an array of processes including energy generation via cell respiration, enzyme activation as well as nitrogen fixation (Kaya *et al*., 2006). Similarly, the presence of nitrogen in these commercial chemical products plays a key role in the synthesis of proteins and chlorophyll, which are essential for rapid growth, improving the quality and quantity of dry matter in leafy vegetables and protein in grain crops (Dawar *et al*, 2011; Uchida, 2000).

Zinc (Zn), on other hand, is an essential micro-nutrient playing a vital role in the synthesis of the essential aromatic amino acid tryptophan, and is also involved in enzymatic reactions where it acts as an inorganic co-factor and in the activation of the enzyme starch synthase (Kaya *et al*., 2006). Reduced Zn suppresses the activity of starch synthase and finally the number of starch grains in kernels (Kaya *et al*. (2006).

Since 2010, different commercial chemical products have entered the Tanzania market, each being claimed to have high effectiveness in improving soil fertility and increasing the productivity of various crops. However, their efficacy and quality have not been evaluated under Tanzanian farming conditions. Therefore, this study was carried out to evaluate the effects of a selected commercial chemical product (supplying N, P and Zn) on maize growth performance and yields.

Materials and methods

Soil and Teprosyn chemical analysis

A greenhouse experiment in pots was conducted on a clay soil (Typic Paleustults) at the Department of Soil Science, Sokoine University of Agriculture (SUA), Tanzania, to study the effects of Teprosyn on maize growth. The bulk surface soil sample was ground to pass through a 2 mm sieve. The physico-chemical properties of the experimental soil determined by standard procedures, are presented in Table 1.

Table 1. The physico-chemical properties of the experimental soil (SUA farm)

Property, units	Value
Sand, %	41.0)[*]
Silt, %	3.0)
Clay, %	56.0)
pH (H_2O)	6.33M[**]
Organic carbon, %	1.72 M
Total nitrogen, %	0.14 L
Bray 1 P, mg/kg	1.02 L
Exchangeable Ca, Cmol(+)/kg	6.35 M
Exchangeable Mg, Cmol(+)/kg	3.22 H
Exchangeable Na, Cmol(+)/kg	0.26 L
Exchangeable K, Cmol(+)/kg	1.10 M
CEC, Cmol(+)/kg	23.0 M
DTPA extractable Fe, mg/kg	38.0 VH
DTPA extractable Mn, mg/kg	67.5 VH
DTPA extractable Zn, mg/kg	0.34 VL
DTPA extractable Cu, mg/kg	2.43 H

Similarly, the quality of the Teprosyn product in terms of its total nutrients contents was determined in the laboratory before being used. The total nutrient contents (macro and micronutrients) in Teprosyn, as determined in the present study, are presented in Table 2. Only the total nitrogen content resembled that in the label of the product package while the total phosphorous (as P_2O_5) and zinc were much lower than the 15% phosphorous pentoxide (P_2O_5) and 18% zinc as quoted in the label.

Table 2. Nutrient contents of Teprosyn

Parameter	Content as determined in laboratory	Content as specified by manufacturer
% N	9.32 ± 0.15	9
% P_2O_5	2.72 ± 0.08	15
% Zn	5.54 ± 0.11	18

Pot experiments

Three kg of the bulk soil samples from the site were placed into 4-L plastic pots, arranged in a randomized complete block design with three replications. The six treatments, namely: i.control (No teprosyn product + no P fertilizers), ii. Recommended rate of teprosyn (4 ml / 0.5 kg seed), iii. Double recommended rate of teprosyn (8 ml / 0.5 kg seed), iv. Half recommended P rate (10 kg P ha^{-1}) + recommended rate of teprosyn (4 ml / 0.5 kg seed), v. Half recommended P rate (10 kg P ha^{-1}) and vi. Full recommended P rate (20 kg P ha^{-1}) were randomly assigned into each pot.

At planting, in order to avoid contamination, all pots that received untreated seeds were first planted, followed by pots whose seeds were to be treated with the commercial chemical product. The certified SITUKA maize seeds were cleaned by rising with water so as to remove storage chemicals before treatment prior to mixing with Teprosyn in plastic bag. The mixture was agitated rigorously for 1 minute. Subsequently, the treated seeds were placed on a sheet of filter paper and allowed to dry indoors for 30 minutes, before being planted in the pots. Three seeds of SITUKA maize variety were planted on the potted soils and seedlings were thinned to two plants per pot 12 days after sowing (DAS).

Rates per pot of 0.26 g N from urea and 0.0528 g Zn from zinc sulphate (ZnSO4.7H$_2$O) were applied to potted soils. To satisfy the suggested rates of P (10 and 20 kg P ha^{-1}) in treatments for evaluating the commercial products, 0.2245 g P and 0.449g P, respectively, from K$_2$HPO$_4$, were applied to potted soils. With exception of N, as urea (recommended rate of 60 kg N ha^{-1}), which was split applied at planting time and 28 days after planting, all treatments for Teprosyn and the other fertilizers were applied prior to planting time. The soils in the pots were frequently watered and maintained at about field capacity throughout the experimental period.

Plant heights were measured to the nearest centimeter from the base to plant tops at 21, 28 and 35 days after sowing (DAS) from the two maize plants from each pot and an average was obtained. At 35 days after planting (DAP), shoot dry matter was also determined after cutting the shoots of the two plants at 1 cm above the soil surface, drying in an oven at 65˚C to constant weight. The dried plant samples were cut into small pieces ground and passed through a 0.5 mm sieve for chemical analysis to determine the plant uptake of N, P and Zn. Similarly, soil samples from each pot were also collected for determination of N, P and Zn. The collected data were then subjected to analysis of variance using the GenStat Discovery 15th edition computer software and the treatment means separation was done using Least Significant Difference (LSD) Test at the 5 % level of significance.

Field experiments
Likewise, an on-station experiment was conducted in on clay soil (Typic Paleustults) during the 2014/15 growing season to assess the effects of Teprosyn on growth and yields of maize, SITUKA variety, at Sokoine University of Agriculture (SUA) farm, Tanzania. The Teprosyn product was evaluated in conjunction with other fertilizers including YaraMila Cereal fertilizer

(containing N, P, K, Mg, S and Zn), Zinc sulphate (ZnSO4.7H$_2$O) and urea (CONH$_2$)$_2$) (46% N) applied in the field experiment to optimize the conditions of maize production. With exception of N, which was split-applied at planting time and the second split later on for all treatments, the other fertilizers were applied only once at planting time. Nitrogen was applied at the recommended rate (60 kg N ha^{-1}) to all treatments in two splits, whereby 50 kg N ha^{-1} of the total amount of N was supplied by YaraMila Cereal fertilizer during planting and the remaining 10 kg N ha^{-1} was applied as urea when maize plants were at knee high. Zinc was applied (as ZnSO4.7H$_2$O) at 13.33 kg Zn ha^{-1} at planting.

The Teprosyn was evaluated in the randomized completely block design (RCBD) with three replications. The treatments in the experiment were as follows: Control (No teprosyn + no P fertilizers), recommended rate of teprosyn (4 ml / 0.5 kg seed), double recommended rate of teprosyn (8 ml / 0.5 kg seed), half recommended P rate (10 kg P ha^{-1}) + recommended rate of teprosyn (4 ml / 0.5 kg seed), half recommended P rate (10 kg P ha^{-1}) and full recommended P rate (20 kg P ha^{-1}), randomly assigned in the plots. Treatment of maize seeds by Teprosyn was done as in the pot experiments. Maize seeds of SITUKA variety were sown at 30 cm within a row and 75cm between rows, giving 40 maize plants per plot. Two seeds were sown, and the plants were thinned to one plant per hill 13 days after planting. Maize was harvested 120 days after sowing.

Data on plant height, plant girth and the number of leaves were collected at 3, 6, 9 and 12 weeks after sowing from four maize plants in two inner rows of each plot. Similarly, at tasseling stage, four maize plants from each plot were sampled (destructive sampling) and used for biomass determination. However, eight plants in one inner row in each plot were left to grow to maturity stage and harvested for grain yield determination. At harvest soil samples from each plot were also collected for determination of N, P and Zn.

Statistical analysis
The collected data were analyzed for variance using the GenStat Discovery 15th edition computer software. Treatment means separation was done using Least Significant Difference (LSD) Test at the 5 % level of significance.
Results

Greenhouse pot experiments

Effects of Teprosyn on maize growth, biomass yields and shoot nutrient concentrations

The effects of Teprosyn on maize growth and biomass yields are presented in Table 3. In the early days of plant growth at 28 DAP, plant height and plant girth did not show any significant (P=0.05) differences across treatments. Teprosyn alone or in combination with K$_2$HPO$_4$ (10 kg P ha^{-1}) did not differ much amongst themselves and sometimes not with the control in terms of plant height and plant girth. However, the number of leaves were significantly (P=0.05) different across the treatments, with the highest leaf number recorded under the K$_2$HPO$_4$ treatments, especially at the rate of 10 kg P / ha.

In the subsequent periods of plant growth, at 35 DAP, the treatments with the combination of Teprosyn (4 ml/0.5 kg seed) + K$_2$HPO$_4$ (10 kg P ha^{-1}) and K$_2$HPO$_4$ alone, especially at the rate of

20 kg P / ha, resulted in significantly (P=0.05) higher plant heights and plant girth. However, the number of leaves did not show significant differences across treatments. Teprosyn treatments, either alone or in combination with K_2HPO_4 at 10 kg P/ ha, somehow differed amongst themselves and sometimes with the control in terms of plant heights and plant girth.

At harvest, biomass yields showed significant (P=0.05) differences across treatments, with the K_2HPO_4 (20 kg P ha^{-1}) treatment resulting in significantly (P=0.05) higher biomass yields.

Table 3. Effects of Teprosyn on plant height, number of leaves, plant girth and biomass yields

Treatment (T)	21 DAP			28 DAP			35DAP			
	Plant Height, cm	No. leaves/plant, cm	Plant Girth, cm	Plant Height, cm	No. leaves/plant, cm	Plant Girth, cm	Plant Height, cm	No. leaves/plant	Plant Girth, cm	Biomass yields, (g/plant)
Control	32.5	5.2	0.6	39.6	6.0	0.6	43.3	7.0	0.6	0.96
Teprosyn (4 ml/0.5 kg seed)	36.2	4.8	0.6	34.8	5.8	0.7	36.3	7.0	0.7	0.95
Teprosyn (8 ml/0.5 kg seed)	39.4	5.0	0.6	39.7	6.0	0.6	38.6	7.3	0.7	1.05
Teprosyn (4 ml/0.5 kg seed) + K₂HPO₄ (10 kg P ha⁻¹)	34.9	5.0	0.5	39.9	6.3	0.6	54.7	7.3	0.7	1.42
K₂HPO₄ (10 kg P ha⁻¹)	42.6	5.0	0.5	33.6	6.8	0.7	51.6	7.7	0.8	1.74
K₂HPO₄ (20 kg P ha⁻¹)	34.8	5.0	0.6	41.3	6.3	0.7	45.1	7.7	0.8	1.89
LSD	12.96	0.29	0.06	10.38	0.74	0.09	13.31	0.88	0.11	0.41
CV (%)	19.4	3.2	5.9	15.0	6.5	7.4	16.3	6.6	8.3	17.0

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The Teprosyn treatments alone did not differ much amongst themselves and sometimes not with the control. Concentrations of P in shoot (as expression of nutrient uptake) did not show significant (P=0.05) differences across treatments (Table 4). Phosphorous in shoots varied from 0.06 % (Control) to 0.19 % (Teprosyn at 4 ml/0.5 kg seed). However, the concentration of nitrogen and zinc in the shoot showed significant (P=0.05) differences across some treatments (Table 4). Nitrogen varied from 2.81 % (Control) to 3.57 % (K_2HPO_4 at 10 kg P ha^{-1}) and zinc ranged from 45.08 mg/kg (Teprosyn at 4 ml/0.5 kg seed) to 70.48 mg/kg (Teprosyn at 4 ml/0.5 kg seed + K_2HPO_4 at 10 kg P ha^{-1}).

The trends of no differences as observed in the early stage of plant growth may be attributed to the fact that the plants were still young and developing their root systems to be able to absorb the nutrients released by the applied fertilizers. However, significant differences in plant heights and plant girth observed in the subsequent periods of plant growth, especially under Teprosyn (4 ml/0.5 kg seed) + K_2HPO_4 (10 kg P ha^{-1}) and K_2HPO_4 (20 kg P ha^{-1}) treatments, may be attributed to supply of nutrients (N, P, K and Zn) from Teprosyn and K_2HPO_4, respectively. The increased maize shoot yields in the reference treatment (K_2HPO_4 at 20 kg P ha^{-1}) confirm that the soils used were infertile and thus responsive to nutrient inputs; hence the conditions were favourable for the various products to show their effects.

Table 4. Effects of Teprosyn on nutrient concentrations in maize shoot and soil after harvest

Treatment (T)	Shoot P (%)	Shoot N (%)	Shoot Zn (mg/kg)	Soil N (%)	Soil P (mg/kg)	Soil Zn (mg/kg)
Control	0.06	2.81	63.09	0.17	0.72	1.43
Teprosyn (4 ml/0.5 kg seed)	0.19	2.89	45.08	0.16	0.57	1.14
Teprosyn (8 ml/0.5 kg seed)	0.05	2.92	60.32	0.18	0.65	1.31
Teprosyn (4 ml/0.5 kg seed) + K_2HPO_4 (10 kg P ha^{-1})	0.10	3.26	70.48	0.16	0.82	1.64
K_2HPO_4 (10 kg P ha^{-1})	0.11	3.57	53.86	0.17	0.82	1.64
K_2HPO_4 (20 kg P ha^{-1})	0.14	3.26	53.39	0.12	1.13	2.25
LSD	0.18	0.58	15.93	0.66	0.19	0.38
CV (%)	92.1	10.3	15.2	22.6	13.1	13.1

The results of the present study, indicating that Teprosyn treatments alone had no significant (P=0.05) effects on plant height and plant girth in early growth or shoot biomass and nutrient (P) concentration at harvest, are in contrast with the findings of by Munyahali (2012). This author, while he observed significant positive effect of Teprosyn on maize height in the early growth stages, also reported insignificant effects of Teprosyn on maize shoot biomass at harvest. Similarly, Peltonen-Sainio *et al*. (2006) evaluated the effect of P seed coating on oats and found that P seed coating enhanced early growth of oats but without increasing yields. Further, Karanam and Vadez (2010) reported an increase in shoot biomass of two- and four- week-old seedlings due to P seed coating of pearl millet compared with non-coated treatment.

With regard to nitrogen, phosphorous and zinc contents in the maize shoots (at harvest), the study findings showed that P concentration in all treatments fell far below the sufficiency range (0.4 - 0.8 %) established for shoots of corn plants 30 to 45 days after emergence (Lockman, 1969; Vandamme, 2008). It was observed (Table 2) that the P content in the Teprosyn product used was low, which, together with low soil P levels, was not sufficient to significantly improve plant growth and plant nutrient contents. Rebafka *et al*. (1993) similarly found no effect of P seed coating on shoot P concentrations by 40 DAP in pearl millet grown on an acid sandy soil. The study, however, reported higher P concentrations in the pearl millet shoots at 20 DAP (at five-leaf stage).

The zinc concentrations (except the treatment with combination of Teprosyn at 4 ml/0.5 kg seed + K_2HPO_4 at 10 kg P ha^{-1}, that was above the sufficiency range) were within the sufficiency range (20 – 50 mg Zn kg^{-1}) established for shoots of corn plants 30 to 45 days after emergence (Lockman, 1969; Vandamme, 2008). This implies that the maize plants from most treatments took up some amounts of zinc, though not in large quantities to result in much improvement in plant growth or shoot biomass yields. The nitrogen concentrations in other treatments (except the combination of Teprosyn at 4 ml/0.5 kg seed + K_2HPO_4 at 10 kg P ha^{-1}) were below the sufficiency range (3.5 – 5.0 %) established for shoot corn plants 30 to 45 days after emergence

(Lockman, 1969). This may also explain the lack of significant improvements in biomass yields (Table 3) in most treatments.

Effects of Teprosyn on nutrient availability in soil

The effects of Teprosyn on nutrients (P, N and Zinc) availability in soil after harvest are presented in Table 4. The concentrations of N in soil did not show significant (P=0.05) differences across treatments (Table 4). Nitrogen varied from 0.12 % (K2HPO4 at 20 kg P ha-1) to 0.18 % (Teprosyn at 8 ml/0.5 kg seed). However, the concentration of P and zinc in the soil showed significant (P=0.05) differences across treatments (Table 3): P increased from 0.57 mg/kg (Teprosyn at 4 ml/0.5 kg seed) to 1.13 mg/kg (K_2HPO_4 at 20 kg P ha^{-1}) and Zn from 1.14 mg/kg (Teprosyn at 4 ml/0.5 kg seed) to 2.25 mg/kg (K_2HPO_4 at 10 kg P ha^{-1}). However, the levels of P are altogether low in the soils.

Teprsoyn was considered as an N, P and Zn supplement. However, Teprosyn alone could not provide sufficient N, P or Zn for adequate crop growth and biomass yields, until when supplemented with P (K_2HPO_4) at half the recommended rate in the soil. The results of this study indicate that the quantities of N, P and Zn contained in the Teprosyn product are too little to meet the nutritional needs of the plant when applied alone to soil/seed and thus, should be supplemented with external N and P to enhance plant growth and yields in P-deficient soils. Therefore, the product tested in the present study was of low quality not only as compared to cited values but also to practically make a substantial difference or improvement in plant growth and crop yields. Although the Zn contents in soils following addition of Teprosyn or YaraMila Cereal fertilizer were above critical levels of 0.5 – 1 mg/kg (REF), the effect of Zn may have been masked due to low amounts of other nutrients.

Field experiments

Effects of Teprosyn on maize growth performance

The effects of Teprosyn on maize growth performance are presented in Table 4. In the early days of plant growth (21 DAP), plant height and number of leaves did not show any significant differences across treatments. However, in the subsequent periods of plant growth, the YaraMila Cereal fertilizer treatments alone, at 84 DAP, resulted in significantly (P=0.05) higher plant heights and some other growth parameters, especially at the rate of 20 kg P / ha. The Teprosyn treatments, either alone or in combination with YaraMila Cereal fertilizer at 10 kg P/ ha, did not differ much amongst themselves and sometimes not with the control.

At tasseling, biomass yields showed significant differences across treatments with the YaraMila Cereal fertilizer treatments alone or in combination with Teprosyn (4 ml/0.5 kg seed) resulting in significantly (P=0.05) higher biomass yields. The Teprosyn treatments alone did not differ much amongst themselves and sometimes not with the control. Concentrations of N, P and Zn in ear leaf (as expression of nutrient uptake) did not show significant differences across treatments (Table 13): N varied from 1.80% (Control) to 2.14 % (YaraMila Cereal at 10 kg P ha^{-1}), P from 0.19 % (Control) to 2.61 % (Teprosyn at 8 ml/ 0.5 kg seed), and Zn from 15.70mg/kg (YaraMila Cereal at 20 kg P ha^{-1}) to 19.57mg/kg (Teprosyn at 8 ml/ 0.5 kg seed).

The trends of no differences as observed in the early stage of plant growth may be attributed to the fact that the plants were still young and developing their root systems to be able to absorb much of the nutrients as already discussed above for pot experiments. However, significant

differences in plant heights and some other growth parameters observed in the subsequent periods of plant growth, especially under the reference treatment (YaraMila Cereal fertilizer at 20 kg P / ha), may be attributed to the high quantities of the nutrients (N, P, K, Mg, S and Zn) available in the fertilizer. The increase in maize shoot biomass in the reference treatment confirms that the soils used were infertile and thus responsive to nutrient inputs, as already discussed.

The results of this study indicate that Teprosyn treatments alone had no significant (P=0.05) effect on plant height in the early growth and shoot biomass and nutrient (N, P and Zn) uptake at tasseling. These results contrast with the findings of other studies. Peltonen-Sainio *et al*. (2006) evaluated the effect of P seed coating on oat and found that P seed coating enhanced early growth of oat without increasing yields. Further, Karanam and Vadez (2010) reported an increase in shoot biomass of two- and four- week-old seedlings due to P seed coating of pearl millet compared with no-coated treatment.

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Table 5. Effects of Teprosyn on plant height, number of leaves, plant girth and biomass yields

Treatment (T)	21 DAP		42 DAP			63 DAP			84 DAP			Biomass at tasselling, g/plant
	Plant Height, cm	No. leaves/ plant	Plant Height, cm	No. leaves/ plant	Plant Girth, cm	Plant Height plant	No. leaves/ cm	Plant Girth, cm	Plant Height, cm	No. leaves/ plant	Plant Girth, cm	
Control	26.8	7.3	61.1	9.3	1.6	186.2	13.3	1.7	241.5	12.1	1.7	206.80
Teprosyn (4 ml/0.5 kg seed)	25.6	7.3	65.7	10.0	1.9	195.6	13.7	1.8	254.2	12.6	1.9	214.80
Teprosyn (8 ml/0.5 kg seed)	27.5	7.3	77.0	11.0	2.2	215.8	15.0	2.0	245.7	12.9	2.0	238.60
Teprosyn (4 ml/0.5 kg seed)+ YaraMilaCereal	27.9	8.0	80.4	10.7	2.2	218.8	14.3	1.9	260.4	13.0	2.1	312.60
YaraMilaCereal (10 kg P ha-1)	29.3	7.7	87.6	11.0	2.3	225.8	14.0	2.0	263.5	13.3	2.1	315.60
YaraMilaCereal (20 kg P ha-1)	29.5	7.7	96.0	11.7	2.4	245.2	15.7	2.3	275.5	13.5	2.3	371.50
LSD	4.33	1.23	15.91	2.02	0.36	31.18	1.10	0.31	28.72	1.21	0.40	75.98
CV (%)	8.3	8.9	11.2	10.4	9.5	8.0	4.2	8.9	6.1	5.2	11.0	15.1

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Table 6. Effects of Teprosyn on maize grain yields and nutrient concentrations in maize ear leaf and soil after harvest

Treatment (T)	Ear leaf N (%)	Ear leaf P (%)	Ear leaf Zn (mg/kg)	Soil N (%)	Soil P (mg/kg)	Soil Zn (mg/kg)	Maize grain yields (kg/ha)
Control	1.80	0.19	18.60	0.15	1.33	3.43	2059
Teprosyn (4 ml/0.5 kg seed)	1.84	0.22	17.64	0.17	1.41	4.38	2111
Teprosyn (8 ml/0.5 kg seed)	2.11	0.26	19.57	0.17	1.39	5.23	2180
Teprosyn (4 ml/0.5 kg seed) + YaraMila Cereal (10 kg P ha^{-1})	2.07	0.24	19.09	0.17	2.25	6.58	1926
YaraMila Cereal (10 kg P ha^{-1})	2.14	0.22	17.15	0.17	2.79	4.83	2815
YaraMila Cereal (20 kg P ha^{-1})	2.01	0.30	15.70	0.17	5.02	3.43	3386
LSD	0.34	0.05	5.98	0.04	0.10	3.09	986.3
CV (%)	9.3	23.3	18.3	11.7	23.2	35.8	22.5

Therefore, the results of this study indicate that the quantities of N, P and Zn contained in Teprosyn product are too little to meet the needs of the plant and should be supplemented with external N, P and Zn to enhance plant growth and yields in these P-deficient soils. The product tested in the present study was of low quality and would, therefore, not qualify for sole use in Tanzania. These quantities could possibly result in better plant performance if the outlook for their use would be to contribute more to nourish soil microorganisms, thereby improving the microorganisms' capacity to mineralize additional quantities of nutrients from soil organic matter. Otherwise, the absolute qualities of these nutrients in these commercial products are too low to make a substantial direct impact on plant growth when applied to soil.

Effects of Teprosyn on maize grain yields
The effects of Teprosyn on maize grain yields and nutrient concentrations in soil after harvest are presented in Table 5. The maize grain yields at harvest showed significant (P=0.05) differences across treatments, with YaraMila Cereal fertilizer, especially at the rate of 20 kg P/ha, resulting higher grain yields. The Teprosyn treatments, either alone or in combination with YaraMila Cereal fertilizer (10 kg Pha^{-1}), did not differ much amongst themselves and not with the control. These findings are supported by the results of Dogan *et al*. (2008), using the wheat crop, who observed insignificant seed yields at harvest following treatment of wheat seeds with a zinc compound (Teprosyn F-2498). However, the current study findings contradict results of Yilmaz *et al*. (1997) who reported increase in wheat seed yield when seeds were treated with a zinc product. Further, Masuthi *et al*. (2009) reported significant increase in seed yield in cowpea (*Vigna unguiculata* L.) over control due to pelleting seed with ZnSO4, as was similarly reported by Singh (2007) in studies using sunflower, maize, wheat, soybean and peanut coated with Teprosyn-ZnP or Teprosyn- Zn products.

The present study findings indicated decrease in grain yields when higher rate (above the recommended rate) of Teprosyn was used (Teprosyn at 8 ml/kg 0.5 seed). Dogan *et al*. (2008) similarly observed decrease in wheat seed yields when higher rates of a zinc compound (Teprosyn F-2498) above the recommended rate were used. The decrease of grain yields may be due to antagonistic effects with other nutrients in soil, making the zinc absorbed to be insufficient to increase yields even if the Zn content of soil was adequate. Antagonistic effects of Zn and P have been documented (Christensen and Jackson, 1981; Singh *et al*., 1986).

Effects of Teprosyn on nutrient availability in soil
At harvest, the concentrations of N and Zn in soil did not show significant (P=0.05) differences across treatments (Table 13). Nitrogen varied from varied from 0.15 % (Control) to 0.17 % (Teprosyn at 4 ml/0.5 kg seed or 8 ml/0.5 kg seed, Teprosyn at 4 ml/0.5 kg seed + YaraMila Cereal fertilizer at 20 kg P ha^{-1}, YaraMila Cereal fertilizer at 10 kg P ha^{-1} and 20 kg P ha^{-1}) and Zn ranged from 3.43mg/kg (Control and YaraMila Cereal fertilizer at 20 kg P ha^{-1}) to 6.58mg/kg (Teprosyn at 4 ml/0.5 kg seed + YaraMila Cereal fertilizer at 10 kg P ha^{-1}) to 2.25 mg/kg). However, the concentration of P in the soil showed significant (P=0.05) difference across

treatments (Table 13): P ranged from 1.33 mg/kg (Control) to 5.02 mg/kg (YaraMila Cereal fertilizer at 20 kg P ha^{-1}).

However, although the present study findings showed significant increase of available P in soil at harvest due to Teprosyn inoculation, the amount of P in the product could not increase maize grain yields, confirming that the quantities of P contained in the Teprosyn product are too little to meet the needs of the plant and, therefore, should be supplemented with external N, P and Zn to enhance plant growth and yields in P-deficient soils.

Conclusions and recommendations

Under greenhouse conditions, Teprosyn, a seed N, P and Zn coating product, can be considered to be of low quality as it did not result in increased maize growth performance and biomass yields until when supplemented with P-fertilizer (at half recommended rate). Similarly, Teprosyn did not increase either shoot P content or soil N content. However, Teproyn led to an increase in shoot N content, shoot Zn content and the concentrations of available P and Zn in the soil after harvest.

Under field experiments, the Teprosyn alone had no effect on growth performance in the early days of maize growth (21 DAP) until in the subsequent periods of plant growth at 84 DAP. Similarly, the application of Teprosyn alone did not increase biomass yields, the concentrations of N, P and Zn in ear leaf or the concentrations of soil N, P and Zn at harvest, until when supplemented with P-fertilizer (at half recommended rate). The Teprosyn alone at recommended rate showed a positive increase in grain yields; however, Teprosyn alone at a higher rate or in combination with the P-fertilizer (at half recommended rate) resulted in decreased maize grain yields. It is recommended that external sources of N, P and Zn should always be supplemented in conjunction with the Teprosyn inoculant to enhance maize growth and yields in P-deficient soils.

References
Adu-Gyamfi, J. J., Myaka, F. A., Sakala, W. D., Odgaard, R., Vesterager, J. M. and Høgh-Jensen, H. (2007). Biological nitrogen fixation and nitrogen and phosphorus budgets in farmer-managed intercrops of maize–pigeon pea in semi-arid southern and eastern Africa. *Plant and Soil 295*(1-2):127–136.
Christensen, N.W. and Jackson, T.L. (1981). Potential for phosphorus toxicity in zinc-stressed corn and potato. <u>*Soil Science Society of America Journal*</u> 45:904–909.

Dawar, K., Khan, I., Khan, S. and Khan, M.I. (2011). Effect of urea with or without urease inhibitor (NBPT) and herbicide on maize yield. Pakistan Journal of Weed Sciences Research 17(2)207-213

Dogan, R., Cakamak, F., Yagdi, K. and Kazan, T. (2008). Effect of Zinc Compound (Teprosyn F-2498) on Wheat (*Triticum aestivum* L.). *Asian Journal of Chemistry* 20 (3): 1795-1800.

Hussaini, M.A., Ogunlela, V.B., Ramalan, A.A. and Falaki, A.M. (2008). Mineral composition of dry season maize (*Zea mays L.*) in response to varying levels of nitrogen, phosphorus and irrigation at Kadawa, Nigeria. *World Journal of Agricultural Sciences* 4:775-780.

Karanam P.V. and Vadez, V. (2010). Phosphorus coating on pearl millet seed in low P Alfisol improves plant establishment and increases stover mover than seed yield. *Experimental Agriculture* 46(4):457-469.

Kaya, M.D., Okçu, G., Atak, M., Çikili, Y. and Kolsarici, O. (2006). Seed treatment to overcome salt and drought stress during germination in sunflower *(Helianthus anus L.)*. *European Journal of Agronomy* 24: 291-295.

Kwesiga, F. and Coe, R. (1994). Potential of Short Rotation *Sesbania sesban* planted fallows in Eastern Zambia. *Forest Ecology and Management* 2-3:199-208.

Lockman R.B. (1969). Relationships between corn yields and nutrient concentration in seedling whole-plant samples. In: Agron. Abstr. American Society of Agronomy, Madison, Wisconsin. pp 97.

Masuthi, D.A., Vyakaranahal, B.S., Deshpande, V.K. (2009). Influence of pelleting with micronutrients and botanical on growth, seed yield and quality of vegetable cowpea. *Karnataka Journal of Agricultural Sciences* 22:898–900.

Munyahali, Z.W. (2012). Effects of commercial chemical products on mazie yield in different Agro-ecological zones in Kenya. The School of Environmental Studies of Kenyatta University. pp 1-85.

Peltonen-Sainio P., Kontturi, M. and Peltonen, J. (2006). Phosphorus seed coating enhancement on early growth and yield components in oat. *Agronomy Journal* 98:206-211.

Pholo, M. (2009). Morphological, physiological and yield response of maize (*Zea mays L.)* to seed treatments. Dissertation submitted in partial fulfillment of the requirements for the master degree of University of the Free State. Bloemfontein

Rebefka F.P., Bationo, A. and Marschner, H. (1993). Phosphorus seed coating increases phosphorus uptake, early growth and yield of pearl millet (*Pennisetum glaucum* (L.) R. Br.) grown on an acid sandy soil in Niger, West Africa. *Fertilizer Research* 35:151-160.

Ros, C., Bell, R.W. and White, P.F. (2000). Phosphorus seed coating and soaking for improving seedling growth of *Oryza sativa* (rice) cv. IR66. *Seed Science and Technology* 28:391-401.

Singh, J.P., Karamanos, R.E. and Stewart, J.W.B. (1986). Phosphorus-induced zinc deficiency in wheat on residual phosphorus plots. *Agronomy Journal* 78:668–675.

Singh, M.V. (2007). Efficiency of seed treatment for ameliorating zinc deficiency in Improving Crop Production and Human Health, Istanbul, Turkey.

Uchida R. (2000). Essential nutrients for plant growth: Nutrient functions and deficiency symptoms. In: Silva J.A. and Uchida R. (eds.). *Plant nutrient management in Hawaii's*

soils, Approaches for Tropical and Subtropical Agriculture. College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa.

Van der Watt, E. (2005). Bio-Stimulatory properties of a *Lupinus albus* L. seed suspension. Ph.D. Thesis, University of Free State.

Vandamme, E. (2008). Nutrient deficiencies in soils of Walungu, South-Kivu, Democratic Republic of Congo. Katholieke Universiteit Leuven, Belgium.

Woomer, P.L. (2012). Integrated Soil Fertility Management in Africa: from Microbes to Markets: Conference Information, Program and Abstracts. An international conference held in Nairobi, Kenya, 22-26 October 2012. CIAT. 122 pp.

Yilmaz, A., Ekiz, H., Torun, B., Gultekin, I., Karanlik, S., Bagci, S.A., Cakmak, I. (1997). Effect of different zinc application methods on grain yield and zinc concentration in wheat cultivars grown on zinc-deficient calcareous soils. *Journal of Plant Nutrition* 20: 461–471.

Zelonka L., Stramkale, V. and Vikmane, M. (2005). Effect and after-effect of barley seed coating with phosphorus on germination, photosynthetic pigments and grain yield. *Acta Universitatis Latviensis* 691:111-119.

1.1.4 EVALUATION OF THE ANTI-APHID PROPERTIES ASSOCIATED WITH RAW SOLANUM INCANUM FRUIT WATER EXTRACTS.

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Abstract

Solanum incanum remains speculated, under the folklore context, to be exhibiting a wide range of herbal and pesticidal properties. However, no scientific studies have been undertaken to validate the claims.. This study sought to establish possible insecticidal activity of ripe fruit water extracts of *S. incanum* on the green peach aphid (*Myzuspersicae*).The study was conducted at Kenyatta University Plant Transformation Laboratory research farm. Fruit water extracts from ripe fruits of *S. incanum,* were sprayed on *M. Persicae* infected *sukuma wiki*(kales) (*Brassica oleracea*) in different dilutions including neat extract as 100% and dilutions of X2 (50%), X6 (17%) and X10 (10%). The study was done for a period of 22 days. Reduction in number of aphids as well as prevention of infestation on kales was monitored with time. Results show that there was no complete prevention or eradication of aphids on both infested and non-infested kales. The 50% dilution was found to be the best in reducing the number of aphids (85%) on the plant by day 13.Raw water extracts of *S. incanum* is therefore suggested to have possible aphicidal properties. Further studies are proposed to establish fractions of the extract for achieving the potent bioactive components and the mode of action associated with the extract on the green peach aphids.

Key words: Biodegradable, eradication, *Myzus persicae*, organic insecticide, *Solunum incanum*

Introduction

The use of traditional pest control techniques is prevalent in many regions of Kenya. The use has contributed to the development of synthetic pest control initiatives. Pesticides, including organophosphates such as *Marathion* that have been utilized in the control of pests such as fruit flies (*Drosophila melanogaster*) over the ages have been rationally developed from the contribution of the folk lore knowledge (Thaiyah et al., 2010). Sodom apple (*Solanum incanum*) is among plants that offer an increased potential for insecticidal exploitation. This is with respect to the partially documented and speculated uses of its raw extract by indigenous communities in Kenya and alleviating various maladies (Mwonjoria et al., 2014). However, little scientific investigation towards accreditation of such claims has been made. Furthermore, no work is yet to be undertaken on its pesticidal qualities.

Solanum incanum grows as a weed or soft shrub that befits the description of a herb (Adeyemi, 2009). It is barely a meter tall with the longest shrubs growing to a height of 1.8 M (Sabuni, 1988). The stem and leaves have spikes while the leaves are hairy velvet. The flowers of the full-grown shrub are purple with a trace of dense blue in their peripherals. The leaves have a wavy margin and a broad base, while the fruits are green with a white stripped at the base while unripe. They turn to a distinct yellow upon ripening. The fruits are spherical in shape. *S. incanum* grows well in areas with poor soil fertility (Lucero, 2009).

Fruit water extracts of *S. incanum* ripen fruits have been used in the regulation of tick infection in cattle (Madzimure et.al, 2013). However, there are limited reports of activity against crops pests and insects in an agricultural setting. We sought to carry out a preliminary investigation into the possible insecticidal properties of the ripen fruit extracts of *S. incanum* against the common vegetable pest *B. Oleracea* or green peach aphid. We report that the ripen fruit extracts have potent aphicidal tendencies of up to 85% comparable to commercial synthetic pesticide KARATEZONE™ from Syngenta Industries, USA.

Materials and methods

Plant material and study site

Samples of naturally ripened *S.incanum* fruits were collected in selected regions of the eastern Kenya including lower section of Embu County namely Mbeere, a section of Kitui County, namely Kwa Vonza; and eastern areas of Nairobi county, called Mwiki/Kasarani. The source areas were selected due to large population of the naturally growing *S. incanum*, and application by farmers in undefined dispelling of crop pests.

The study was carried out at the Kenyatta University Research farm in simulated field conditions where plants were grown in large pots (buckets) filled with soil and watered daily *ad-libitum*.

Experimental design

Seeds of *B. Oleracea* (sukuma wiki or kale) were germinated in 17L buckets filled three-quarter way with loamy soil mixed with farmyard compost manure. Each pot was sown with three seeds which upon successful germination were thinned to a single seedling per pot .The plants in the buckets wee arranged in completely randomised blocks of 5 plants per group and replicated twice as shown in Table 1. Each group was subjected routine spraying, either with the fruit extracts of *S.incanum*, KARATOZONE or distilled water after registering heavy infestation of the aphids. Spraying was done at three-day intervals, with routine count of insect population conducted before each spray. The spraying was timed, between 9am-10am on each spraying day.

The commercial insecticide KARATEZONE^{tm} (Syngenta industries, USA)that hasλ-cyhalothrin as its active ingredient (Li-Ming et al, 2008; Oluah and Agatha, 2014) was applied at a rate of twenty grams per twenty litres of water according to the manufacturer's instructions.

Results

The ability of the *S. incanum* fruit water extracts to eliminate aphids on kales was tested by comparing number of insects on the control set of plants (both positive and negative) and the neat extract. The average number of aphids per set of plants was determined and is presented in Table 2.

Results in Table 3 indicate that 50 % extract dilution was the best in reducing number of aphids on plants. The data further indicates that by day 13 (Figure 1) all the aphids had been reduced to below 40per plant in all the treatments except 50% dilution that exhibited a reduction of 10 aphids per plant. Additionally, there was no complete eradication of aphids for all treatments even for the commercial pesticide KARATOZONE™.When the insecticidal activity of the extracts was compared within treatments at different durations; there was a remarkable significant difference (ANOVA $p < 0.05$). Using student's t-test analysis to compare the individual paired means, within treatments against varying durations, significance differences were also observed. ($p < 0.05$ Figure 2).

The results also show that only the 50% treatment was significantly more effective than the commercial control (KARATEZONE™) in its aphicidal qualities. The 100% treatment followed closely but was not as effective as the positive control in its aphicidal qualities. It is followed by the 17% treatment then 10% treatment as the least effective when compared to the positive control (Figure 1).

The neat extract showed slight aphid reduction ($P<0.05$ by t-test) as compared to the 50% dilution while 50% dilution had higher aphid reduction qualities as compared to that of 17% dilution. The 17% dilution had lower aphid reduction qualities as compared to the 10% dilution.

Discussion

Spraying kale plants infested with *S. incanum* was shown to exhibit possible inhibition properties over the attacks by the insects in this study. Uninfested *B. oleracea* failed to attract possible *M. persicae* during the entire period it was sprayed with the undiluted raw fruit water extracts of *S. incanum.* Such an observation may be suggested by various aspects of the entire extract. Concerns such as scent and the possible aphicidal qualities may be suggested to explain on the observation. Kihampa et al (2014) pointed on the foul smell associated to the fruit extracts as being a distract. This implies that the eventual role of the extracts in the repelling of the aphids may be attributed to foul smell. However, this cannot completely rule out a possibility of toxic effect of the raw extracts. Thaiyah *et al*. (2012) suggested the fruits to be toxic to higher mammals, with specified reference being made on sheep.

M. persicae have been documented to prefer sucking the sap of green leaves, a property that requires intimate interaction of the pest with the pesticidal compounds on the leaf surface or systemic location. Since the extract was not sprayed with a surfactant to facilitate entry into the plant cells through the cell walls and cuticle or stomata and pres, it is still likely that persistence of the extract on the surface of the leaves effectively contributed to potency. The aphids actively avoided leaves (or parts thereof) sprayed with the extract especially the net. Such an observation points to the prospective aphicidal or aphid repellent qualities that may be associated to the

extract. Similar observations were made with the positive control, although the raw extract prevailed over the commercial insecticide in regards to the number of aphids observed over time.

The key question that emerges from this study is that the 50% dilution exceeded the activity of the neat crude treatment. This may narrow to the activity of the active elements that assist in the promotion of the suggested aphicidal and aphid-repellent qualities. For instance, the agonists and antagonists that may be combining to effect may be dose dependent either way, shifting the threshold equilibrium for potency. This is with respect to the activity of the both the inhibitors and the antagonists observed earlier (Madzimure *et al*., 2013). The active agonists seem to be inactive at a higher concentration due to unknown activities of interfering antagonists or stimulatory component of the same agonists.

Diluting the treatment to 50% may have allowed for the express activity of the agonists. Further dilution seems to be diluting the active components beyond good activity hence reduced potency. Apparently, agonists and antagonists have been documented to be having different molecular interaction of pesticidal activity (Oluah and Agatha, 2014).

Conclusion
Some aphicidal activities by fresh ripen water extracts of *S. incanum* have been demonstrated in this study. For more comprehensive and conclusive undertakings, it is recommended that better methods that would allow for the extraction of potent extract (for example using organic solvents) should pave way for the establishment of the active components of the extract and discernment of the mode of action in the achievement of the considered aphicidal properties.

References

Adeyemi, O., R., &Olaniyi, M. (2009). "Critical Period for Weed Removal in Garden Egg (SolanumIncanum)". Nigerian Journal of Horticultural Science; (HORTSON) Vol 13, No 1: 122-143.

Amri, E., &Kisangau, D., P., (2012). "Ethnomedicinal study of plants used in villages around Kimboza forest reserve in Morogoro, Tanzania". Journal of ethnobiology and ethnomedicine, Vol 8: 12-16.

Beaman-Mbaya, V., &Muhammed, S. I. (1976). Antibiotic Action of Solanumincanum Linnaeus. Nairobi, Oxford, pp 67-89.

Kihampa,C., Mwegoha, W., J., S., Kaseva, M., E., &Marobhe, N. (2011). "Performance of Solanumincanum Linnaeus as natural coagulant and disinfectant for drinking water". African Journal of Environmental Science and Technology, pp 34-43.

Li-Ming He, J., Troiano, A., W., and Kean, G. (2008) "Environmental Chemistry, Ecotoxicity, and Fate of Lambda-Cyhalothrin". Reviews of Environmental Contamination and Toxicology. 71 Springer Vol 34/5: 177-201.

Lucero, D. P., & Boggs, J. E. (2009). Soil fertility. New York: Nova Science Publishers. Pp 13-34.

Madzimure, James, Nyahangare, Emmanuel T., Hamudikuwanda, Humphrey, Hove, Thokozani, Belmain, Steve R., Stevenson, Philip C., &Mvumi, Brighton M. (2013). Efficacy of Strychnosspinosa (Lam.) and Solanumincanum L. aqueous fruit extracts against cattle ticks. Springer Netherlands. Pp 67-87.

Mwonjoria, J., K., Joseph, J., N., Helen, N., K., Charles, G., G., Micah, N., S., Stanley, N., W. (2014) "Etho Medicinal, phytochemical and pharmacological aspects of Solunum incanum (lin.)" International Journal of Pharmacology and Toxicology Vol 2/2: 17-20.

Oluah, N., S. and Agatha C. (2014). "Alterations in the biochemical parameters of the African catfish clariasgariepinus [burchell] exposed to sublethal concentrations of lambda-cyhalothrin" Annals of Environmental Science, Vol 8, 1-7.

Sabuni, G. A. (1988). Invasion of the Serengeti National Park by Solanumincanum. Longhorn publishers. Nairobi. Pp. 22.

Thaiyah, A.G, Nyaga, P.N, MaribAI, J.M, Nduati, D, Mbuthia, P.G, &Ngatia, T.A. (2010). "Experimental Solanumincanum L. poisoning in goats". Bulletin of Animal Health and Production in Africa; Inter-African Bureau for Animal Resources. Vol 58, No 1. 564-576.

Thaiyah, AG, Nyaga, PN, MaribAI, JM, Ngatia, TA, Kamau, JPM, &Kinyuru, JM. (2012). "Acute, sub-chronic and chronic toxicity of Solanumincanum L in sheep in Kenya". Kenya Veterinarian Association; Vol 35, No 1 (2011); 1-8.

Appendices

Appendix i

Table 1: Experimental layout for investigating aphicidal activity of S. incanum fruit water extracts at different dilutions as compared to both positive commercial pesticide and water only controls.

Group Designation	Treatment
AI-1	Sprayed with neat extract (100% v/v)
AI-2	Sprayed with X2 dilution (50% v/v)
AI-3	Sprayed with X6 dilution (17% v/v)
AI-4	Sprayed with X10 dilution (10% v/v)
AI-5	Sprayed with KARATEZONE™ commercial pesticide (Positive Control)
AI-6	Sprayed with distilled water (Negative control)

Key: AI = after infestation with aphids

Appendix ii

Table 2: Mean number of aphids observed on plants sprayed after onset of infestation. Values are mean ±Standard Error of means

Duration	Neat extract	2% extract	17% extract	1% Crude extract	Positive control	Negative control
Day 1	66.6±16.9	68±4.8	94.4±3	87.8±10.9	88.2±26.9	113.2±1.7
Day 4	60.4±53	42.8±10	84.4±8.3	69±14.1	72±14.2	112±4.1
Day 7	50.2±4.6	24±3.1	68.2±13.1	64.2±12.0	66±8.1	120.6±11.8
Day 10	28.8±9.9	33.8±1.1	63±2.6	57.6±6.3	35.4±7.5	94.8±4.6
Day 13	16.2±5.4	10.4±2.8	39.2±14.4	33.2±6.5	18.2±6.8	95.8±4.0
Day 16	27.2±4.5	14.2±1.3	17±18.1	18.8±5.3	17.8±5.8	98.4±4.7
Day 19	14.6±14.8	12.2±9.6	23±7	19.2±15.2	18.4±30.3	106.4±2.7
Day 22	16.8±11.8	13.4±8.2	44±8.4	17.4±12.3	19.4±22	103.2±2.6
MEANS	31.2	27.35	54.15	45.9	41.925	105.55
Variance	439.2571	404.042	783.9743	740.2629	839.1079	84.94571
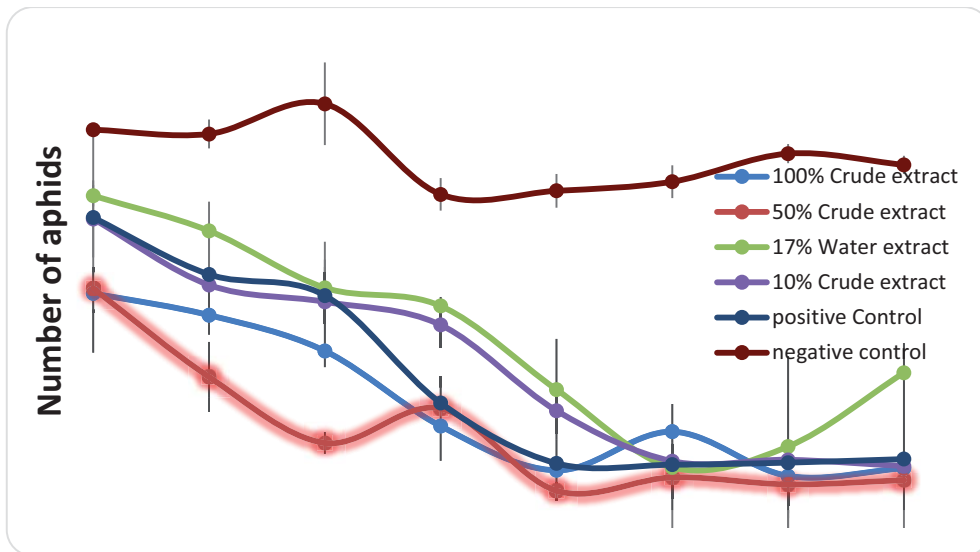
Figure 1: Mean number of aphids observed on plants sprayed after onset of infestation. The figure indicates the best performing concentration in relation to both the positive (Karatezone™) and negative control (Not sprayed). Values are mean±SE

Appendix iv
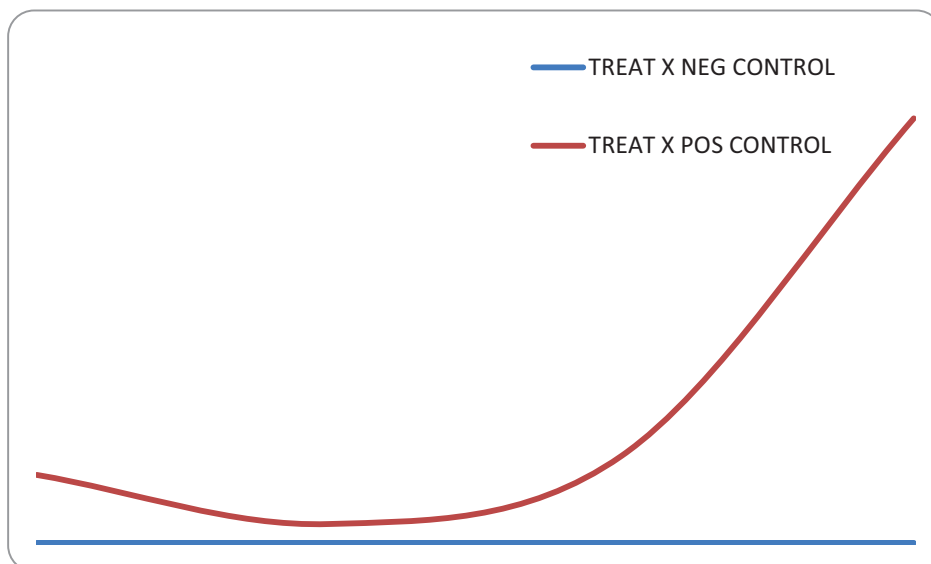
Figure 2: Dosage comparisons of the means of both the positive and negative controls against each of the dilutions of S. incunum's fruit water extract extracts.

1.1.5 EFFECT OF Striga WEED PRESSURE ON USE EFFICIENCY OF MINERAL FERTILIZER USE BY MAIZE VARIETIES

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Abstract

Striga hermonthica (*Del.*) *Benth* is a major constraint to the cereal based cropping systems of Eastern Africa. On-farm studies were conducted during the short rainy season (2012B) and long rainy season (2013A) to evaluate the effect of *Striga* pressure on the efficiency of mineral fertilizer use by two improved maize varieties, *Longe10H* (Hybrid) and *MM3* (OPV). A split plot design was used; N was applied at 0, 25, 50 and100 kg ha^{-1}; P at 0, 15 and 30 kg ha^{-1} and K at 60 kg ha^{-1}. *Striga* counts were also taken in the 6th, 8th and 10th week. At maturity, yield data was collected; Agronomic Efficiencies (AE) calculated and analyzed for variance with *Striga* counts as covariates. The AE-N were significantly different by fertilizer (P<0.001), variety (P<0.05) and fertilizer-variety interaction (P<0.05) at high weed pressure, *Striga* count reduced the AE-N, (R=-4.10). The AE-P were significantly (P<0.5) different by fertilizer at high weed pressure, *Striga* count reduced the AE-P (R=-0.37). In combined application, there were significant differences in the AE-N and AE-P by fertilizer (P<0.001), in AE-N (P<0.001) and AE-P (P<0.01) between the varieties and AE-N for treatment-variety interaction (P<0.05), the *striga* count reduced the AE-N (R=-0.05) and did not affect the AE-P (0.00022). *Striga* weed stress therefore decreased the AE-N and AE-P in single and combined nutrient application.

Key words: Agronomic efficiency N, Agronomic efficiency P, Maize variety, *Striga hermonthica*, Weed pressure

Introduction

Over the years of agricultural evolution, weeds particularly the parasitic weeds have been the greatest set back to agricultural production (Sauerborn *et al.*, 2007). According to Bouwmeester *et al.* (2003), *Striga* species and *Orobanche* species are the parasitic weeds that cause the greatest threat and damage to Agriculture in many parts of the World. *Striga* species a parasitic angiosperm weed is particularly a major problem in the production of cereal crops causing huge losses in grain yield (Massawe *et al.*, 2001; Sikwese *et al.*, 2003; Mignouna *et al.*, 2011 and Atera *et al.*, 2012), the resulting loses have been estimated to be greater than that caused by fungal diseases and insect pests combined (Isah and Kumar, 2012). *Striga* has seriously devastated field crops in Africa (Kim and Adetimirin, 2001) with yield losses estimated up to 85% (Rodenburg *et al.*, 2005).

Out of the 28 *Striga* species that occur naturally, infecting grasses and legumes in sub-Saharan Africa (Atera *et al.*, 2011), *Striga hermonthica* (Del.) Benth. is the major and the economically most important species in maize (*Zea mays L*), milletum (*Pennisetum glaucum L.*), sorghum (*Sorghum bicolor L.*) and rice (*Oryza sativa L.*) in the semi-arid tropics (DeGroote *et al.*, 2008), particularly in agro-ecosystems where high human population density imposes a strong pressure on arable land (Van Ast *et al.*, 2005).

The extent to which *Striga hermonthica* affects the growth of its hosts is variably influenced by the host plant genotype, parasite infestation level and environmental conditions (Van Ast *et al*., 2005). *Striga* is mainly associated with areas that have low potential for agricultural production (Oswald, 2005, Mignouna *et al*., 2011 and Atera *et al*., 2012). The effect of *striga* is more serious in soils that are degraded and poor in nutrients (Oswald, 2005). Emechebe *et al*. (2004) also noted that poor soil fertility is the major reason for a continuous *striga* infestation.

Build up in the parasitic weed infestation is greatly influenced by the degradation of the environment (Reda *et al.,* 2005) and the problem gets more wide spread in areas where both soil fertility and rainfall are low (Khan *et al*., 2001; Oswald 2005), because *Striga* seeds are well adapted to hot, dry conditions where they can remain dormant until when rains come (Csurhes *et al*., 2013).

Adagba *et al*. (2002) and Vanlauwe *et al*. (2008) report that N and P deficiency accelerates and is closely related to the severity of damage by the *Striga* weed to its host plant, this was confirmed by Jamil *et al.* (2012) who found out that the exudation of *strigolactone* the bio-chemical responsible for *Striga* seed germination were highest under the lowest N, P and NP levels and decreased with increase in the application of the nutrients. Unfortunately, soils in most sub-Saharan African countries have inherently low fertility and do not receive adequate nutrient replenishment (FAO, 2001), the problem of declining soil fertility is widely spread in the region because of continued cultivation of crops with limited nutrient inputs (Zingore, 2011) and is the major cause of low per capita food production and increased food insecurity in small holder farming systems in the region (Bekunda *et al*., 2002).

About 2/3 of the farm land under cultivation in sub-Saharan Africa is infested with *Striga*, this affects the lively hoods of more than 300 million people in over 25 countries (Timko *et al*., 2012) and causes more than 7billion USD worth of estimated yield losses (Parker, 2009). Maize is the most susceptible crop to *Striga* (Kim and Adetimirin, 2001), and its production suffers a major biological constraint from the weed (Jamil *et al*., 2012). *Striga* attacks the roots of its hosts (Rodenburg *et al*., 2005) and siphons off water and nutrients from the crops for its own growth in addition to producing phyto-toxins which are harmful to the host crop (Ahmed and Alamun, 2010).

Striga infestation in Uganda covers 107,799 hectares of farm land (MacOpiyo *et al*., 2009), of which 62,000 hectares is land in which maize is one of the crops grown, this causes economic losses of 8 million USD per year (AATF, 2009). The most affected are the cereal production areas of Eastern Uganda and West Nile (Olupot *et al*., 2005). Several methods among which cultivation of improved varieties and use of inorganic fertilizers have been identified to improve crop yields in fields infested with *Striga* (Showemimo *et al*., 2002; Azeez, 2009). It is how ever not known how *Striga* weed pressure influences the use efficiency of applied mineral nutrients when sole applied or applied in combination in maize varieties. This study was conducted to investigate the effect of *Striga* weed pressure on the use efficiency of applied mineral fertilizers in improved maize varieties. Specifically the study sought to determine the use efficiency of the applied mineral N and P fertilizers under high and low *Striga* weed pressure.

Materials and methods

The study area
The study was conducted in Pallisa District, (1º43'N and 33º 37' E), Eastern Uganda. Pallisa district is found within the Southern and Eastern Lake Kyoga Basin Agro-ecological zone which covers an area of 10,154 km^2 and lies about 1075m above sea level (Wortmann and Eledu, 1999), within the plains of Lake Kyoga drainage system (Nanduddu, 2010). The study was specifically conducted in Kakoro sub-county, because of the high *Striga* infestation in the area, availability of farmer groups willing to to offer land and to participate in the experiment establishment.

Land preparation and experimental establishment
Composite soil samples were obtained at a depth of 0-20cm from each of the farmer fields before treatment application, and analyzed for pH, Organic matter, total N, exchangeable Ca, Mg, K and Na, extractable P and texture using methods described in Okalebo *et al*. (2002). The farmer fields were measured to ensure that each could accommodate a block; the fields were then cleared of bush or any older crop residues before being subjected to the first and second land preparations using Ox-ploughs. The experiment was laid using the split plot design and was replicated 10 times, 5 replications in areas with high *Striga* weed pressure and the other five in areas with low *Striga* weed pressure, the individual farmer's fields were the replicates. *Striga* weed pressures are classified as <4 plants m^{-2} being low, 4-9 plants m^{-2} being medium and >9 plants m^{-2} as high (MacOpiyo *et al*., 2009). Each treatment plot was 5m by 6m and treatment as well as variety separation was 1m.

Treatment allocation and varieties tested
The nutrients applied were nitrogen (N), phosphorus (P), and potassium (K). N was applied at four rates of 0 kg ha^{-1}, 25 kg ha^{-1}, 50kgha^{-1} and 100kgha^{-1} (Wopereis *et al*., 2006), P at 3 rates of 0kg ha^{-1}, 15kg$ha^{-1}$and 30kgha^{-1} while K was mainly basal applied; at rate of 60kgha^{-1} (Kaizzi *et al.,* 2012) mainly to ensure that K shortage would not constitute a constraint (Wasonga *et al*., 2008). All fertilizers were applied through band application at 5cm distance from the maize row, for a maximum utilization by the plant. N and K were applied in 2 splits, the first splits were applied shortly after germination and the second splits at 45 days after germination. Urea fertilizer was used to supply N, Triple Super Phosphate (TSP) to supply P and muriate of potash (MOP) to supply K. These fertilizers were chosen because they are single fertilizers which can be used to produce combinations of different nutrient levels.

Two improved maize varieties were planted; *MM3* selected because of its short period to maturity (90 days) which makes it suitable for the study area which has short seasons, and *Longe10H*, which is the most commonly grown hybrid in the study area.

Management practices
Planting for season 2012 B was from 6th to 10th September, 2012 while for season 2013 A from 3rd to 6th April 2013. Each plot was planted with 4 rows of *MM3* and 4 rows of *longe10H*, at a spacing of 75cm x 25cm giving a plant density of 53,333 plants ha^{-1} (Kamara *et al.,* 2002). The experiments were kept weed free throughout the growing season of the crop by weeding three

different times (Ahmed and Alamun, 2010) but without disturbing *Striga* weeds that germinated. *Striga* counts were taken from each plot in the 6th week, 8th week (Meseka and Nour, 2001), and the 10th week to determine the effects of the fertilizers and the varieties on *Striga* germination. Harvesting for season 2012 B was from 3th to 7th January 2013 and for season 2013 A was from 6th to 11th August 2013, and was done when the crops were mature (Matata *et al*., 2011). At harvesting, plants were taken from the two center rows at a distance of 1.375m from the start of each of the two center lines (area of 2mx1.5m) (Azeez and Adetunji, 2007), cut at ground level and separated into stover (leaf and stem) and cob (grain and rachis) (Matata *et al*., 2011).

Data was then collected on fresh biomass, number and fresh weight of cobs and fresh weight of grains; *Striga* counts were also taken from each treatment at the high *Striga* weed pressure fields in the 6th and 8th week (Maseka and Nour, 2001) and at harvesting to be used as a covariate to the grain yield. Stover (stem and leaves) samples and cob (grain and rachis) samples were collected oven dried at 70º C and weighed to determine the dry matter content, (Wasonga *et al*., 2008; Matata *et al*., 2011), grain yield was then recorded on oven dry weight basis after separating the grain from the rachis (Matata *et al*., 2011). Different results for each treatment plot were extrapolated per hectare. N and P use efficiencies were calculated as Agronomic Efficiency (AE) according to methods proposed in Baligar *et al*., (2001) and Snyder and Bruulsema, (2007).

Data processing and analysis

Agronomic efficiencies were calculated as follows;
Agronomic Efficiency,

$$(AE) = \frac{(YieldF,\ kg\ -\ YieldC,\ kg)}{(Quantity\ of\ Nutrient\ applied, kg)}\ kg\ kg^{-1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{[i]}$$

Data sets collected were Log transformed to stabilize variances (Leydesdorff and Bensman, 2006) except *Striga* count data because of the existence of zero counts (O'Hara and Kotze, 2010). Statistical analysis of variance (ANOVA) was performed using Genstat software for Bio-Sciences with *Striga* count analyzed as a covariate to agronomic efficiency in other to adjust the means (Owen and Froman, 1998) and to control for the effect of *Striga* (Flores-Lopez *et al*., 2010). The significant differences between the fertilizer effects and the variety effects were compared using Fishers Least Significant Difference (LSD) test at P≤0.05, the covariate regression coefficients obtained were used to determine the effect of *Striga* weed pressure on the use efficiencies of the applied mineral fertilizers.

Results

Initial soil characterization

Table 1: Selected soil characteristics of the fields selected for experimentation in high and low weed pressure areas in Kakoro sub-county (M±SD)

Parameters	Weed pressure levels		**Critical Values
	High (N=10)	Low (N=10)	
pH	6.10±0.22	5.51±0.14	5.50
Soil Organic Matter (%)	1.58±0.07	1.45±0.13	3.00
Total N (%)	0.11±0.01	0.10±0.01	0.20
Exchangeable Ca (cmol kg^{-1})	4.94±0.48	3.99±0.17	4.50
Exchangeable Mg (cmol kg^{-1})	1.12±0.13	0.89±0.04	0.60
Exchangeable K (cmol kg^{-1})	0.40±0.03	0.32±0.03	0.40
Exchangeable Na (cmol kg^{-1})	0.07±0.01	0.06±0.01	0.01
Extractable P (mg kg^{-1})	4.08±0.52	5.05±0.51	15.00
%sand	66.70±1.34	69.20±2.44	-
%silt	14.50±0.65	13.16±0.28	-
%Clay	18.80±1.27	17.72±2.45	-

**Critical values for most crops in East Africa (Okalebo *et al*., 2002)

Agronomic efficiency of N under sole application

Analysis of the agronomic efficiencies of *Longe10H* and *MM3* for sole application of N showed a significant difference between fertilizers ($P<0.001$), Varieties ($P<0.05$) and fertilizer x variety interactions ($P<0.05$) under high *Striga* weed pressure, the regression between agronomic efficiency and *Striga* count had a negative (-4.10) coefficient. Under low *Striga* weed pressure, significant difference ($P<0.001$) between agronomic efficiencies only existed between the fertilizers, (Table 2) the varieties and the interactions were not significantly different. The highest agronomic efficiency for *Longe10H* (57.3 kg kg^{-1}) and *MM3* (34.2 kg kg^{-1}) at high weed pressure were obtained at 50kg N ha^{-1}. At low weed pressure, the largest agronomic efficiencies were 36.3 kg kg^{-1} and 41.5 kg kg^{-1} at 100 kg N ha^{-1} (*Longe10H*) and 50 kg ha^{-1} (*MM3*) respectively.

Table 2: Grain yield and agronomic efficiencies of sole N under high *Striga* weed pressure and low *Striga* weed pressure (data for 2 seasons)

	High Weed Pressure				Low Weed Pressure			
	Grain yield (kg ha^{-1})		AEN (kg kg^{-1})		Grain yield (kg ha^{-1})		AEN (kg kg^{-1})	
Treatments	*Lon10H*	*MM3*	*Lon10H*	*MM3*	*Lon10H*	*MM3*	*Lon10H*	*MM3*
Control	1437	1379	0.0	0.0	2157	2136	0.0	0.0
25N	2646	2703	24	31.2	4575	4227	24.2	20.9
50N	5079	3696	**57.3**	**34.2**	3017	3174	34.4	**41.5**
100N	4568	3880	18.7	14.9	3973	3607	**36.3**	29.4
SED								
Fertilizer	260.6***		6.53***		128***		6.7***	
Variety	171.3*		4.26*		129.9ns		4.7ns	
Fert*Vrt	214.2*		8.27*		259.7ns		9.4ns	

***=P<0.001; *=P<0.05; SED= standard error of difference; Fert= fertilizer; Vrt= variety; Lon.10H=Longe10H; AE= Agronomic efficiency.

Agronomic efficiency of P under sole application

Significant differences (P<0.05) in agronomic efficiency were only observed between the fertilizer treatments at high *Striga* pressure, varieties and all the interaction were not significantly different. The highest agronomic efficiencies of P (12.7 kg kg^{-1} and 30.1 kg kg^{-1}) were observed at 15kg P ha^{-1} for *Longe10H* and at 30kg P ha^{-1} for *MM3* respectively. The regression coefficient between Agronomic efficiency P and *Striga* count was negative (-0.37). While under low *Striga* weed pressure, *Longe10H* had the best agronomic efficiency of 29.8 kg kg^{-1} at 15kg P ha^{-1} while for *MM3* (25.8 kg kg^{-1}) was at 30kg P ha^{-1}.

Table 3: Grain yield and agronomic efficiencies of sole P under high *Striga* weed pressure and low *Striga* weed pressure (data for 2 seasons)

	High Weed Pressure				Low Weed Pressure			
	Grain yield (kg ha^{-1})		AEP (kg kg^{-1})		Grain yield (kg ha^{-1})		AEP (kg kg^{-1})	
Treatments	*Lon10H*	*MM3*	*Lon10H*	*MM3*	*Lon10H*	*MM3*	*Lon10H*	*MM3*
Control	1921	1951	00.0	00.0	2157	2136	00.0	00.0
15P	2304	2334	**12.7**	23.1	2604	2227	**29.8**	06.1
30P	2928	2741	9.2	**30.1**	2827	2910	22.3	**25.8**
SED								
Fertilizer	171.3***		8.87*		234.0*		14.5ns	
Variety	165.1 ns		8.31ns		179.1ns		11.8ns	
Fert*Vrt	247.6ns		12.83ns		310.2ns		20.5ns	

***=P<0.001; *=P<0.05; ns= not significant; SED= standard error of difference; Fert= fertilizer; Vrt= variety; L.10H=Longe10 hybrid; AE= Agronomic Efficiency.

Agronomic efficiency of combined applications of N and P

The effect of combined application of N and P resulted into an increase in the agronomic efficiencies of both nutrients for both *Longe10H* and *MM3* (figure 8 and 9). A significant increase in the agronomic efficiency (P<0.001) was recorded between the fertilizer treatments for combined application of N and P under the condition of high *Striga* weed pressure, a significant difference was also observed in the agronomic efficiency N (P<0.001) and agronomic efficiency P (P<0.01) between the varieties under high *Striga* weed pressure condition, and *Longe10H* generally had better agronomic uses of N and P under combined application of the nutrients than *MM3*. Fertilizer x variety interaction was also significantly different (P<0.05) for agronomic efficiency of N under high *Striga* weed pressure. Negative regression coefficient between the agronomic efficiency of N and P (-0.05) were observed. Under low *Striga* weed pressure, a significant difference (P<0.001) was only observed for the agronomic efficiencies of N and P between fertilizer treatments while no significant differences were observed between the varieties. Also between the nutrient combinations, similar rates of N combined with 30kg of P ha^{-1} were predominantly higher in agronomic efficiency of N than those that received 15kg of P ha^{-1}, but not significantly different except for AEN at 25 kg N ha^{-1} and 30kg P ha^{-1} (Figure 1). However for agronomic efficiency of P at the same rates of N, 15kg of P ha^{-1} generally performed significantly better (Figure 2).
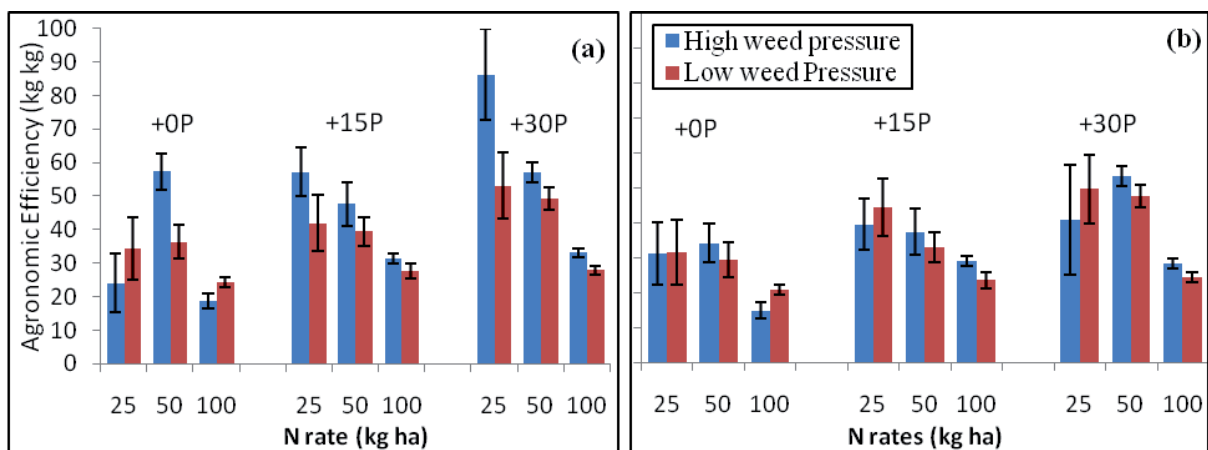
Figure 1: Agronomic efficiencies of N as affected by different P rates for *longe10H* (a) and *MM3* (b) (data for 2 seasons)
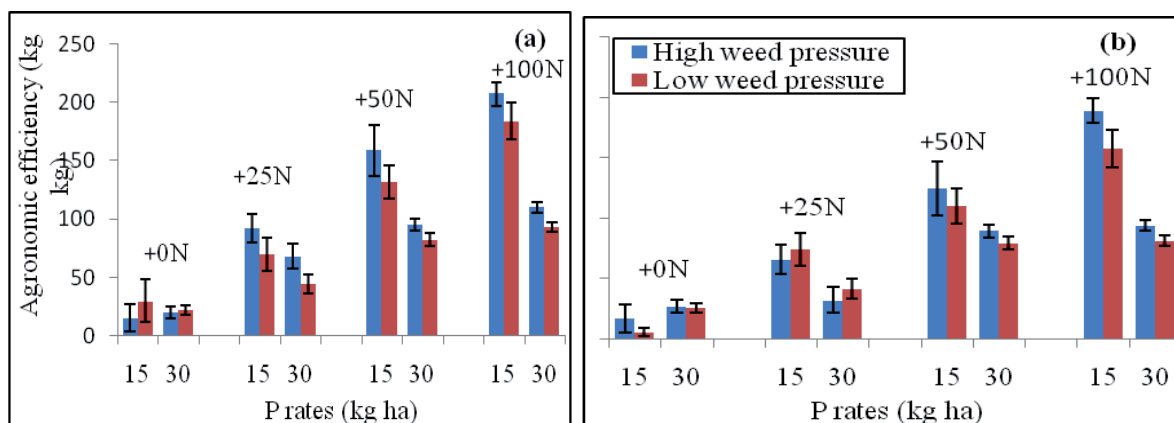
Figure 2: Agronomic efficiencies of P as affected by different N rates for *longe10H* (a) and *MM3* (b) (data for 2 seasons)

Discussions

Agronomic efficiency of N under sole application

Significant differences were noted in the agronomic efficiency of N for sole application of N under both high *Striga* weed pressure and low *Striga* weed pressure; similar results have also been reported by Eivasi and Habibi, (2013). Generally, N use efficiency was low at 25kg N ha^{-1} and increases in 50kg N ha^{-1} and then dropped at 100kg ha^{-1} except 25kg N ha^{-1} at high *Striga* weed pressure. Many researchers have reported only decreases in agronomic efficiency of N with increase in N rates (Anbessa and Juskiw, 2012; Nemati and Sharifi, 2012). The low AEN at 25kg N ha^{-1} could be because of the low organic matter content in the soils. Soil organic matter is a key element in the soil quality (Reeves, 1997) and affects nutrient cycling, soil structure and water availability (Rashidi and Saisepour, 2009). The presence of adequate organic matter in the soil is also closely associated with its ability to supply nutrients, mainly N (Cooperband, 2002). N use efficiency is governed by the interaction between soil N levels, N availability due to microbial activities in the rhizosphere and the ability of plant to assimilate and use acquired N for plants growth (Kriz and Larkins, 2009) and the quantity of nutrients, particularly N in the soil that is available to plants is relative to the ability of the plants to acquire those nutrients (Vasquez *et al.*, 2008). The efficient use of N is influenced by more organic matter in the soil which gives it a better structure as this allows the roots to explore the soils more efficiently (Johnston, 2011). This is because organic soils are composed of a stable recalcitrant soil organic matter pool which improves soil fertility by holding plant nutrients and preventing them from leaching to the sub-soil, out of the reach of plants roots (Cooperband, 2002)

The regression between the agronomic efficiency for N and *Striga* count generally had a negative coefficient, probably because *Striga* weed reduced the nutrient uptake and growth of maize plant as suggested by Aflakpui *et al.* (1998). According to Peña-Asin *et al*. (2013), one of the most important stress factors in maize fields is weed competition which reduces the yield of the crop by competing for light, water and nutrients, this causes a significant reduction in N uptake, utilization and use efficiency (Azeez and Adetunji, 2007). Jalali *et al*. (2012) also reported a high

uptake of N by weeds at an early maize growth stage; this was further confirmed by Najafi and Ghadiri (2012) when they observed an increase in total weed biomass with increase in applied N.

Longe10H had asignificantly better agronomic efficiency at high *Striga* weed pressure than *MM3* probably because of its genetic ability to perform better. Hybrids generally have a better genetic potential and mostly yield higher than the open pollinated variety (Karunaratne, 2001; Sutch, 2008; Kpotor, 2012). This also corresponds with the findings of other researchers (Kogbe and Adediran, 2003; Vanlauwe *et al*., 2011; Bello *et al.,* 2012).

Agronomic efficiency of P under sole application

Agronomic efficiencies for sole P application were generally lower than for sole N application probably because of poor availability of the applied P. Only a small proportion of soil P is always immediately available to plants, applied P is equally poorly available (Richardson *et al*., 2009), with more than 80% not available to plants (Holford, 1997). Dhankhar *et al*. (2013) also states that only little of the applied P remains in the available pool, because of its sparingly soluble nature. P could have also been fixed by iron (Fe) and Aluminium (Al) irons (Shen *et al.,* 2011) as the pH of the soils were within the range of possible P fixation through precipitation by those elements (<6) according to the hills and valleys of P fixation (CRI, 2012). It is also possible that deficiency of N in the soil impaired the uptake of the other nutrients including P, leading to a low efficiency of their use (Ciampitti *et al*., 2013; Rao *et al*., 2014). The regression coefficient between the agronomic efficiency for P and *Striga* count was generally negative, probably because *Striga* weed reduced P uptake and growth of maize thus affecting the P use efficiency. Frost *et al*. (1997) reported significantly less shoot and root biomass and significantly smaller leave areas in infected plants than in uninfected plants. An asymptotic decline in the N concentration in the leaves, stem and roots of infected plants and a higher N concentration in *Striga* than in maize was also found out by Aflakpui *et al*. (1998). *Striga* after its attack on the host becomes a metabolic sink for photo assimilates and nutrients, depletion of especially N affects the host physiology and provokes lower host photosynthesis rates hence reducing several photosynthetic parameters (Spalleck *et al*., 2013).

Agronomic efficiency for combined application of N and P

Generally the agronomic efficiencies of both N and P increased compared to sole application of either nutrients, probably because of an interaction between N and P similar to what was reported by Akram *et al*. (2007). Interactions among nutrients are very important because deficiency of one nutrient tends to restrict the uptake and use of another, the interaction for instance between N and other nutrients, primarily P and K significantly increase crop yield and N use efficiency (Roberts, 2008), Hussaini *et al*. (2008) also reported significant P concentration and N accumulation in maize grains as a result of N and P interaction. An interaction between N and P fertilisationss on the productivity of plants therefore suggests a co-limitation of productivity by both nutrients (Niinemets and Kull, 2005), which is often a major constraint to primary production in plants (Harpole *et al*., 2011).

The significant variation in the agronomic efficiencies between the varieties under high *Striga* weed pressure is probably because of their difference in nutrient use efficiency. Plant genotypes differ in their capacity to access soil nutrients (Tilman *et al*., 2002; Rangel and Marschenner, 2005). These differences in nutrient use efficiency are attributed to the variation in the quality and quantity of the plants root systems (Gallais and Hirel, 2004), characteristics of plants roots such as the amount and the composition of root exudates (Jones *et al*., 2004), root density and

depth of penetration (Kashiwagi *et al*., 2006) and root architecture (Gudu *et al*., 2005). Significant differences in nutrient use between different varieties have also been reported by Hawkesford, (2012).

It could also be that the two varieties have different abilities to tolerate or resist *Striga* weed. Different varieties of the same host species may have different tolerance to parasitic plants (Cardoso *et al.,* 2011). The existence of a high variability among commercial maize varieties with respect to *Striga* parasitism has been noted (Oswald and Ransom, 2004), with different varieties possessing their own level of resistance (Rodenburg *et al*., 2005) and supporting different levels of *Striga* densities (Oswald and Ransom, 2004). Resistant varieties can reduce both new *Striga* seed production and *Striga* seed bank in the infested soils (Haussmann *et al*., 2000). For tolerant varieties, the amount of the germination stimulant (*strigolactone* biochemical) produced in the root exudates is often low leading to a smaller number of attachments or delayed attachments, reducing the parasitism effect on the yield (Gurney *et al*., 2006), thus produces less yield reduction than the susceptible cultivars (Haussmann *et al*., 2000). Open pollinated and hybrid maize varieties that are tolerant have been identified (AATF, 2006).

Treatment and variety interaction was significantly different for agronomic efficiency only under high *Striga* weed pressure; similar results were also obtained by Ajorin *et al*. (2013) in his research on *Striga* resistant composite maize varieties. Indeed a previous research had reported a significant effect of variety on *Striga* emergence, count and rating (Olakojo and Olaoye, 2007).

Conclusion
Longe10H uses the applied N and P better than *MM3* under both high and low *Striga* weed pressure conditions. Increase in *Striga* weed stress causes a decrease in the agronomic efficiency of both N and P when both singly applied and when applied in combination for both varieties as shown by the negative coefficients of the regression between the agronomic efficiency and *Striga* count.

Acknowledgements

References

AATF, (2006). Empowering African Farmers to eradicate *striga* from maize crop lands. *The African Agricultural Technology Foundation*. Nairobi, Kenya, p.1-17

AATF. (2009). Base line study of smallholder Farmers in *Striga* Infested Maize Growing Areas of Eastern Uganda. Nairobi, Kenya: *African Agricultural Technology Foundation*, p.1-86

Adagba, M. A., S. T. O. Lagoke and E. D. Imolehin. (2002). Nitrogen Effect on the Incidence of *Striga hermonthica* (DEL.) Benth in Upland Rice. *Acta Agronomica Hungarica*, Vol.50 No.2, pp. 145-150

Aflakpui, G. K. S, P. J. Gregory and R. J. Froud-William. (1998). Uptake and Partitioning of Nitrogen by Maize Infected with *Striga hermonthica. Annals of Botany*, Vol. 81, pp. 287-294.

Ahmed, U. A. and T. M. Alamun. (2010). Evaluation of different plants based products for *striga hermonthica* control in sorghum (*sorghum bicolar*) under Sudanese field conditions. *Pak. J. Weed Sci. Res*. Vol.16, No.4, pp. 443-449

Akram, A., M. Fatima, S. Ali, G. Jilani and R. Asghar. (2007). Growth, Yield and Nutrients Uptake of Sorghum in Response to Integrated Phosphorus and Potassium Management. *Pak. J. Bot*, Vol.39, No.4, pp. 1083-1087

Anbessa, Y and P. Juskiw. (2012). Nitrogen Fertilizer Rate and Cultivar Interaction Effect on Nitrogen Recovery, Utilization Efficiency, and Agronomic Performance of Spring Barley. *International Scholarly Research Network*, p1-8, doi:10.5402/2012/531647

Anjorin, F. B. (2013). Comparative Growth and Grain Yield Response of Five Maize Varieties to Nitrogen Fertilizer Application. *Greener Journal of Agricultural Sciences*, Vol.3, No12,pp. 801-808

Atera, E. A., K. Itoh and J. C. Onyango. (2011). Evaluation of Ecological and Severity of *Striga* weed on rice in sub-Saharan Africa. *Agriculture and Biology Journal of North America*, Vol.2, No.5,pp. 752-760, doi:10.5251/abjna.2011.2.5.752.760

Atera, E. A., K. Itoh, T. Azuma and T. Ishii, (2012). Response of NERICA rice to *Striga hermonthica* infections in Western Kenya; *International journal of agriculture and biology,* Vol.14, No.2, pp.271-275

Azeez, J. O. (2009). Effects of Nitrogen Application and Interference on Performance of Some Tropical Maize Genotypes in Nigeria. *Pedosphere*, Vol.19, pp. 654-662

Azeez, J. O., and M. T. Adetunji. (2007). Nitrogen-use Efficiency of Maize Genotypes under Weed Presure in Tropical Alfisol in Northern Nigeria. *Tropicultura*, Vol.25, No.3, pp.174-179

Baligar, V. C., N. K. Fageria and Z. L. He. (2001). 'Nutrient use efficiency in plants'. *Communications in soil science and plant analysis*, Vol.32, No.7&8, pp.921-950; DOI: 10.1081/CSS-100104098

Bekunda, M. A., E. Nkonya, D. Mugendi and J. J. Msaky, (2002). Soil fertility status, management, and research in East Africa; *ast African journal of rural development*, pp.1-24

Bello, O. B., M. S. Afolabi, S. A. Ige, S. Y. Abdulmaliq, M. A. Azeez and J. Muhamud. (2012). Nitrogen Use Efficiency and Grain yield in a Diallelic Cross of Maize Populations. *International journal of Plant Research*, Vol.2, No.3, pp.94-102, DOI: 10.5923/j.plant.20120203.08

Bouwmeester, H. J, R. Matusova, S. Zhongkui and M. H. Beale. (2003). Secondary metabolite signalling in host-parasitic plant interactions. *Current opinion in plant biology*, Vol.6, pp.358-364, DOI: 10.1016/S1369-5266(03)00065-7

Cardoso, C., C. Ruyter-Spira & H. J. Bouwmeester. (2011). Strigolactones and root infestation by plant-parasitic *striga, Orobanche* and *Phelipanche* spp. *Plant science,* Vol.180, pp.414-420, DOI:10.1016/j.plantsci.2010.11.007.

Ciampitti, I. A., J. J. Camberato, S. T. Murrell and T. J. Vyn. (2013). Maize Nutrient Accumelation and Pertition in Response to Plant Density and Nitrogen Rate: I. Macronutrients. *Agronomy journal,* Vol.103, No.3, pp. 783-795

Cooperative Resources International (CRI), (2012). Soil phosphorus reactions; *AgSource Harris, a division of cooperative resources international*. Lincolin.agsource.com

Cooperband, L. (2002). Building soil organic matter with organic amendments: *A resource for urban and rural gardens, small farmers, turfgrass managers and large-scale producers*, pp.1-13

Csurhes, S., A. Markula and Y. Zhou, (2013).Wittch weeds; *Striga* spp weed risk assessment, pp.1-17.

De Groote, H., Wangare, L., Kanampiu, F., Odendo, M., Karaya, H., & Friesen, D. (2008). The potential of a herbicide resistant maize technology for Striga control in Africa. *Agricultural Systems,* Vol.97, No.1, pp.83-94.

Dhankhar, R., S. Sheoran, A. Dhaka and R. Soni. (2013). The Role of Phosphorus solublizing Bacteria (PSB) in Soil Management-An Overview. *International Journal of Development Research*, Vol.3, No.9, pp.031-036

Eivazi, A and F. Habibi. (2013). Evaluation of Use Efficiency in Corn (*Zea mays* L.) Varieties. *World Applied Sciences Journal*, Vol.21 No.1, pp.63-68, DOI: 10.5829/idosi.wasj.2013.21.1.2423

Emechebe, A., J. Ellis-Jones, S. Schulz, D. Chikoye, B. Douthwaite, I. Kureh, G. Tarawali, M. A Hussaini, P. Kormawa and A. Sanni. (2004). Farmers' perception of the *Striga* problem and its control in northern Nigeria. *Experimental Agriculture,* Vol.40 No.2, pp. 215-232.

Flores-Lopez, F., Z. M. Easton and T. S. Steenhuis, (2010). A multivariate analysis of covariance to determine the effects of near stream best management practices on nitrogen and phosphorus concentrations on a dairy farm in the New York conservation effects assessment project watershed, Vol.65, No.6, pp.438-449;doi:10.2489/jswc.65.6.438

Food and Agricultural Organisation (FAO), (2001). Soil fertility management in support of food security in sub-Saharan Africa, pp.1-66

Frost, D. L., A. L. Gurney, M. C. Press and J. D. Scholes, (1997). *Striga hermonthica* reduces photosynthesis in sorghum: the importance of stomatal limitations and a potential role for ABA? *Plant cell and environment,* Vol.20, pp.483-492

Gallais, A. and B. Hirel, (2004). An approach to the genetics of nitrogen use efficiency in maize; *Journal of experimental botany,* Vol.55 No.396, pp.295-306; DOI:10.1093/jxb/erh006

Gudu, S. O., J. R. Okalebo, C. O. Othieno, P. A. Obura, O. O. Ligeyo, D. Shulze and C. Johnston, (2005). Response of five maize genotypes to nitrogen, phosphorus and lime on acid soils of western Kenya; *African crop science conference proceedings,* Vol.7, pp.1109-1115

Gurney, A. L., J. Slate, M. C. Press & J. D. Scholes. (2006). A novel form of resistance in rice to the angiosperm parasite *Striga hermonthica, New Phytologist,* Vol.169, pp.199-208

Harpole, W. S., J. T. Ngai, E. E. Cleland, E. W. Seabloom, E. T. Borer, M. E. S. Bracken, J. J. Elser, D. S. Gruner, H. Hillebrand, J. B. Shurin and J. E. Smith, (2011). Nutrient co-limitation of primary producer communities; *Ecology letters,* Vol.14, pp.852-862; doi:10.1111/j.1461-0248.2011.01651.x

Haussmann, B. I. G., D. E. Hess, H. Welz and H. H. Geiger. (2000). Improving Methods of breeding *Striga*-Resistant sorghum. *Field Crops Research*, Vol.66, pp.195-211

Hawkesford, M. J. (2012). The diversity of nitrogen use efficiency for wheat varieties and the potential for crop improvement; *Better crops,* Vol.96 No.3, pp.10-12

Holford, I. C. R, (1997). Soil phosphorus: its measurement and its uptake by plants; *Australian journal of soil research,* Vol.35 No.2, pp.227-240

Hussaini, M. A., V. B. Ogunlela, A. A. Ramalan and A. M. Falaki. (2008). Mineral Composition of Dry Season Maize (*Zea mays* L.) in Response to Varying Levels of Nitrogen, Phosphorus and Irrigation at Kadawa, Nigeria. *World Journal of Agricultural Science*, Vol.4, No.6, pp.775-780

Isah, K. M. and N. Kumar, (2012). Influence of non host crop rotation on the reaction of cereal host crop genotypes to *striga hermonthica* of different eco types; *Indian Journal of Scientific Research,* Vol.3 No.1, pp.179-190

Jalali, A. H., M. J. Bahrani and A. R. Kazemeini. (2012). Weed Nitrogen Uptake as Influenced by Nitrogen Rates at Early Corn (Zea mays L.) Growth Stage. *J.Agr. Sci. Tech.* Vol.14, pp.87-93

Jamil, M., F. K. Kanampiu, H. Karaya, T. Charnikhova and H. J. Bouwmeester, (2012). *Striga hermonthica* parasitism in maize in response to N and P fertilizers; *Field crop research,* Vol.134, pp.1-10; http://dx.doi.org/10.1016/j.fcr.2012.03.015

Johnston, J. (2011). The essential role of soil organic matter in crop production and the efficient use of nitrogen and phosphorus: Soil organic matter, part 2; *Better crops,* Vol.95 No.4, pp.9-11

Jones, D. L., A. Hodge and Yakov Kuzyakov, (2004). Plant and mycorrhizal regulation of rhizodeposition; *New phytologist,* Vol.163, pp.459-480; doi:10.1111/j.1469-8137.2004.01130.x

Kaizzi, K. C., J. Byalebeka, O. Semalulu, I. Alou, W. Zimwanguyizza, A. Nansamba, P. Musinguzi, P. Ebanyat, T. Hyuha and C. S. Worthmann. (2012). Maize response to fertilizer and nitrogen use efficiency in Uganda. *Agronomy Journal,* Vol.104, No.1, pp.73-82.

Kamara, A. Y., A. Menkir and N. Sanginga, (2002). Nitrogen use efficiency of maize genotypes improved for tolerance to low Nitrogen and drought stress, pp.1-10

Karunaratne, K. M. (2001). Variety development and productivity enhanced of hybrid maize in Sri Lanka. *Annals of the Sri Lanka Department of Agriculture.* Vol.3, pp.79-86

Kashiwagi, J., L. Krishnamurthy, J. H. Crouch, and R. Serraj, (2006). Variability of root lenth density and its contributions to seed yield in chickpea (*Cicer arietinum* L.) under terminal drought stress; *Field crops research,* Vol.95, pp.171-181

Khan, Z., J. Pickett, L. Wadhams and F. Muyekho. (2001). Habitat management strategies for the control of cereal stemborers and *striga* in maize in Kenya. *International Journal of Tropical Insect Science,* Vol.21 No.04, pp.375-380.

Kim, S. and V. O. Adetimirin. (2001). Conditioning effects of *Striga hermonthica* seed on field performance of maize. *Crop protection,* Vol.20, pp.159-161

Kogbe, J. O. S. and J. A. Adediran. (2003). Influence of nitrogen, phosphorus and patassium application on the yield of maize in the savanna zone of Nigeria. *African journal of biotechnology,* Vol.2 No.10, pp.345-349

Kpotor, P. (2012). Evaluation of newly released maize varieties in Ghana for yield and stability under three nitrogen application rates in two agro-ecological zones. *A thesis submited to the school of graduate studies, Kwame Nkrumah University of science and technology in partial fulfilment of the requirement for the degree of masters of science in agronomy (plant breeding,* pp.1-87

Kriz, A. L. and B. A. Larkins, (2009). Biotechnology Approaches to Improving maize Nitrogen use efficiency. *Molecular Genetic Approaches to maize Improvement Biotechnology in Agriculture and Forestry*, Vol.63, pp.65-77

Leydesdorff, L. and S. Bensman, (2006).Classification and power laws; *Journal of American society of information science and technology,* pp.1-40

MacOpiyo, L., J. Vitale, and J. Sanders. (2009). An *ex ante* impact assessment of *striga* control program in East Africa. *A final report submitted to Klimotrust*, pp.1-114.

Massawe, C. R., J. S. Kaswende, A. M. Mbwaga and J. P. Hella. (2001). On-farm verification of maize /cowpea intercropping on the control of *striga* under subsistence farming; *Seventh Eastern and Southern Africa Regional Maize Conference*; 11th-15th February, 2001: pp.165-167

Matata, P. Z., B. M. Gama, A. Mbwaga, M. Mpanda and D. A. Byamungu. (2011). Effect of sesbania sesban fallows on *striga* infestation and maize yield in Tabora Region of Western Tanzania; Journal of soil science and environmental management, Vol.2 No.10, pp.311-317. http://www.academicjournals.org/JSSEM

Meseka, S., & Nour, A. (2001). Screening maize (zea mays) genotypes for striga hermonthica resistance in sudan: a three-year progress report. *Screening,* Vol.11, pp.179-182.

Mignouna, D. B., K. D. S. Mutabazi, E. M. Senkondo and V. M. Manyong, (2011). Imazapyr-resistant maize technology adoption for witch weed control in Western Kenya; *African crop science journal,* Vol.19 No.3, pp.173-182

Najafi, B. and H. Ghadiri. (2012). Weed Control and Grain Yield Response to Nitrogen Management and Herbicides. *J. BIOL.ENVIRON. SCI,* Vol.6 No.16, pp.39-47

Nanduddu, S. (2010). Community based adaptation to climate change in Africa (CBAA); Lived experiences; Adaptation to climate change in Gogonya sub-county, palisa District, Uganda, pp1-12

Nemati, A. R. and R. S. Sharifi. (2012). Effect of rates and nitrogen application timing on yield, agronomic characteristics and nitrogen use efficiency in corn. *International Journal of Agriculture and Crop Science,* Vol.4 No.9, pp.534-539

O'Hara, R. B. and D. J. Kotze, (2010). Do not log transform count data; *Methods in ecology and Evolution,* pp.1-5; doi:10.1111/j.2041-210x.2010.00021.x

Okalebo, J.R., K.W. Gathua and P. L. Woomer. (2002). Laboratory methods of soil and plant analysis. *A working manual. 2nd Edn. TSBF-CIAT and SACRED Africa, Nairobi, Kenya.* pp.1-128

Olakojo, S. A. and G. Olaoye. (2007). Response of Maize (*Zea mays* L) to different Nitrogen Fertilizer Formulations Under *Striga lute* (LOUR) Artificial infestation. *Tropical and Sub tropical Agro Ecosystems*, Vol.7 pp.21-28

Olupot, J. R., I. Abaijuka, F. Dradiku, P. Edema & J. Mukalazi. (2005). *Striga* infestation in the West Nile Agro-Ecological Zone of Uganda: The Socio-Economic perspective and the way forward, *African Crop Science Conference Proceedings,* Vol.7, pp.1507-1511.

Oswald, A. (2005). *Striga* control-technologies and their dissemination. *Crop Protection,* Vol.24 No.4, pp.333-342.

Oswald, A. and J. K. Ransom. (2004). Response of maize varieties to striga infestation, *Crop protection,* Vol.23, pp.89-94

Owen, S. V. and R. D. Frman, (1998). Focus on quality methods; Uses and abuses of the analysis of Covariance; *Research in nursing and health*, Vol.21, pp.557-562

Paker, C. (2009). Observations on the current status of *Orobanche* and *Striga* problems Worldwide. *Pest management Science,* Vol.65, pp.453-459

Pena-Asin, J., A. Costar and A. Alvarez. (2013). Effect of weeding management on the performance of local maize populations. *Spanish journal of Agricultural research,* Vol.11 No.4 pp.0-7

Rao, P. V., G. Subbaiah and R. Veeraraghavaiah, (2013). Agronomic response of maize to plant population and nitrogen availability- A review. *International journal of plant, animal and environmental sciences*, Vol.4 No.1, pp.107-116

Rashidi, M. and M. Seilsepour, (2009). Modeling of soil total nitrogen based on soil organic carbon; *ARPN Journal of agricultural and biological sciences,* Vol.4 No.2, pp.1-5

Reda, F., Verkleij, J., & Ernst, W. (2005). Relay cropping of sorghum and legume shrubs for crop yield improvement and Striga control in the subsistence agriculture region of Tigray (Northern Ethiopia). *Journal of Agronomy and Crop Science,* Vol.191 No.1, pp.20-26.

Reeves, D. W. (1997). The role of soil organic matter in maintaining soil quality in continuous cropping system; *Soil and tillage research,* Vol.43, pp.131-167

Rengel, Z. and P. Marschener, (2005). Nutrient availability and management in the rhizosphere: Exploiting genotypic differences; *New phytologist*, Vol.168, pp.305-312; doi:10.1111/j.1469-8137.2005.01558.x

Roberts, T. L. (2008). Improving Nutrient Use Efficiency. *Turk J Agric For*, Vol.32, pp.177-182

Rodenburg, J., L. Bastiaans, E. Weltzien and D. E. Hess. (2005). How can field selection for *Striga* resistance and tolerance in Sorghum be improved? *Field Crops Research,* Vol.93 pp.34-50.

Sauerborn, J., D. Müller-Stover and J. Harshenhorn. (2007). The role of biological control in managing parasitic weeds. *Crop pro.,* Vol.26, pp246-254.

Shen, J., L. Yuan, J. Zhang, H. Li, Z. Bai, X. Chen, W. Zhang, and F. Zhang, (2011). Phosphorus dynamics: From soil to plant; Update on phosphorus dynamics in the soil-plant continuum; *Plant physiology,* Vol.156, pp.997-1005; doi/10.1104/pp.111.175232

Showemimo, F. A., C. A. Kimbeng and S. O. Alaba. (2002). Genotypic response of sorghum cultivars to nitrogen fertilization in the control of *Striga hermonthica*. *Crop Protection*, Vol.21, pp.867-870

Sikwese, M., H. R. Mloza-Banda, V. H. Kabambe and H. K. Phombeya. (2003). The potential of multipurpose tree species in the integrated management of striga in maize fields in Malawi. *African Crop Science Conference proceedings, Uganda*, Vol.6, pp.133-137

Snyder, C. S. and T. W. Bruulsema. (2007). Nutrient Use efficiency and effectiveness in America: Indices of Agronomic and Environmental Benefit. *International Plant Nutrition Institute (IPNI)*, pp.1-4, www.ipni.net.

Spalleck, T., J. M. Mutuku and K. Shirasu, (2013). Pathogen profile: The genus *Striga*: A witch profile; *Molecular plant pathology,* pp1-9; DOI:1111/mpp.12058

Sutch, R. C. (2008). Henry Agard Wallace, The IOWA corn yield tests, and the adoption of hybrid corn-NBER working paper series. *National bureau of economic research,* pp.1-38

Tilman, D., K. G. Cassman, P. A. Matson, R. Naylor and S. Polasy, (2002). Agricultural sustainability and intensive production practices; *Insight review articles,* pp.1-7

Timko, M. P., K. Huang, and K. E. Lis. (2012). Host resistance and parasite virulence in *striga*-host plant interaction: A shifting balance of power. *Weed Science*, Vol.60, pp.307-315

Van Ast, A., L. Bastiaans and S. Katile. (2005). Cultural control measures to diminish yield loss and parasite success under *striga hermonthica* infestation; Crop protection, Vol.24, pp.1023-1034

Vanlauwe, B., F. Kanampiu, G. D. Odhiambo, H. De Groote, L. J. Wadhams and Z. R. Khan. (2008). Integrated management of *Striga hermonthica,* stemboreres, and declining soil fertility in Western Kenya. *Field Crop Research*, Vol.107, pp.102-115

Vanlauwe, B., J. Kihara, P. Chivenge, P. Pypers, R. Coe and J. Six. (2011). Agronomic use efficiency of N fertilizer in maize-based systems in sub-Saharan Africa within the context of integrated soil fertility management. *Plant Soil,* Vol.339, pp.35-50, DOI 10.1007/s11104-010-0462-7

Vasquez, E., R. Sheley and T. Svejcar. (2008). Creating Invasion Resistant Soils via Nitrogen Management. *Invasive plant Science and management*, Vol.1, pp.304-314, DOI: 10.1614/IPSM-07-059.1

Wasonga, C.J., D.O.Sigunga, and A.O. Musandu. (2008). Phosphorus Requirements by Maize Varieties in different soil types of Western Kenya: African Crop Science Journal, Vol.16 No.2, pp.161-173

Wopereis, M., Tamélokpo, A., Ezui, K., Gnakpénou, D., Fofana, B., & Breman, H. (2006). Mineral fertilizer management of maize on farmer fields differing in organic inputs in the West African savanna. *Field Crops Research,* Vol.96 No.2, pp.355-362.

Wortmann, C. S., and Eledu, C. S. (1999). Uganda's agro ecological zones. *A guide for planners and policy marker.*

Zingore, S. (2011). Maize production and response to fertilizer use as affected by soil fertility variability, manure application, and cropping system; *Better crops,* Vol.95, pp.4-6

1.1.6 ONFARM ASSESSMENT OF THE MAIZE YIELD GAP OBTAINED BY CURRENT AVERAGE FARMING PRACTICES AND IMPROVED CROP NUTRITION IN THE SEMI-ARID SOUTHERN RANGELANDS OF MAKUENI COUNTY IN KENYA

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Abstract

Yield gap partitioning studies were conducted at Kambi ya Mawe, a semi-arid site in the southern rangelands of Makueni County in Kenya. Three onfarm trials were established in October 2012 during the short rains and harvested in February 2013. Ten integrated nutrient management regimes were tested. All plants had only one cob irrespective of the treatment. Maize supplied with N had significantly higher ($P \leq 0.05$) moisture content than those with NPK + Mavuno + Manure + Lime. Plants with N had higher cob yield than those supplied with NPK + Mavuno + Manure + Lime, and Control (no fertilizer). Plants supplied with NK had a higher cob shelling index than those with NPK + Mavuno + Manure + Lime. Maize supplied with N had a lower harvest index than all other treatments. All treatments produced a cob harvest index ranging between 0.77 and 0.82. Maize supplied with NPK had higher stover yield than those under NPK + Mavuno + Manure + Lime. Plants supplied with Mavuno + ZN had the highest grain yield. Maize supplied with Mavuno + ZN had higher biomass than those supplied with NPK + Mavuno + Manure + Lime, and nil fertilizers. Plots supplied with NPK + Mavuno + Manure + Lime had higher harvest index than those applied with PK, N, K, and Control (nil fertilizers). Application of fertilizers should be done with caution if grain yield is the targeted harvest.

Keywords: integrated nutrient management, fertilizers maize yield gap, semi-arid

Introduction

Pressure in the semi-arid lands of Kenya has been increasing as a result of the rapid population increase, caused by the high population growth rate and influx of communities migrating from the overcrowded high potential areas in search of new farmlands in low potential areas leading to intensive land use without sufficient replenishment of nutrients with consequent decline in soil fertility. Studies by Nadar and Faught (1984), Ikombo (1984), Okalebo *et al*. (1992), and Gachimbi *et al*. (2005), have shown that soils in the semi-arid areas have low organic matter content and are deficient in nitrogen (N) and phosphorus (P). Organic matter causes loss of water-stable structures and reduced water conductivity manifested as slaking of cultivated seedbeds, reduced infiltration rates and increased proportion of rain lost as runoff (McCown and Jones, 1992). Nadar and Faught (1984); Ikombo, (1984), Okalebo *et al*. (1992), and Gachimbi *et al*. (2005) have reported low organic matter content and N and P deficiencies in the arid and semi-arid areas. Evidence by McCown and Jones (1992) showed that manure is the best amendment for increasing soil fertility as it provides carbon, prevents acidification and generally provides the balance of all nutrients. Nutrient monitoring studies in this region have also shown

that the outflow of nutrients in most farms far exceeds input flows (Smaling *et al.,* 1993; Gachene *et al*., 2000; Gachimbi *et al*., 2005) a scenario attributed to continuous cultivation without adequate replenishment of nutrients, removal of crop residues for livestock feed and loss of nutrients through erosion, leaching and runoff. Probert *et al*. (1992) and Watiki *et al*. (1999) have reported low levels of N in manure produced on smallholder farms in the ASALs. Mugirwa and Shumba (1986) reported N levels of 0.98% and 1.05% in manure from Chiota and Svose communal areas, respectively, in Zimbabwe. Low levels of N in manure produced in smallholder farms have also been reported by Mokwunye (1980), working in West Africa, who reported N levels ranging from 0.48 to 1.95%. The low levels of N have been attributed to mixing of manure with soil when scooping manure from bomas, which in most cases do not have a concrete floor, denitrification brought about by wet conditions in the boma, leaching and volatilization occurring when manure is heaped outside after it has been removed from the boma and left uncovered (Probert *et al*., 1992). This situation prevails a lot among smallholder farmers in Kenya and especially in the ASALs. Recent studies in Nigeria (John *et al*. 2004 and Ayeni, 2011) advocated for combined use of low level of mineral fertilizer with organic manures for the supply of adequate plant nutrients in proper balance for sustainable crop production while minimizing environmental impact from nutrient use. Management of mineral fertilizers has become increasingly critical in crop production from both economic and environmental standpoint. MOSES (2009) supported the view that soils fertilized with mineral fertilizers do not supply adequate organic matter needed for optimum crop performance. Many farmers prefer combined application of mineral fertilizers with organic manures in Southwestern Nigeria. Organomineral fertilizers combined the attributes of both organic and inorganic fertilizers (Ayeni *et al*.,2008). Smallholder farmers in the ASALs have similar practices of combining manures with mineral fertilizers. Kihara *et al.* (2011) suggested that cropping system management should entail integrated soil fertility management combinations which could include an appropriate tillage system, application or retention of organic resources, and the use of inorganic fertilizers. The objectives of this study was therefore to conduct an assessment of the yield gap obtained by current average farming practices and the optimum maize yield that can be attained through enhanced crop nutrition, alone or through integrated soil fertility management options. Consequently, yield gap partitioning studies were conducted among smallholder farmers in Wote, a semi-arid area in the southern rangelands of lower eastern Kenya during the 2012 short rains in October.

Materials and Methods

Three onfarm trials were established at KARI Katumani sub-Centre Kambi ya Mawe were established at the onset of the short rains cropping season in October 2012 and harvested in February 2013. The trials treatments included 10 integrated nutrient management regimes as shown in Table 1.

Table 1: Planting and topdressing fertilizers used for experiments at Kambi ya Mawe during the 2012 – 2013 short rains cropping season

Treatment	Basal Fertilizer at Planting		Top dressing 1 Urea	Top dressing 2 Urea
1. Control	-		-	-
2. NPK	Urea TSP Potash	137 g 360 g 209 g	215g	235 g
3. PK	TSP Potash	360 g 209 g	-	-
4. NP	Urea TSP	137 g 360 g	215g	235 g
5. NK	Urea Potash	137 g 209 g	215g	235 g
6. N-P-K-S-Ca-Mg-Zn	Mavuno ZnSO4	637 g 25 g	215g	235 g
7. N-P-K-S-Ca-Mg-Zn + manure + lime	Mavuno ZnSO4 Manure Lime	637 g 25 g 18 kg 9 kg	215g	235 g
8. N	Urea	137 g	215g	235 g
9. P	TSP	209 g	-	-
10. K	Potash	418 g	-	-

The trials were replicated three times at each site. The Katumani Composite B (KCB) maize was planted in each site as the test crop in plots measuring 6m x 6m for each treatment at spacing of 75cm x 50cm. Except for the above treatments; all other farmers' cultural practices were observed. The plants were scored for number of cobs per plant, grain moisture content, Hundred Seed Weight, cob harvest index, cob shelling index per plant, cob yield, stover yield, grain yield, biomass yield, and harvest Index at 3.5 months after planting.

The maize crop was harvested in February 2013 3.5 months after planting and yield data collected. Total fresh weight of the unshelled cobs, and stover were taken and the yields sub-sampled where necessary. Total stand counts and number of cobs were counted and recorded per plot. Total fresh weights were taken where the yields were very low; the sub-sample fresh weight was taken. The samples were taken to the KARI Katumani laboratory where the maize were shelled and weighed. The cobs and shelled maize grain samples were weighed. The samples were oven-dried to a constant weight. Constant dry weights of the respective samples were obtained. Plant sample dry matter content was expressed as a percentage. The weights taken were used to extrapolate the yields per hectare in each treatment. Stover, cob, grain yields as t/Ha were obtained. Biomass and harvest index were computed. The data was subjected to analysis of variance using the method described by Gomez and Gomez (1984) and the treatments means

were separated using the Least Significant Difference (LSD) test using the SAS statistical package SAS 1990).

Results

All maize plants had only one cob on average irrespective of the fertilizer treatment they were subjected to (Table 2). Maize supplied with N (Urea 137g) had significantly higher moisture content (31.1%) than 18.3% of those supplied with NPK + Mavuno + Manure + Lime (Mavuno 637g + ZnSo4 25g + Manure 36kg + Lime 18kg). NPK + Mavuno + Manure + Lime (Mavuno 637g + ZnSo4 25g + Manure 36kg + Lime 18kg) and Mavuno + ZN (Mavuno 637g + ZnSo4 25g) had significantly higher hundred seed weight (20.33g and 21.33g, respectively) than those supplied with K (Potash 209g), PK (TSP 360g + Potash 209g), NK (Urea 137g + Potash 209g), and NP (Urea 137g + TSP 360g; Table 2).

Table 2. The effect of integrated nutrient management regimes on number of cobs per plant, Moisture Content (%) and a Hundred Seed Weight (g) of grain of maize planted on three farms at Kambi ya Mawe in semi-arid eastern Kenya during the 2012 – 2013 short rains cropping season

Treatment	Treatment details	Number of cobs per plant	Moisture content (%) of grain	Hundred Seed Weight (g)
Control	Nil fertilizer	0.9	25.1	19.78
K	Potash 209g	0.9	24.4	17.44
NPK + Mavuno + Manure (10T/Ha) manure + Lime (1000kg/Ha)	Mavuno 637g + ZnSo4 25g + Manure 36kg + Lime 18kg	0.9	18.3	21.33
Mavuno + ZN	Mavuno 637g + ZnSo4 25g	0.9	22.9	20.33
N	Urea 137g	0.9	31.1	18.67
NK	Urea 137g + Potash 209g	0.9	30.4	18.44
NP	Urea 137g + TSP 360g	0.9	29.9	18.44
NPK	Urea 137g + TSP 360g + Potash 209g	0.9	24.2	19.22
P	TSP 360g	0.9	27.3	18.67
PK	TSP 360g + Potash 209g	0.9	30.7	18.00
Means		0.9	26.4	19.03
E.S.E.		0.04	3.28	0.958
S.E.D.		0.06	4.64	1.355

		0.11	9.23	2.698
LSD		0.11	9.23	2.698
S.E.		0.12	9.84	2.875
CV (%)		12.9	37.2	15.1

Table 3 shows maize plants with N (Urea 137g) had significantly higher cob yield (0.29 t/Ha) than those in plots supplied with NPK + Mavuno + Manure + Lime (Mavuno 637g + ZnSo4 25g + Manure 36g + Lime 18kg) (0.19t/Ha), and Control (Nil fertilizer) (0.16t/Ha). Similarly plants supplied with NK (Urea 137g + Potash 209g) had a significantly higher cob shelling index (0.11) than those in plots supplied with NPK + Mavuno + Manure + Lime (Mavuno 637g + ZnSo4 25g + Manure 36g + Lime 18kg) which produced a shelling index of 0.06. Maize supplied with N (Urea 137g) had a significantly lower harvest index (0.77) than all other treatments. However, all treatments produced a similar high cob harvest index ranging between 0.77 and 0.82.

Table 3 also shows maize plots supplied with NPK (Urea 137g + TSP 360g + Potash 209g) had significantly higher stover yield (1.81t/Ha) than those under NPK + Mavuno + Manure + Lime (Mavuno 637g + ZnSo4 25g + Manure 36g + Lime 18kg) (0.87 t/Ha). Maize plants supplied with Mavuno + ZN (Mavuno 637g + ZnSo4 25g) had the highest grain yield (1.25t/Ha) which was significantly higher than P, PK, N, NPK + Mavuno + Manure + Lime, K and Control (nil fertilizers). Maize plants supplied with Mavuno + ZN (Mavuno 637g + ZnSo4 25g) had significantly higher biomass (3.23t/Ha) than those in plots supplied with NPK + Mavuno + Manure + Lime, and Control (nil fertilizers) which produced 1.91t/Ha and 2.45 t/Ha, respectively. Plots supplied with NPK + Mavuno + Manure + Lime (Mavuno 637g + ZnSo4 25g + Manure 36g + Lime 18kg) had significantly higher harvest index (0.44) than those applied with PK, N, K, and Control (nil fertilizers).

Table 3. The effect of integrated nutrient management regimes on cob harvest index, shelling index, cob, stover, grain, and biomass yields (t/ha), and harvest index of maize planted on three farms at Kambi ya Mawe in semi-arid eastern Kenya during the 2012 – 2013 short rains cropping season

Treatment	Treatment details	Cob yield (t/ha)	Cob Shelling index per plant	Cob harvest index	Stover yield (t/ha)	Grain yield (t/ha)	Biomass yield (t/ha)	Harvest Index
Control	Nil fertilizer	0.16	0.09	0.82	1.56	0.72	2.45	0.32
K	Potash 209g	0.21	0.08	0.81	1.65	0.91	2.77	0.34
NPK + Mavuno + Manure (10T/Ha) manure +	Mavuno 637g + ZnSo4 25g + Manure 36g +	0.19	0.06	0.81	0.87	0.84	1.91	0.44

Lime (1000kg/Ha)	Lime 18kg						
Mavuno + ZN	Mavuno 637g + ZnSo4 25g	0.28	0.07	0.82	1.70	1.25	3.23	0.40
N	Urea 137g	0.29	0.10	0.77	1.59	0.95	2.83	0.34
NK	Urea 137g + Potash 209g	0.24	0.11	0.81	1.61	1.05	2.91	0.36
NP	Urea 137g + TSP 360g	0.25	0.10	0.82	1.59	1.12	2.96	0.38
NPK	Urea 137g + TSP 360g + Potash 209g	0.25	0.08	0.81	1.81	1.04	3.10	0.37
P	TSP 360g	0.19	0.08	0.82	1.37	0.89	2.45	0.37
PK	TSP 360g + Potash 209g	0.25	0.10	0.79	1.76	0.96	2.96	0.33
Means		0.23	0.09	0.81	1.55	0.97	2.757	0.36
E.S.E.		0.029	0.014	0.014	0.219	0.090	0.2744	0.028
S.E.D.		0.041	0.020	0.019	0.310	0.127	0.3881	0.040
LSD		0.082	0.040	0.039	0.617	0.253	0.7726	0.080
S.E.		0.087	0.042	0.041	0.657	0.269	1.064	0.085
CV (%)		37.7	49.4	5.1	42.4	27.7	28.1	23.4

Discussion

The results in Table 2suggest that the number of ears per plant is not influenced by the soil fertility status. Table 2 also suggests that the introduction of N lowered the moisture content of maize which is a desirable outcome. The supply of N seems to favour the increase of moisture content which is undesirable which seems to be counteracted by the introduction of NPK + Mavuno + Manure + Lime. By implication, this means that the presence of sufficient amounts of N favours the increase of the dry matter content of maize which is a highly desirable parameter. It seems NPK + Mavuno (micronutrients) contributed positively to the assimilation, partitioning, and accumulation of dry matter in the grains. It also appears that the major elements, NPK, either singly or combined in twos do not contribute efficiently towards dry matter accumulation in the grains without the presence of micronutrients. As such, there is need to conduct further research to determine the individual contribution of each element and hence its importance in the assimilation, partitioning, and accumulation of dry matter in the maize grains.

Table 3 shows the effect of integrated nutrient management regimes on cob harvest index, shelling index, cob, stover, grain, and biomass yields (t/ha), and harvest index of maize. They suggest that the addition of N had a positive effect on cob yield when farmer managed in farmers' fields. The addition of NK had a positive effect on cob shelling index suggesting that supplying maize plants with a larger cocktail (NPK + Mavuno + Manure + Lime) of nutrients strengthens the attachment of grains to cobs thereby reducing their shelling index. However, results suggest cob harvest index is not under the control of soil fertility amendments.

Further results suggested that NPK had a highly positive influence on stover production whose effect could be lowered by the introduction of Mavuno and ZnSo4. It is suggested that the application of Mavno + Zinc or any other soil amendment should be done in consideration with other desirable attributes. It seems an oversupply of nutrients to maize plants might cause the partitioning of assimilates to the vegetative parts (stover) rather than to the grains. It is possible that the addition of Mavuno + ZN could have introduced positive effects on the increase of biomass. As such, the application of fertilizers should be done with caution if grain yield is the targeted harvest as is the case in most instances.

Conclusions

The number of ears per plant is not influenced by the soil fertility status. The introduction of N lowered the moisture content of maize which is a desirable outcome. The supply of N seems to favour the increase of moisture content which is undesirable which seems to be counteracted by the introduction of NPK + Mavuno + Manure + Lime. The presence of sufficient amounts of N favours the increase of the dry matter content of maize which is a highly desirable trait. NPK + Mavuno (micronutrients) contributed positively to the assimilation, partitioning, and accumulation of dry matter in the grains.

It seems the major elements, NPK, either singly or combined in twos do not contribute to efficiently towards dry matter accumulation in the grains without the presence of micronutrients. As such, there is need to conduct further research to determine the individual contribution of each element and hence its importance in the assimilation, partitioning, and accumulation of dry matter in the maize grains.

The addition of N had a positive effect on cob yield when farmer managed in farmers' fields. The addition of NK had a positive effect on cob shelling index. Supplying maize plants with a larger cocktail (NPK + Mavuno + Manure + Lime) of nutrients strengthens the attachment of grains to cobs thereby reducing their shelling index. Harvest index is not under the control of soil fertility amendments.

NPK had a highly positive influence on stover production whose effect could be lowered by the introduction of Mavuno and ZnSo4. The application of Mavno + Zinc or any other soil amendment should be done in consideration with other desirable attributes. It seems an oversupply of nutrients to maize plants might cause the partitioning of assimilates to the vegetative parts (stover) rather than to the grains. The addition of Mavuno + ZN could have

introduced positive effects on the increase of biomass. The application of fertilizers should be done with caution if grain yield is the targeted harvest as is the case in most instances. There is need to investigate further the effect if any lime has on maize production. Micronutrients should be applied to soils where maize is planted or at planting in addition to NPK and manure.

References

Ayeni, L.S., Adetunji, M.T., Ojeniyi, S.O., Ewulo, B.S. and Adeyemo, A.J. (2008), Comparative and cumulative effect of cocoa pod husk ash and poultry manure on soil and nutrient contents on maize yield. American – Eurasian Journal of Sustain. Agric. 2(1): 92-97.

Ayeni, L.S. (2011), Effect of Sole and Combined Cocoa Pod Ash, Poultry Manure and NPK 20:10:10 Fertilizer on Soil organic carbon, available P and forms of nitrogen and of Alfisols in Southwestern Nigeria. International Journal of Agriculture and Soil Science. 1 (3): 77 – 82

Gachene, C.K.K., Mureithi, J.G., Anyika, F. and Makau, M. (2000), Incorporation of green manure cover crops in maize-based cropping systems in semi-arid and sub-humid environments of Kenya. In: Mureithi, J., Gachene, C.K.K., Muyekho, F.N., Onyango, M., Mose, L. and Magenya, O. (Eds.). Participatory technology development for soil management by smallholders in Kenya. Proceedings of the Second Scientific Conference of the Soil Management and Legume Research Network Projects, Mombasa, Kenya, June 2000. PP. 105 - 115

Gachimbi, L.N., Keulen van H., Thuranira, E.G., Karuku, A.M., Jager, de A., Nguluu, S., Ikombo, B.M., Kinama, J.M., Itabari, J.K. and Nandwa, S.M. (2005), Nutrient balances at farm level in Machakos (Kenya), using a participatory nutrient monitoring (NUTMON) approach. Land Use Policy, 22: 13-22.

Gomez, K. A. and Gomez A. A. (1984), Statistical procedures for agricultural research, 2nd edition. Wiley, New York, 680 pp.

Ikombo, B. M. (1984), Effects of farmyard manure and fertilizers on maize in semi-arid areas of Eastern Kenya. E. Afr. Agric. For. J. 44: 266 – 274.

John, L.W., Jamer, D.B., Samuel, L.T., Waner, L.W. 2004. Soil fertility and fertilizer. An introduction to nutrient management. Person Education, India, 11, 106 – 153

Kihara J., A. Bationo, D. N Mugendi, C. Martius and P. L. G. Vlek. (2011), Conservation Tillage, Local Organic Resources, and Nitrogen Fertilizer Combinations Affect Maize Productivity, Soil Structure and Nutrient Balances in Semi-Arid Kenya. In: A. Bationo, B. Waswa, J. M. Okeyo, F. Maina and J. Kihara (Eds.): Innovations as Key to the Green Revolution in Africa: Exploring the Scientific Facts, Volume 2, ISBN 978-90-481-2541-8 © Springer Science+Business Media B.V. 2011. pp. 155 – 168.

McCown, R. L. and Jonnes, R. K. (1992), Agriculture of semi-arid Kenya: problems and possibilities. In: Probert, M. E. (ed.). A search for strategies for sustainable dryland cropping in semi-arid Eastern Kenya. Proceedings of a Symposium held in Nairobi, Kenya, 10-11 December 1990. ACIAR Proceedings No. 41. Canberra, Australia. pp. 8-14.

Mokwunye, U. (1980). Interaction between farmyard manure and NPK fertilizers in savanna soils.In: Organic recycling in Africa. Rome, FAO, Soils Bulletin No. 43:192-200.

Moses. 2009. The importance of organic matter to soil fertility and crop health www.mosesorganic.org

Mugwira, L. M. and Shumba, E. M. (1986), Rate of manure applied in some communal areas and the effect on plant growth and maize grain yields. Zimbabwe Agricultural Journal. 83: 99-104.

Nadar, H. M. and Faught, W. A. (1984), Maize yield response to different levels of nitrogen and phosphorus fertilizer application: A seven-season study. E. Afr. Agric. For. J. Special Issue 44: 147 – 156.

Okalebo, J. R., Simpson, J. R. and Probert, M. E. (1992), Phosphorus status in cropland soils in the semi-arid areas of Machakos and Kitui Districts, Kenya. In: Probert, M. E. (Ed.). A search for strategies for sustainable dry land cropping in semi-arid Eastern Kenya. Proceedings of a symposium held in Nairobi, Kenya, 10-11 December 1990. ACIAR Proceedings No.41. 10-21, Canberra, Australia.

Probert, M. E., Okalebo, J. R., Simpson, J. R. and Jones, R. K. (1992), The role of boma manure for improving soil fertility. In: Probert, M. E. (Ed.). A search for strategies for sustainable dry land cropping in semi-arid eastern Kenya. Proceedings of a symposium held in Nairobi, Kenya, 10-11 December 1990. ACIAR Proceedings No. 41. 63 – 78, Canberra, Australia.

SAS (1990), Statistical analysis system users' quide, vol 1, ACECLUS-FREQ version 6, 4th edn. SAS Institute, Cary, NC, 890 pp.

Smaling, E.M.A., Stoorvogel, J.I. and Windmeijer, P.N. (1993), Calculating soil nutrient balances in Africa at different scales. II. Different Scale. Fert. Res. 35, 237-250.

Watiki, J.M., Gichangi, E.M., Itabari, J.K., Karuku, A.M. and Ngulu, S.N. (1999), The effects of rate and placement of boma manure on maize yield in semi-arid eastern Kenya. In: Proceedings of the 6th Biennial KARI Scientific Conference, Nairobi, Kenya, 9-13 November 1998.

1.1.7 EVALUATION OF TOLERANCE OF COWPEA VARIETIES TO WATER STRESS AT UMBELUZI-BOANE AGRARIAN STATION

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Abstract
A field trial was conducted in Umbeluzi Agrarian Station, between February and May 2009 to evaluate the tolerance of 36 varieties of Cowpea (*Vigna unguiculata* (L.) Walp) to water stress under irrigated and water stressed environment. In stressed environment, the water supply was stopped from flowering to physiological maturity, while in irrigated environment; the plants were fully watered to maintain the soil condition at field capacity. The experimental design was a randomized complete block (RCB), with three (3) replications. Field data collected was: number of seeds per pod (NSP), number of pods per plant (NPP), weight of 100 seeds (W100S) and grain yield (Y). Significant differences between the varieties ($P < 0.05$) were observed for grain yield, weight of 100 seeds and number of pods per plant. The interaction between environment and varieties showed significant effects ($p < 0.05$) for the variables grain yield and number of pods per plant. Overall, according to index of susceptibility, 19 varieties were classified as being tolerant to water stress, and 17 varieties were classified as being susceptible. However, among the varieties considered tolerant, 7 had higher productivity in stressed environment. According to

water stress tolerance and yield, varieties were grouped into four (4) groups: group A, consisting of tolerant varieties with high productivity, group B, tolerant and low productivity, group C, likely with high productivity and Group D, likely with low productivity.

Key Words: Cowpea, Environment, Index of susceptibility, Tolerance, Water stress.

Introduction

The cowpea (*Vigna unguiculata* (L.) Walp) is an important food crop in many semi-arid regions of the world, especially for the poorest people in developing countries (Ojimelelukwe, 2002). The crop is mainly produced in Africa where more than 95% of cultivated area and production takes place (FAO, 2008). Among the regions of Africa, West Africa contributes mostly in production, reaching just over 4.6 million tonnes (covering 85% of production in Africa). The largest producers of cowpea in the region, the continent and the world are Nigeria and Niger with more than 75% of world production (FAO, 2008). The culture is also important in the eastern and southern regions of Africa which highlights countries such as Ethiopia, Kenya, Uganda, Zambia, Zimbabwe, Botswana, and Mozambique (Rachie & Singh, 1985).

In most countries of the world, cowpea is produced mainly for obtaining grain for human consumption and for industry such as in the United States and Brazil. In Africa, beyond the grain, also takes up the leaves for human consumption, such as in Mozambique, and the remains of culture are used to feed livestock case of most West African countries (Rulkens, 1996).

The cowpea is particularly important for poor people, given its richness in protein (23-25%), essential amino acids, carbohydrates (62%), vitamins and minerals, as well as having low amount of fats (oil content 2%) and contains no cholesterol (Straliotto & Teixeira, 2000).

In Mozambique, the cowpea is the fifth most important crop after maize, cassava, groundnuts and rice (INE, 2008), and is produced mainly by smallholders mostly on areas less than 2 ha (TIA, 2008). Is usually intercropped with maize and sorghum and cassava in the South in the North, mainly to obtain grain and leaves for family consumption in rural areas and for marketing near large urban centers. Despite its importance, the observed yields remain low. National statistics show that the yields obtained in farmers' fields ranging from 170-400 kg / ha (INE, 2008) although high yields of over 1000 kg / ha are observed when the crop is sown between January and February, using more varieties productive in pure culture with good cultural management.

Water stress for example has been referred to as one of the major constraints on crop production and food insecurity in Mozambique, but few studies have been conducted to interaction between varieties and water regimes. Despite cowpea be considered drought tolerant, studies have shown that the occurrence of drought stress predominant phases of flowering, pod formation and grain filling severely reduces the yield (Gomes-Filho & Tahim, 2002). However, other studies have shown the existence of wide genetic variability of tolerance between the cowpea varieties and lines suggesting the possibility of selecting drought tolerant varieties. Given the importance of culture, there is a need to conduct research on the major constraints of crop.

This study can help to identify varieties with broad adaptation to all kinds of (wet and dry) environments and varieties with a restricted adaptation (wet or dry environments). On the other

hand, knowledge of the interaction between varieties and environment (water regime) can produce useful information for breeding programs. This study is a contribution in this direction by assessing the interaction between 36 varieties of cowpeas and two water environments (stressed and irrigated). In this work were identified varieties with broad adaptation and varieties with restricted adaptation as also give contribute to the development of a breeding program for the cowpea drought tolerance through the assessment of tolerance of 36 cowpea varieties when grown in irrigated and stressed environment.

Materials and methods

Description of the study area
The trial was conducted between February and May 2009 in the Umbelúzi-IIAM Agrarian station with geographical coordinates of 26 03' South Latitude and 32 ° 23' longitude east. The area is characterized by having soils with high clay content, high water retention capacity, average annual rainfall of 679 mm, and irregular rainy season from November to March (MAP, 1996).
During the test, the maximum monthly temperature ranged between 29 and 31.3ºC and minimum monthly temperature ranged between 14.9 and 23 ° C. The relative humidity ranged between 61 and 88%, being April and May less and more humid, respectively. The total rainfall during the test was 258 mm, with March recording the maximum 76.3 mm, and the month of May recording the minimum 1.7 mm. The total evapotranspiration was 632 mm, with the maximum recorded in April of 124.4 mm and the minimum in May of 113.6 mm (EMEAU, 2009); which led to a water deficit of 374 mm, where supplied by irrigation.

Description of test and treatments
To evaluate the tolerance of the varieties to water stress, they were grown in two environments (irrigated and stressed). In stressed environment, the water supply was stopped from flowering to physiological maturity the grain while in the irrigated environment the plants were irrigated throughout the cycle in order to keep the soil in the field capacity.

To avoid water to cross from irrigated to stressed environment, the two environments were separated by 15 m. The experimental design used was a randomized complete block with 36 treatments and 3 replications for each environment. The varieties used in the test are presented in Table 1. The experimental unit consisted of three (3) rows with 2.5 m apart 70 cm in length between lines of plants spaced 20 cm on the line. The usable area for data collection consisted of a central line having been left on the line the two plants of the tips.

The sowing was done using two (2) seeds per hole and thinning was done 10 days after the complete emergence, leaving one plant per hole, followed by topdressing with 50 kg/ha of NPK fertilizer (12-24 -12) done at 12 days after emergence. After plant emergence, plant protection treatments preventively from the third (3rd) week with the range of 10 days were applied. The weed control was done manually where the incidence was observed. Watering was by gravity, being applied once every 10 to 15 days.

Table 1: Characteristics of varieties

Order	Name of the variety	Country origin	Habito of grown	Cycle
1	FN-1-13-04	Mozambique	Prostrate	Long
2	FN-1-14-04	Mozambique	Prostrate	Long
3	FN-2-9-04	Mozambique	Prostrate	Long
4	FN-2-11-04	Mozambique	Prostrate	Long
5	FN-2-13-04	Mozambique	Prostrate	Long
6	FN-2-14-04	Mozambique	Prostrate	Long
7	INIA 17B	Mozambique	Prostrate	Long
8	INIA 17G	Mozambique	Prostrate	Long
9	N'diambour	Senegal	Prostrate	Long
10	INIA 19F	Mozambique	Prostrate	Long
11	INIA-35	Mozambique	Prostrate	Long
12	INIA-40	Mozambique	Prostrate	Long
13	INIA-41	Mozambique	Prostrate	Long
14	INIA-72	Mozambique	Prostrate	Long
15	INIA-73	Mozambique	Prostrate	Long
16	INIA-120	Mozambique	Prostrate	Long
17	INIA-152	Mozambique	Prostrate	Long
18	Timbawene creme	Mozambique	Prostrate	Long
19	Ecute	Mozambique	Prostrate	Long
20	EP2-Kunde 1	Mozambique	Prostrate	Long
21	EP2-Kunde 2	Mozambique	Prostrate	Long
22	GileK-2 local	Mozambique	Prostrate	Long
23	Maputo	Mozambique	Prostrate	Long
24	Massava-5	Mozambique	Prostrate	Long

25	Massava-11	Mozambique	Prostrate	Long
26	Massava-14	Mozambique	Prostrate	Long
27	Muinana Iawe	Mozambique	Prostrate	Long
28	Tete-2	Mozambique	Prostrate	Long
29	Timbawene moteado	Mozambique	Prostrate	Long
30	Xingove	Mozambique	Prostrate	Long
31	Zimbabwe	Mozambique	Prostrate	Long
32	IT93K-503-1	IITA	Prostrate	Long
33	IT97K-556-6	IITA	Prostrate	Long
34	SuVita2	INERA-Burkina	Prostrate	Long
35	IT97K-819-132	IITA	Prostrate	Long
36	UC-CB46	US	Prostrate	Long

The weight of 100 seeds, the number of seeds per pod, number of pods per plant and yield per plot were measured after physiological maturity. We calculated the yield per hectare using the following formula:

$$\text{Yield (kg/ha)} = \frac{10000 * \text{Yield (plot)}}{1000 * C * N^o \text{ of harvest plants}}$$

Where:
Yield by plot in – (g);
C – Compass in (m^2);
10000 – Conversion factor of m^2 to ha;
1000 – Conversion factor from g to kg;

To assess tolerance of varieties to water stress was used index of susceptibility to stress and the stress intensity according to Fisher & Maurer (1978) by the following formulas:

Susceptibility index (1)

$$SI = 1 - (Y_{str} / Y_{irrig})$$ (1); where:

IS – Susceptibility Index;

Y_{irrig} – is the average yield of the grain at harvest in the irrigated environment;
Y_{Str} – is the average grain yield in the stressed environment.

Stress intensity (2)

$$SI_{nt} = \left[1 - (M_{str} / M_{irrig})\right]$$ (2); onde:

SI = Stress intensity;
M_{irrig} = Average yield in irrigated environment;
M_{str} = Average yield in stressed environment.

The varieties were classified into tolerant when its stress index is lower than the intensity of stress (0.24) and susceptible those made stress index greater than stress intensity.

For the grouping of the varieties according to the average productivity of varieties and tolerance, we determined the overall average of the trial by the following formula (3):

$$\bar{Y}_{general} = \left(\bar{Y}_{irrig} + \bar{Y}_{str}\right)/2$$ (3); where

Data analysis
The data were analyzed using the statistical package-SAEG for analysis of variance (ANOVA) and mean comparison test. The analyzes were made of: ANOVA for each water environment and combined ANOVA of the two environments of water with varieties for the following variables: number of pods per plant, number of seeds per pod, 100 seed weight and yield (kg/ha). For significant variables, comparison of means were performed using the statistical Scott Knott test at a significance level of 5%. Correlation analysis between yield and yield components was made to explain the contribution that each component has on grain yield.

Results
The results of the separate analysis of variance (ANOVA) show that there was a significant effect of the variety factor in the number of seeds per pod, weight of 100 seed, and grain yield for the two environments of water (stressed and irrigated). There was also a significant effect of the variety factor for the number of pods per plant only for stressed environment (Table 2).

Table 2: Significance of variety factor in the grain yield, number of seed per pod, number of pods per plant and 100 seeds weight (Y, NSP, NPP, W100S) in two environment

Water environment	Variable	Variety
Irrigated	Y (kg/ha)	(S)
	NPP	(NS)
	NSP	(S)
	W100S	(S)
Stressed	Y (kg/ha)	(S)
	NPP	(S)
	NSP	(S)
	W100S	(S)

Note: (S)-significative; (NS)-non significative at 5% of significance.

The combined analysis of variance of the two water environments shows that there was significant effect of the water environment factor in weight of 100 seeds and grain yield and was not significant for the number of pods per plant and number of seeds per pod. The variety factor had significant effects on all measured variables, namely, number of pods per plant, number of seeds per pod, weight of 100 seeds and grain yield (Table 3). The interaction between the variety factors and water regime was only significant for the variables number of pods per plant and grain yield. The significant interaction shows that varieties responded differently when grown in different water environment. This suggests that it is possible to select varieties for growing in good conditions and limited water availability (Table 3).

Table 3: Significance of the variety factor, water environment and interaction between the variety factor and water environment for the variables grain yield and yield components (Y, NPP, NSP, W100S)

Variable	Water environment	Variety	Water environment x Variety
Y	(S)	(S)	(S)
NPP	(S)	(S)	(S)
NSP	(NS)	(S)	(NS)
W100S	(S)	(S)	(NS)

Note: (S)-significative; (NS)-non significative at 5% of significance.

Table 4: Average of yield and yield components of cowpea in irrigated environment

Variety	NSP	Variety	W100S (g)	Variety	Y (kg/ha)
INIA-40	17 **A**	GileK-2 local	23.00000 **A**	Massava-5	2101.361 **A**
EP2-Kunde 1	17 **A**	Maputo	20.33333 **A**	FN-2-14-04	2094.697 **A**
INIA 19F	16 **A**	Tete-2	19.66667 **A**	EP2-Kunde 2	1925.661 **A**
FN-2-9-04	16 **A**	FN-2-11-04	19.66667 **A**	UC-CB46	1819.312 **A**
Timbawene crème	16 **A**	INIA-35	19.00000 **A**	INIA-72	1747.307 **B**
INIA-35	11 **B**	INIA-73	11.00000 **B**	SuVita2	875.8503 **D**
Timbawene moteado	10 **B**	INIA 17G	11.000000 **B**	INIA-152	870.8333 **D**
SuVita2	10 **B**	INIA 17B	10.66667 **B**	Massava-11	858.8436 **D**
IT97K-819-132	9 **B**	EP2-Kunde 1	10.33333 **B**	IT93K-503-1	706.0847 **E**
N'diambour	7 **B**	INIA-152	7.333333 **B**	N'diambour	592.2800 **E**

Note: Average with same letter on the column are not different according to SCOTT – KNOTT test with de 5% of significance.

Table 5: Average of yield and yield components of cowpea in stressed environment

Variety	NPP	Variety	NSP	Variety	W100S (g)	Variety	Y (kg/ha)
IT93K-503-1	26 **A**	EP2-Kunde 1	18 **A**	GileK-2 local	23.66667 **A**	UC-CB46	1548.876 **A**
INIA-72	21 **A**	Ecute	16 **A**	Timbawene crème	21.66667 **A**	Tete-2	1474.026 **A**
INIA 19F	18 **A**	INIA-152	16 **A**	INIA-41	21.33333 **A**	SuVita2	1440.146 **A**
EP2-Kunde 2	18 **A**	INIA-73	16 **A**	Massava-5	21.33333 **A**	INIA-35	1364.749 **A**
INIA 17G	18 **A**	FN-2-13-04	15 **A**	Xingove	20.66667 **A**	Zimbabwe	1308.768 **B**
Massava-	6 **B**	Massava-11	10	INIA 17G	11.33333	INIA-41	730.8802

14			B		D		D
GileK-2 local	5 B	INIA-120	10 B	INIA-152	11.33333 D	Massava-14	607.3696 D
FN-1-13-04	5 B	IT97K-819-132	9 B	EP2-Kunde 1	11.33333 D	GileK-2 local	532.0347 D
FN-1-14-04	3 B	IT97K-556-6	9 B	INIA-73	11.00000 D	FN-2-9-04	300.8658 E
FN-2-9-04	2 B	N'diambour	7 B	INIA-72	9.000000 D	FN-1-14-04	251.4731 E

Note: Average with same letter on the column are not different according to SCOTT – KNOTT test with de 5% of significance.
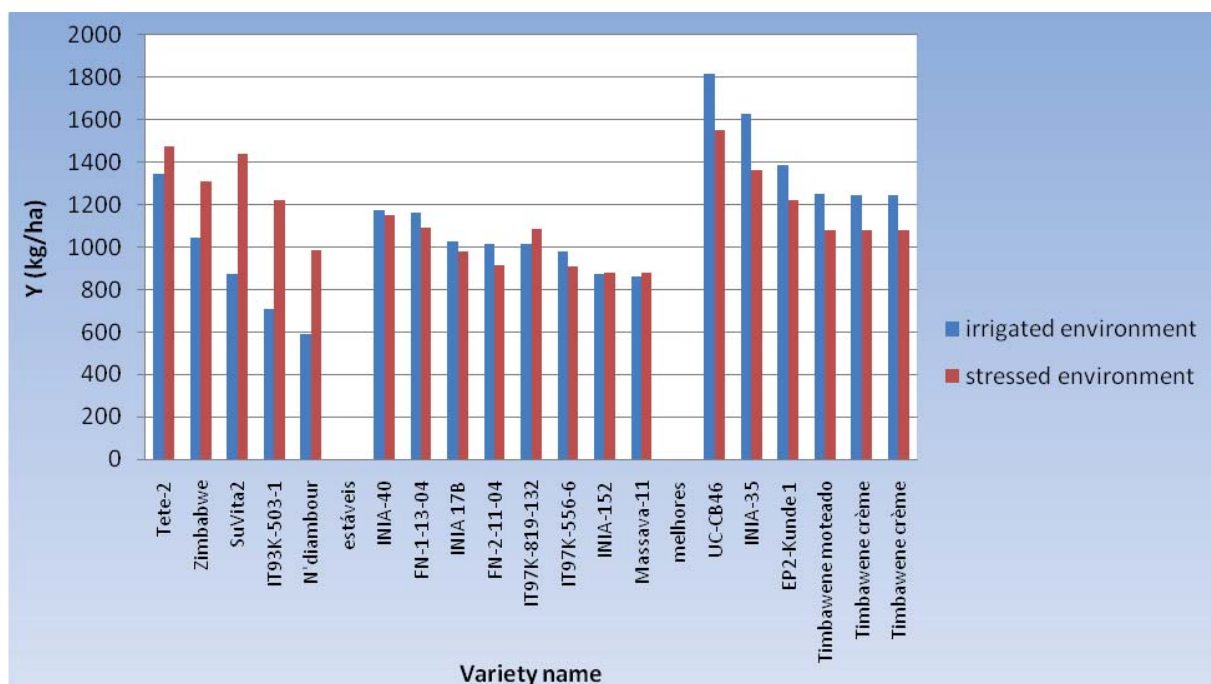
Figure 1: Yield of tolerant varieties in different environments
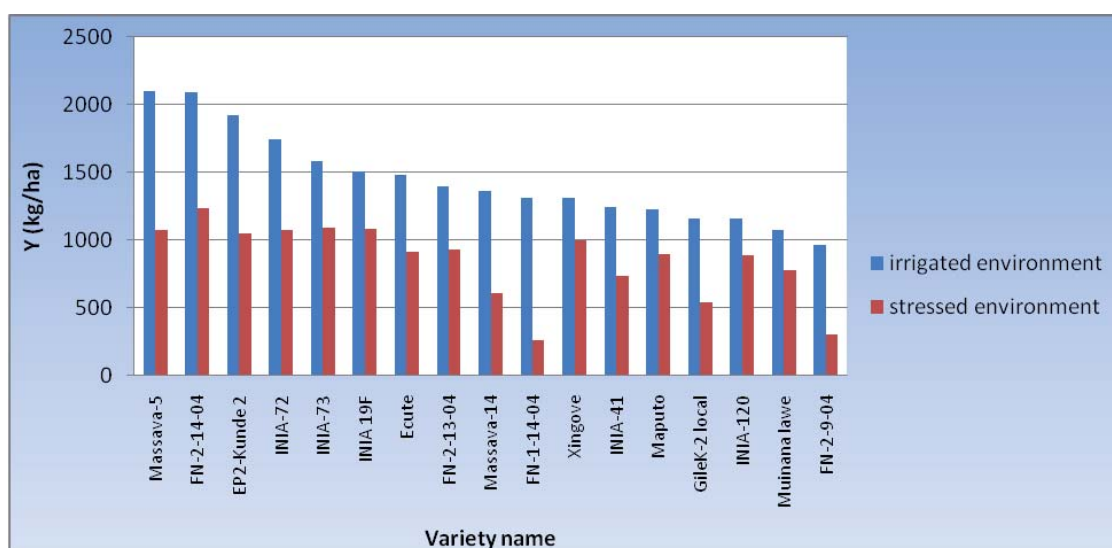
Figure 2: Yield of susceptible varieties in different environments

Correlation analysis done for the variables, number of pods per plant, number of seeds per pod and weight of 100 seeds (yield components) showed a positive correlation between them and the yield of grain at a significance level of 5% in two water environments (Table 6). However, the strong positive correlation was only for the variable number of pods per plant in stressed environment, suggesting that the performance was strongly influenced by this variable.

Table 6: Correlation between number of pods per plant (NPP), number of seed per pod (NSP), weight of 100 seeds (W100S) and grain yield at 5% of significance

Variable	Environment	
	Irrigated	**Stressed**
	Yied	Yied
NPP	0.3129	0.6094
NSP	0.1757	0.0648
W100S	0.177	0.1304

Evaluation of tolerance of varieties to water stress

We evaluated the tolerance of varieties based on the susceptibility index and intensity of stress, where they were classified as susceptible varieties with greater susceptible index than intensity of stress of 0.24 and tolerant that with susceptibility index less than intensity (Table 7).

Table 7: Classification of variety based on susceptibility index

Variety	SI	Tolerant	Variedade	SI	Tolerant	Susceptible
IT93K-503-1	-0.73	X	INIA-35	0.16	X	
N'diambour	-0.66	X	INIA-120	0.24		X
SuVita2	-0.64	X	Xingove	0.24		X
Zimbabwe	-0.25	X	Maputo	0.27		X
Tete-2	-0.09	X	Muinana Iawe	0.28		X
IT97K-819-132	-0.07	X	INIA 19F	0.28		X
Massava-11	-0.03	X	INIA-73	0.31		X
INIA-152	-0.01	X	FN-2-13-04	0.34		X
INIA-40	0.02	X	Ecute	0.38		X
INIA 17B	0.05	X	INIA-72	0.39		X
FN-1-13-04	0.06	X	FN-2-14-04	0.41		X
IT97K-556-6	0.07	X	INIA-41	0.41		X
FN-2-11-04	0.10	X	EP2-Kunde 2	0.46		X
EP2-Kunde 1	0.12	X	Massava-5	0.49		X
Timbawene creme	0.13	X	GileK-2 local	0.54		X
Timbawene moteado	0.14	X	Massava-14	0.55		X
UC-CB46	0.15	X	FN-2-9-04	0.69		X
INIA 17G	0.16	X	FN-1-14-04	0.81		X

Obs: *The varieties with negative SI automatically have increase in yield in stressed environment, therefore are considered tolerant.* **Note: IS** - susceptibility index;

$$I_{nt}S = \frac{1269 - 997}{1269} = 0{,}24 \text{ (moderated stress)}$$

Grouping of varieties according to yield and tolerance to water stress
Based on the average productivity of varieties and susceptibility index of varieties to stress, four groups of varieties were identified, namely: tolerant of high productivity (group A), tolerant of low productivity (group B), susceptible of high productivity (group C) and susceptible of low

productivity (group D). The average productivity of the trial was 1133 kg/ha. Thus, the varieties that produced more than 1133 kg/ha were categorized as having a high productivity and those with less as having low productivity (Table 8).

$$\bar{Y}_{geral} = (1269 + 997)/2 = 1133 kg/ha$$

Table 8: **Grouping of varieties according to productivity and stress index**

Variety	Average productivity ($\bar{Y}$)	Susceptibility index (IS)	Group
UC-CB46	1684	0.15	**Tolerant, high productivity** **(A)**
INIA-35	1497	0.16	
Tete-2	1411	-0.09	
EP2-Kunde 1	1303	0.12	
Zimbabwe	1176	-0.25	
Timbawene moteado	1167	0.14	
Timbawene crème	1163	0.13	
INIA-40	1162	0.02	
SuVita2	1158	-0.64	
FN-1-13-04	1128	0.06	**Tolerant, low productivity** **(B)**
IT97K-819-132	1048	-0.07	
INIA 17B	1003	0.05	
INIA 17G	979	0.16	
IT93K-503-1	965	-0.73	
FN-2-11-04	963	0.10	
IT97K-556-6	945	0.07	
INIA-152	875	-0.01	
Massava-11	870	-0.03	
N'diambour	789	-0.66	

FN-2-14-04	1662	0.41	
Massava-5	1588	0.49	
EP2-Kunde 2	1484	0.46	
INIA-72	1409	0.39	**Susceptible, high productivity**
INIA-73	1337	0.31	
INIA 19F	1291	0.28	**(C)**
Ecute	1197	0.38	
FN-2-13-04	1158	0.34	
Xingove	1149	0.24	
Maputo	1058	0.27	
INIA-120	1017	0.24	
INIA-41	988	0.41	
Massava-14	984	0.55	**Susceptible, low productivity**
Muinana Iawe	925	0.28	
GileK-2 local	843	0.54	**(D)**
FN-1-14-04	779	0.81	
FN-2-9-04	633	0.69	

Discussion

Predictably varieties responded differently to the two environments, irrigated and stressed, the variables grain yield and yield components except number of pods per plant did not differ in irrigated condition. Some varieties showed stability in income while others showed a decrease of income as a result of water stress. This suggests that among these varieties there is also great variability of tolerance to water stress suggesting the existence of varieties with specific adaptation to good water availability (varieties that were affected by stress) and varieties with general adaptation to all environments humid and dry environments.

However, studies by Nogueira *et al*. (2007) found that water stress imposed during the reproductive phase in the cowpea crop did not produce different effects on the variables: average size of pods, number of seeds per pod and the average weight of 100 seeds of cowpea. This contrast is explained by the wide genetic variability found in the crop of cowpea. The interaction between varieties and water environment in these varieties also revealed that there is a genetic

variability in relation to their water stress, which shows the possibility of selecting drought tolerant varieties.

Analyzing income differences recorded, Santos *et al*. (2009) explains that the highest values of observed yields, is probably due to intrinsic characteristics of varieties to absorb nutrients from the soil, more efficient water retention system in the plant and greater efficiency in the photosynthetic system of tolerant varieties, which promote higher production and translocation of assimilates to the plant, providing greater dry matter accumulation, especially during phases of higher requirement of cowpea (flowering, pod formation and grain filling), which is reflected in higher yield of grain susceptible varieties.

Assessing the susceptibility index, we find that the varieties with negative indices were grouped in group of tolerant plants, these in turn can be termed as highly tolerant plants, as water stress caused no reduction in their income. The other possibility would be that some varieties feel your roots asphyxiated as they reacted positively in terms of productivity achieved in low water availability, the case of varieties: IT93-503-1, N'diambour, Suvita2, Zimbabwe, Tete-2, IT97-819-132, Massava-11, INIA - 152.

Conclusion

In the irrigated environment among the varieties that had grain yield above average (1269kg/ha), the highlighted were: Massava-5, FN-2-14-04, Kunde EP2-2, UC-CB46-72 and INIA. The Suvita2, INIA-152, Massava-11-IT93K-503-1 and N'diambour varieties were those who had lower grain yield among those who had income below average. In terms of number of pods per plant, there were no significant differences among the varieties. For the number of seeds per pod stood out positively varieties: INIA-40 EP2-Kunde 1, INIA-19F, FN-9-2-04 and Timbawene crème with a record above average (13.16); the INIA-35, Timbawene moteado, Suvita2, IT97K-819-132 and N'diambour those varieties were registered lower values, lower than 13.16. As for the weight of 100 seeds, varieties that stood out positively were: GILEK-2 site, Maputo, Tete-2, FN-2.11.04 and INIA-35, weighing more than 15.7g; while the INIA-73, INIA-17G, INIA-17B, EP2-Kunde 1 and INIA-152 varieties recorded values below average (15,7g), lower.

In the stressed environment had the highest grain yield and above the average (997kg/ha) the following varieties: UC-CB46, Tete-2, Suvita2, INIA-35 and Zimbabwe. The INIA-41-14 Massava, GILEK-2 site, FN-2-9-04 and FN-1-14-04 varieties had income below average (997kg / ha). For the component number of pods per plant stood out positively varieties: IT93K-503-1, INIA-72, INIA 19F, EP2-Kunde 2 and INIA 17G, with above 12.36 higher values. The Massava-14, GILEK-2 local, FN-1-13-04, 1-14-04 and FN-FN-1-9-04 varieties were those made at lower values lower than 12.36. For the number of seeds per pod stood out positively varieties: EP2-Kunde 1, Ecute, INIA-152, INIA-73 and FN-2-13-04, with a record above average (12.98). The Massava-11, INIA-120, IT97K-819-132, IT97K-556-6 and N'diambour varieties recorded values below 12.98 highlighting by negative. As for the weight of 100 seeds, varieties that stood out positively were: GILEK-2 local, Timbawene crème, INIA-41, Massava-5, Xingove, weighing more than 16,31g; while the varieties INIA 17G, INIA-152, EP2-Kunde 1, INIA-72 and INIA-73 showed lower average values (16,31g).

The current study dictated the varieties IT93K-503-1, N'diambour, Suvita2, Zimbabwe, Tete-2, IT97K-819-132, Massava-11, INIA-152, INIA-40, INIA 17B, FN-1-13-04, IT97K-556-6, FN-11.02.04, EP2-Kunde 1, Timbawene crème, Timbawene moteado, UC-CB46, INIA 17G and INIA-35 as tolerant, whereas the other varieties susceptible to water stress.

References

EMEAU. 2009. Dados Meteorológicos da Estação Agrária de Umbelúzi. Maputo, Moçambique.

FAO.2008.Crop statistics. Diponível emhttp://faostat.fao.org/site/567/Desktopfault.asp?PageID#, acessado aos 03/08/2010.

Fisher, R. A. & Maurer, R. 1978. Drought resistence in spring Wheat cultivars. 29, 897-912. In Grain yield responses. *Aust. J. Agric. Res*.

Gomes-Filho, R. R. & Tahim, J. F. 2002. Respostas fisiológicas de cutivares de caupi (*Vigna unguiculata,*(L.) Walp) erectos e decumbentes à diferentes níveis de irrigação. *Engenharia na agricultura*, viçosa, 10, (1-4).

INE. 2008. Censo Agro-Pecuário. *Evolução da produção agrícola das culturas alimentares básicas*. Moçambique 6p. Disponível em www.ine.gov.mz/agricultura/feijaonhemba, acessado aos 26/07/10.

MAP. 1996. Ministério de Agricultura e Pesca de Moçambique. Processo de formulação do PROAGRI. Zonas agro-ecológicas e sistemas de produção**.** *Programa de investigação em extensão agrária, documento de trabalho* (2B). Primeira versão de Junho, Maputo.

Nogueira, R. J. M. C., Roselita, M. S. M, Tavora, F. J. A. F e Pitombeira, J. B. 2007. Relações fonte-dreno em feijão-de-corda submetido à deficiência hídrica. *Revista Ciência Agronómica*. 38 (1), 95-103.

Ojimelelukwe, P. C. 2002. Changes indicated by infestation of some chemical properties of cowpea seeds. *Plant Food for Human Nutrition*. 57, 219-224.

Rulkens, T.(1996); Feijões. FAEF, Universidade Eduardo Mondlane; Maputo-Moçambique.

Santos, M. C. C. A, Santos, J. F, Grangeiro, J. I. T & Brito, C. H. 2009. Produção e componentes produtivos de variedades de feijão nhemba. Cariri Paraibano. Brasil.

Singh, S.R. & Rachie, K. O. 1985. Cowpea research production, and utilization. John Wiley & Sons, New York. 460pp.

Straliotto, R. & Teixeira, M.G. 2000. A variabilidade genética do feijoeiro (*Phaseolus vulgaris* L.): aplicações nos estudos das interações simbióticas e patogênicas. Seropédica: *Embrapa Agrobiologia*. 59p.

TIA. 2008. Área cultivada com as principais culturas, pequenas e médias explorações por culturas, ano e província. MINAG/DE. 4p. Disponível em www.ine.gov.mz/agriculltura/feijaonhemba, acessado aos 03/08/2010.

1.1.8 EFFECT OF CULTIVARS IN NUTRITIONAL COMPOSITION OF ROOTS AND LEAVES OF ORANGE FLESH SWEET POTATO (*IPOMOEA BATATAS* LAM) PRODUCED AT UMBELUZI-BOANE

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Abstract

Sweet potato (*Ipomoea batatas*) has untapped potential as a nutritious food crop in many developing countries. To figure out the influence of crop variety on nutritional composition of leaves and tuber in orange flesh sweet potato, a field experiment was conducted at Umbeluzi Agrarian Station. A Randomized Complete Block Design (RCBD) with three replicates was, carried out, to test fifteen new varieties namely, Amelia, Bela, Cecilia, Delvia, Esther, Erica, Gloria, Ininda, Irene, Jane, Lourdes, Melinda, Namanga, and Sumaia e Tio Joe in two harvest dates, 40 and 80 days after sowing. The treatments were arranged in split plot design in a factor of 15*2. Dry matter, crude protein, potash, calcium, phosphorus and magnesium were determined in leaves, while dry matter, starch, reduced sugar, beta-carotene, protein, iron and zinc in tubers. The analysis of variance and comparison of means by Tukey test at 5% significance were performed using the statistical package *Stata*. The results showed that phosphorus content in leaves differ between varieties, while the dry matter, phosphorus and magnesium contents varies accordingly to the leaf harvest date, leaves harvested at 80 days after sowing had higher contents of this compounds. On the other side, tubers have shown different nutrition contents values between varieties in all compounds determined, only Erica, Esther and Tio Joe varieties had low levels in almost all of the compounds. Our results show that both factors variety and harvest time affects the nutrition value of the crop. These findings pave the way for improved dietary of many people mainly in rural areas.

Key Words: Sweet potato, varieties, nutritional composition, contents, harvest date.

Introduction

Sweet potatos (*Ipomoea batatas* (L) Lam) belongs to the family Convolvulaceae and is an important food crop in many semi-arid regions of the world, especially for the poorest people in many countries (An, 2005 & Barbosa, 2005). The crop is mainly produced in Asia with 90 % of world production, and Africa responds with 5 % and the remainder to other continents. With an annual production about 3685247 tons, China is the world's largest producer. In Africa, Mozambique occupies the eighth position with an estimated production of 893 619 tons per year (Faosat, 2013).

In Mozambique, sweet potato is the fourth most produced food crop after cassava, corn and cane sugar. Its importance goes beyond the scope merely food often serving as a source of income and employment. The majority varieties produced and consume by the poor and rural people are from white pulp, associated with low yields (2-5 tons per hectare), without any content of beta – carotene (the precursor of vitamin A), fact that can be related to the high levels of prevalence of vitamin A deficiency in children especially in rural areas (Low *et al*., 2000).

In order to change this scenario, the International Potato Center in partnership with the National Research Agrarian Institute launched 15 orange flesh varieties of sweet potato as a result of a breeding program. These varieties are dual purpose interest because they can be produced for the consumption of roots and leaves. Moreover, they have higher yields (about 30 tons per hectare) and, substantial amounts of beta- carotene, which makes them suitable for the combat against the deficiency of vitamin "A" affecting around 65 % of children especially in rural areas (Andrade *et al.*, 2010).

However, given the existence of few studies concerned with nutritional composition of the leaves and roots on sweet potato, combined with, the need to know the nutritional composition of roots and leaves of these recent released varieties, this study, aimed to determine the composition and nutritional value of these varieties, either in leaves and tubers. Thus, the results of this study will be important in assessing the potential use of this crop on the National nutritional programs.

Materials and methods

Description of the study area

The trial was conducted between December 2012 and April 2013, at Umbeluzi Agrarian station, located in the district of Boane 30 km from Maputo City, with the coordinates 26 03' South Latitude and 32 ° 23' longitude east. The area is characterized by having soils with high clay content, high water retention capacity, average annual rainfall of 679 mm, and irregular rainy season from November to March (Candua, 2003).

During the study, the maximum monthly temperature ranged between 28 and 33 ºC and minimum monthly temperature ranged between 17 and 22 ° C. The relative humidity ranged between 61 and 88%. During the test, the total rainfall was 495.3 mm, which in February was the wettest month and April the driest months. The total evapotranspiration was 579 mm, where the deficit was replenished by irrigation (EMEAU, 2013).

Experimental Design

The trial area had 702 m^2, consisting of three replication of 15 plots each. Each plot was comprised of three ridges separated by 0.75 meters. The ridges were raised of 0.3 -0.4 meters using a ridge. The vines (0.3 m of length) of the fifteen varieties used were obtained in the field of multiplication at International Potato Center located in the same site, Umbeluzi agrarian stations and each variety planted on a separate plot.

The sowing was done using one vine per hole. After plant establishment, protection schedule treatments against pest incidence were done preventively, from the second (2nd) week until harvesting. For this treatment, Cipermetrin Ripcod 20% EC was applied. The weed control was done manually where the incidence was observed. Watering was done by gravity, being applied once every 7 days. The other agronomic practices were done according to the norms of this culture technique.

To evaluate the effect of varieties and harvest dates on the nutritional composition of leaves and roots, a randomized complete block design with three replicates was carried out with (2 * 15) treatments arranged in split plot design, combining two harvest dates, 40 and 80 days after sowing and, 15 varieties, namely Amelia, Bela, Cecilia, Delvia, Erica, Esther, Gloria, Ininda, Irene, Jane, Lourdes, Melinda, Namanga, and Sumaia e Tio joe.

Sampling and evaluated parameters

The leaves samples were taken 40 and 80 days after sowing. Thirty leaves (two leaves per plant) in each plot were harvested, identified and taken to the laboratory for of soil and plants of Eduardo Mondlane University. With these samples the dry matter was determined by submitting for 72 hours at 65 degrees Celsius in oven dried. The samples of 100 mg each were also digested in sulfuric acid through Kjeldahl method to determine the total nitrogen according to the methodology proposed by Miyezewa *et al*. (2010). Then, the crude protein content was determined by multiplying the total nitrogen by 6.25. On the other hand, 500 mg of sample were digested in nitric and perchloric acid to determine the phosphorus (P) content through the colometry method, potassium (K) by photometry, calcium (Ca) and magnesium (Mg) by atomic absorption according to the methodology proposed by Miyezewa *et al*. (2010) and Malinga *et al*. (1989).

Roots samples were harvested 17 weeks after sowing. Three roots per plot were picked up totaling 45 samples. Samples were identified and taken to International Potato Center Laboratory for analysis. In the laboratory, the roots were washed, peeled and cut lengthwise. 50 gr was taken to the freezer dried for 72 hours to obtain the dry matter. Dried samples were milled, and then using the NIRS (Near Infrared Reflectance Spectroscopy) was determined on the basis of the dry weight starch, beta-carotene, reduced sugars (glucose + fructose + sucrose), proteins, zinc and iron.

Data analysis

To evaluate the effect of variety and plant age on the parameters determined in the leaves and roots, the data were submitted to analysis of variance (ANOVA) at 5% of significance, using the Statistical Package STATA. When the values were significant ($p < 0.05$), the means were compared using Tukey test in order to choose the best.

Results

Nutritional composition of Leaves

The analysis of variance showed that the varieties differ only in the content of phosphorus in the leaves, while the harvest date had a significant effect on dry matter phosphorus and magnesium (table 1). Only Jane, Irene and Sumaia with 0.2 % of dry matter, were the varieties that showed relatively low levels of phosphorus in the leaves. On the other hand, the leaves harvested at 80 days after sowing, showed higher levels of dry matter, phosphorus and magnesium.

Table 1. Analysis of variance of certain contents in the leaves

Factors	Dry matter	Protein	Phosphorus	Potassium	Magnesium	Calcium
Variety (var)	NS	NS	S	NS	NS	NS
Harvest date (Hd)	S	NS	S	NS	S	NS
Var*Hd	Ns	NS	NS	NS	NS	NS
CV(%)	3.44	4.06	5.77	5.23	6.43	5.17

Legend: NS: Not significant; S: significant at 5%

Table 2. Values of compounds determined in the leaves in the two harvest dates

Variety	Dry matter		Protein		Phosphorus		Potassium		Magnesium		Calcium	
	40	80	40	80	40	80	40	80	40	80	40	80
Amelia	19.8	17.5	20.6	21.5	0.3	0.3	0.2	0.2	0.6	0.6	1.7	0.9
Bela	15.5	21.4	25.6	18.1	0.3	0.4	0.2	0.4	0.4	0.5	1	1.2
Cecilia	14.7	19.7	25.2	12.7	0.2	0.4	0.2	0.2	0.4	1.1	1.2	1.2
Delvia	16.7	20.7	23.5	17.1	0.2	0.4	0.4	0.3	0.5	0.5	0.8	1.3
Esther	17.3	21.3	20.8	17.5	0.3	0.4	0.2	0.2	0.5	0.9	1.3	1.1
Erica	16.7	23.6	23.6	26.7	0.2	0.4	0.2	0.3	0.6	1	1	1.2
Gloria	17.3	20.9	22.9	16.9	0.3	0.4	0.3	0.2	0.4	0.7	0.8	0.9
Ininda	16.7	25.7	24.6	26.7	0.3	0.4	0.1	0.4	0.9	1.3	1.2	0.8
Irene	17.1	24.5	26.0	19.4	0.2	0.2	0.2	0.2	0.5	0.7	1.2	1.1
Jane	17.6	19.6	27.9	18.1	0.2	0.4	0.3	0.3	0.5	0.7	0.8	1.2
Lourdes	17.6	20.5	25.2	19.8	0.2	0.4	0.2	0.2	0.4	0.7	1	0.9
Melinda	18.0	18.6	21.4	15.2	0.3	0.4	0.1	0.2	0.4	0.8	0.9	0.7
Namanga	16.4	19.9	24.0	20.8	0.2	0.4	0.2	0.3	0.4	1	1.4	0.8
Sumaia	17.2	21.1	11.7	15.0	0.2	0.3	0.2	0.1	0.6	0.8	1.2	0.9
Tio Joe	16.9	19.3	19.2	21.0	0.2	0.4	0.2	0.3	0.4	0.8	1	1.1
Mean	**17b**	**21a**	**22.8**	**19.1**	**0.2b**	**0.4a**	**0.2**	**0.3**	**0.5b**	**0.8a**	**1.1**	**1.0**

Nutritional composition of Roots

Analysis of variance showed differences varieties root contents between in all compounds analyzed (table 3). Amelia, Bela, Cecilia, Delvia, Gloria, Ininda, Irene, Lourdes, Melinda, Namanga and Sumaia varieties had high dry matter and starch contents then Esther, Erica and Tio Joe varieties. In contrast, Esther, Erica, Tio Joe varieties had the highest levels of Beta - Carotene and Iron contents. The majority varieties had low levels of proteins, with the exception of Bela, Irene, Lourdes and Sumaia.

Table 3: effect of varieties on the parameters determined in the roots

Variety	Dry matter % fw	Bata-carotene % of dw	Starch	reducer sugar	protein	Zinc	Iron
Amelia	29.6a	11.5c	69.1a	15.8bc	3.83b	1.2bc	1.7b
Bela	28.2ab	17.1bc	61.6a	13.5bc	5.93a	1.4ab	2ab
Cecilia	27.9ab	28.1ab	61.5a	14.9bc	4.62b	1.3ab	1.9ab
Delvia	31a	0.7c	63.9a	11.5	4.96b	1.1bc	1.7b
Esther	24.7b	4.2bc	52.5b	24.6ab	4.1b	1.1bc	1.7b
Erica	22.9b	25.3ab	51.9b	26.9a	2.95b	0.9c	1.7b
Gloria	29.4a	32.2ab	60.8a	15.8bc	4.65b	1.2bc	1.9ab
Ininda	27.1a	8.4bc	62.6a	15.3bc	4.6b	1.2bc	1.8ab
Irene	28.3a	3.3c	56.8ab	15.9bc	7.9a	1.5bc	2.2a
Jane	27.1a	32ab	59.9a	17.5b	3.9b	1.2bc	1.8ab
Lourdes	28.4a	27ab	58.4a	17.5b	5.5ab	1.4ab	2.2a
Melinda	26.4ab	13.6bc	58.3a	18.3ab	4.5b	1.3ab	1.9ab
Namanga	27ab	30.6ab	57.7ab	19ab	5.17a	1.3ab	2±b
Sumaia	29.2a	19.5b	62.3a	13.9bc	5.2a	1.4ab	1.9ab
Tio Joe	25.1b	36.9a	57.8ab	18.7ab	4.1b	1.2ab	1.9ab
Mean	27.48	19.36	59.67	17.27	4.79	1.25	1.87
Effect	S	S	S	S	S	S	S
CV (%)	6.43	2.17	3.39	3.99	18.99	24	24.8

Means followed by the same lowercase letter in the column do not differ statistically according to Tukey test at 5% Significance, ** significant effect, CV: Coefficient of Variation

Discussion

Nutritional composition of leaves

Accordingly to the statistical analyses, differences were found within the levels of phosphorus in the leaves, with Jane, Esther and Sumaia varieties recorded the lowest levels of this nutrient (with 0.2% of dry matter). Many studies found the same, highlighting Elcher *et al*. (2009) and

Filho & Canto (1999) who claims that nutritional composition of the leaves varies not only among varieties but also with plant age.

On the other hand, the results suggest that any variety of this study is suitable for human consumption, due its nutritional contents which are relatively higher, with great levels of proteins (4.4 %). Compared with other vegetables such as cabbage, lettuce and carrots these varieties have much more content of protein.

Regarding to the harvest date, only contents of dry matter, phosphorus and magnesium varied during growth stage, showing an increasing trend with the crop age. Similar results were obtained by Solis *et al*. (1982), Elcher *et al*. (2009) and Monamodi *et al*. (2003), which observed an increasing trend for dry matter, phosphorus and magnesium, including other minerals such as calcium and potassium. Differently, calcium and potassium did not have the same tendency in this experiment. These differences may be explained due to the time lag and the number of harvesting, which may not have been sufficient to observe any variation.

Nutritional composition of roots

The analysis of variance showed that there are differences between varieties contents (P<0.05) in the roots compounds. These results were at certain point expected, because differences in nutritional composition are reflected in differences in the genetic makeup (woolfe, 1992 and Bradbury & Holloway, 1988). The content of dry matter in the roots of the varieties studied ranged from 22.9% to 31% of fresh weights. As many other roots and tubers crops, the sweet potato has a high moisture content resulting in relatively low dry matter content as we can figure out from the results mentioned above.

The average dry matter content is approximately 30% but varies widely depending on factors such as cultivar, location, climate, day length, soil pest diseases, and cultivation practices (Rose & Vasanthakaalam, 2011). In this study, the average dry matter was approximately 28 %, fairly below the average. This, it is partial explained due the high contents of beta - carotene which have a negative correlation with the dry matter contents (Heginamana, 2000). However, Amelia, Bela, Delvia, Gloria, Irene, Lourdes and Sumaia varieties have showed the ß-carotene levels were above the average.

The content of ß-carotene in the varieties analyzed in this study ranged from 0.7 to 36.9 % of dry matter. This variation well reflects that despite being all varieties of orange flesh, they exhibit differences in the intensity of color. The color is positively correlated to the content of ß-carotene (Hagenimana *et al*., 2000). As referenced above, varieties with high contents of dry matter have on the other side, the lowest levels of ß-carotene and vice versa.

Like other roots and tubers crops, sweet potato has high contents of carbohydrates, especially starch and reducing sugars. In this study, the contents of starch ranged from 51.9 to 69.1 % of dry matter while the content of reducing sugars ranged from 11.5 to 26 % of dry matter. The starch content is within the acceptable range for this crop around 50-80 % of dry matter according to Tumwegamire (2011), the same for reducing sugars value positioned greater than the range of 5 to 15 % found in the white-fleshed varieties (Tomllins, 2012) making orange-fleshed relatively more sweeter than white flesh varieties. However, Esther and Erica varieties shown lower starch content and higher levels of reducing sugars. These are explained due the negative correlation existing between these two compounds (Tomllins, 2012).

Unlike the leaves, the sweet potatoes roots have shown low levels of proteins and minerals contents, such as zinc and Iron, even though, the average content of protein was 4.7 % of dry

matter acceptable value within the range of 3-8 % of dry matter similar with the contents found by Ravindram *et al.* (1995) on orange flesh varieties produced in Asia.

Conclusion
The nutritional composition of orange flesh sweet potato leaves does not differ between varieties, therefore this increase throughout the growth cycle. The varieties showed great levels contents for leaves consumption as vegetables mainly when harvested after 80 days after sowing.
The roots nutritional value also differs between varieties. It has been found that varieties with high levels of ß-carotene and iron, showed low levels of dry matter, starch and reducing sugars. However, the varieties Bela, Cecilia, Gloria, Irene, Jane, Lourdes, Melinda, Namanga, Sumaia and Tio Joe, showed the highest levels in the majority of compounds determined.

Acknowledgement

References
Andrade, M., Naico, A., Ricardo, J., Álvaro, A., Moniz, S., Sitoe, A. 2010. Results of the evaluation of Multi-location trial of 64 clones selected from all advanced yield trial established 200/06 and 2009/10 in Umbeluzi, Chókwè, Guruè and Angónia. CIP. Maputo.

Barbosa, A. 2005. Rendimento de batata-doce com adubação orgânica. Universidade Federal de Paraíba. Dissertação de Mestrado. Paraiba.

Bradbury, J., Hollyway, W. 1988. Chemistry of tropical roots Crops: Significance for nutritional and Agriculture in the pacific. Australian center for International Agriculture Research. Cambera.

Candua, A. 2009. Maneio da Batata-doce para a producao de forragem e raizes de reserva. FAEF-UEM. Tese de Licenciatura. Maputo.

Echer, F., Dominato, J., Creste, J.2009. Absorção de nutrientes e distribuição da massa fresca e seca entre os órgãos da Batata-doce. Horticultura brasileira volume 14, nr 27 pag 176-182. Paraiba.

EMEAU. 2013. Dados Meteorológicos da Estacão Agraria de Umbeluzi. Maputo-Mocambique.

Faostat (Fao statistic). 2013. available in: www.faostat.org. Accessed at February 21, 2014. Filho, A e Canto, M. 1999. Qualidade nutricional de plantas forrageiras. Diamantina.

Hagenimana, V., Carey, E., Gichul, S., Oyunga, M., Imunga, J. 2000. Carotenoid Contents in fresh, dried and processed sweet potatos products. International Potato center. Nairobi.

Low, L., Uaene, R., Andrade, M., Howard, J. 2000. Batata-doce de polpa alaranjada-parcerias prometedoras para assegurar a integração de aspectos nutricionais na Investigação e Extensão agrícola. MADER. Maputo.

Malinga, L., Van vark, W., Houba, V., Van der Lee, J. 1989. Plant Analysis Procedures: Soil and plant analysis, part 7. Wageningen Agriculture University. Syllabus.

Miyezewa, M., Pavan, M., Muraoka, T., Carmo, L., Melo, W. 2009. Manual de Analises químicas de solos, plantas e fertilizantes: Analise Quimica te tecido vegetal. Embrapa. 2nd Edicao. Brasilia.

Monamodi, E., Bok, I., Karikari, S. 2003. Changes in nutritional composition and yield od two sweet potatos cultivars during their growth in Botswana. Journal of agriculture. Volume 11, nr 21. Pag 5-14. Gaberone.

Ravindran, V., Ravindran, G., Silvakenesam, R., Rajaguru, S. 1995. Bopchemical and Nutritional assessment of tuber from 16 cutlivars of sweet potato. Journal of Agriculture food chemistry vol 15, nr 43, pag 2646-2651. Sri-lanka.

Rose, I., Vasanthakaalam, H. 2011. Comparison of the composition of four sweet potato varieties cultivated in Rwanda. American Journal of food and Nutritional, vol 1, ISSN 2157-1317, pag 34-38. Kigali.

Solis, F., Haag, H., Minami, K., Diehl, W. 1982. Nutricao mineral de hortalicas: Acumulacao de nutrientes na cultura do pepino em condições de campo. Anais da Escola Superior de Agricultura Luiz de Queiroz. São Paulo.

Tomllins, K., Owori, C., Bechoff, A., Menya, G., Westby, A. 2012. Relashionship between the carotenoid content, dry matter content and sensory attributes of sweet potato. Greenwich Academic literature Archive. London

Tumwegemire, S., Kapinga, R., Rubaihayo, P., Labonte, D., Gruneberg, D., Mwanga, M. 2011. Genetic variation Diversity and genotype by environment Interactions of Nutritional quality traits in East Africa Sweet potato. American Society for Horticulture Science volume 46. Kampala.

Woolfe, J. 1992. Sweet potato: Untapped food resource. Cambrige University Press. 1st edition. New York.

1.1.9 PERFORMANCE OF LOW PHOSPHORUS TOLERANT BEAN GENOTYPES ON ACIDIC SOILS OF RWANDA

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Abstract

Bean (*Phaseolus vulgaris L.*) production is highly limited by soil fertility decline, particularly phosphorus (P); yet the typical small-scale farmers are incapable of obtaining inputs. Promotion of use of low phosphorus tolerant bean genotypes is a pro poor strategy among small holder farmers who are the major producer of beans in Rwanda. Moreover, the performance of beans under the widespread soil related stresses like acidic soils is not clear. Thus, pot experiments were established in greenhouses in Rubona, Rwanda. Each pot was filled with 5 kg of highly acidic and P deficient soil collected from Nyamagabe district. The objective of the experiment was to identify superior yielding and nodulating bean genotypes suitable for such acidic soil and their response to P application. Four low P tolerant genotypes used (G2858, RWR 1873, RWV 1668; and RWV 1348) and 59/1-2 were subjected to three rates of P (0, 5, 10 mg kg^{-1}) and treatments were raid in completely randomized design with 6 replications. RWV 1348 had the highest grain yield (6.4 g pot^{-1}) and the application of P at 5 mg kg^{-1} soil increased its yield 4 times. RWR 1873 and RWV 1668 yield was 2.4 and 2.5 g pot^{-1} respectively and P rate of 5 mg kg^{-1} increased their yield 8 times. Nodulation efficiency was 73% for RWR 1873, 54% for RWV 1348 and 50% for RWV 1668. Application of P did not influence nodulation of the genotypes

except for RWR 1873 where nodulation was suppressed about 26%. The low P tolerant bean genotypes perform well under the high soil acidity such of Rwanda; but their performance improved markedly when local lime and P was applied.

Introduction

Bean is a significant household food and source of cash income eastern Africa. For instance, in Rwanda, average bean consumption ranges between 50 to 60 kg per person per year (Buruchara *et al.,* 2011), and provided about 38% of protein intake in the country in 2000. However, bean yield has declined drastically over the past 10 years to about 678 kg ha^{-1} in Rwanda. This is far inferior to the potential yield that is estimated at 2.5 t ha^{-1} for bush bean (Mutijima, 2004) and 4 t ha^{-1} for climbing beans (Lunze *et al.*, 2011). Low soil fertility is estimated to be responsible for over 1.12 million tons of unrealized bean yield every year in SSA. The most limiting nutrient is P in most soils (Yamoah *et al*., 2003; Nabahungu *et al*., 2007; Karen, 2009; Gunasekhar *et al*., 2009). Bean is mainly produced by small-scale farmers, with little capacity to apply inorganic fertilizers to replenish their soils (Mukuralinda *et al*., 2010; Lunze *et al*., 2011). To increase bean production, farmers adapted a strategy of recycling organic material as source of P. Unfortunately, the quantity of available P through this means is usually not sufficient to guarantee increases in bean production (Mukuralinda *et al*., 2010; Lunze *et al*., 2011). Low bean production is believed to have cascaded into poor nutrition among communities in Rwanda. Fortunately, there are bean genotypes that are capable of acquiring P from otherwise typically P deficient levels, and with capacity to yield reasonably. Moreover, the performance of beans under the widespread soil related stresses like acidic soils is not clear under the overly acid soils such as those of Rwanda. The main objective of this research was to increase bean productivity on the extensively acidic and phosphorous deficient soils such of Rwanda in determining low phosphorus tolerant bean genotypes with superior grain yield and high nodulation efficiency; and evaluating their response to different P levels.

Materials and methods

Nature of experiment

A greenhouse experiment was conducted at RAB Rubona research site in Rwanda during November 2011 to July 2012. A pot experiment was established using soil collected from Ruhunga cell of Kibirizi sector of Nyamagabe district. The soil used is a member of MUNINI series (Appendix i and ii) with contents as shown in Table 1 and characterized as 'Clayey-skeletal, kaolinitic, isothermic Ultic Tropudalfs' family (Birasa *et al*., 1990).

Table 1. *Pre-experiment soil characteristics*

Parameter	Value
pH H_2O	3.82
OM (%)	0.95
Total N (%)	0.63
Bray I P (mg kg^{-1})	1.6
CEC (cmol kg^{-1})	9.23
Exch. Al^{3+}(cmol kg^{-1})	6.25
Textural class	Clay loamy
Bulk density (g/cm^3)	1.28
[†]WFC (%)	20.47

[†] Water at Field Capacity

Characteristic of experimental bean genotypes

Four low P tolerant beans and one local check were used in the first part of experiment to evaluate their performance on acidic soils. Bean genotypes with a documented history of tolerance to low soil fertility were used in this study. Specifically, the following genotypes were involved in the study: RWR 1873, RWV 1343, and RWV 1668 and 59/1-2 (Table2).

Table 2*: Low P tolerant bean genotypes and a local check used in the study*

Line code	Seed Size	Seed colour	Growth type	Source
RWR 1873	Medium	Carima	Bush	Kawanda-Uganda
RWV 1668	Large	Dark	Bush	Rubona –Rwanda
[†]59/1-2	Small	Red	Climbing	Rubona –Rwanda
G 2858	Small	Tan	Climbing	Kawanda-Uganda
RWV 1348	Small	Red	Climbing	Rubona –Rwanda

Source: Lunze *et al*. (2011); [†]Local check.

Soil sampling

Soil samples for site characterization were collected randomly from 0 to 20 cm depth, using a soil auger. The sub-samples were collected from a field which had been subjected to cultivation, but without known history of fertilizer use for a period of one year.

The sub-samples were bulked into a plastic basin for quarter sampling, after. Approximately 500 g of the thoroughly mixed composite sample was taken into a polythene bag and labeled. Three such composite samples were taken from the same site. Concurrently, six soil samples for bulk density determination were collected using a core sampler. Other soils samples were collected in each pot after harvesting. The samples of each treatment were mixed to make a composite sample and labeled for analysis.

Treatments and experimental design

The experiment was divided into two parts and the first one was screening high yielding bean genotypes under highly acidic soils. The genotypes used in screening included GR2858, RWR 1873, RWV1343, RWV 1668, and 59/1-2 (Garukurare) as a local check. Five treatments (genotypes) were replicated seven times and experimental units was laid out into completely randomized design (CRD).

For the second part of the experiment, three low P high performing bean genotypes were selected from seven genotypes that had been previously screened for performance on the basis of their yield and efficient nodulation. These materials selected as outstanding included RWR1873, RWV1668 and RWV 1348. They were subjected to the evaluation for performance under different P levels. The levels of P used were 0, 5 and 10 mg kg^{-1} soil in the pots; which were equivalent to 0, 10 and 20 kg P ha^{-1}. The experiment was factorial and was laid out in a completely randomized design, with six replicates.

In both experiments, 5 kg of soil were filled in pots of 6 litre-capacities; after perforating the pots in the sides and bottoms to help in aeration and drainage of excess water. Drained water and dissolved nutrients were retained by bucket covers which were put under pots and returned in the bucket. At planting, in each soil-filled pot, six seeds were planted at a depth of 5 cm. The inter pots line and intra pots space was 50 cm in order to minimize sunlight competition.

Fertilizer application

Triple superphosphate (TSP) was used as source of P and all dosages were spot applied. The application rate of TSP was determined using a conversion factor of 0.44 of P in P_2O_5 (Frederick and Tomson, 2005). Lime, rhizobium (CIAT 889) and muriate of potash were blanket applied to all treatments.

Muriate of potash (MOP) was used as a source of potassium and applied at planting at the rate of 5 mg kg^{-1} soil. The conversion factor used for MOP was 0.22; the equivalent of K in K_2O. Travertine ($CaCO_3$) applied two weeks before planting at the rate of 31 g per pot. Lime requirement was calculated following Kamprhat (1970) method, modified by Bray (2002).

Experimental management

Planting was done using six bean seeds per pot and subsequently thinned to three seedlings after two weeks. Weeding was by hand whenever weeds appeared in the pots. Watering was done up to field capacity which was approximately 1.5 L in 5 kg of soil. For climbers (RWV 1348, GR2848 and 59/1), one bamboo stake per seedling (3 stakes per pot) was plugged into each pot at about three weeks after emergence. Pots were spaced at about 50 cm between pots to minimize inter-plant competition for solar radiation.

Data collection

Nodulation efficiency was computed by first determining the number of effective nodules per plant, on the basis of nodule's possession of pink cross-sectional pigment (Corbin et al., 1977). This was done by viewing cross sections of all nodules per plant.

$$\text{Nodulation efficiency} = \frac{\text{Effective nodules}}{\text{Total No. of nodules}} \text{ X } 100 \qquad \text{(Eq. 1)}$$

Grain yield was assessed by harvesting pods from the two remaining plants per port at about two weeks after physiological maturity of each genotype.

Laboratory analysis

The soil samples collected as described in subsection 3.3 of this study, were used for analysis of pH (H_2O), organic matter (OM), total Nitrogen, Bray I P, cation exchange capacity (CEC), exchangeable aluminum, textural classes, bulk density and water at field capacity (WFC). The procedures used for soil analysis are described as follows: Soil pH was determined using a pH meter in 1:2.5 soils: water (Page *et al*., 1982). Organic carbon was determined by the Walkey and Black method (Page *et al*., 1982). Total N was determined using semi-micro Kjeldahl procedure (Page *et al*., 1982). Available P was extracted by Bray-1 method (Page *et al*., 1982). Cation exchangeable capacity was determined by the ammonium acetate saturation method (Rhoades, 1982). Exchangeable Al^{3+} and H^+ were determined by atomic absorption. Particle size analysis was done by the hydrometer method (Gee and Bauder, 1986), and textural classes were determined using the USDA textural class triangle determined calorimetrically using the ascorbic acid method (IITA, 1979).

Plant materials for shoot dry weight were used for tissue P determination. The procedure used was that described by Moberg (2000). The content of P in the digest was determined using the ascorbic acid-molybdate blue method.

Statistical analysis

The data obtained from the soil and crop samples, were statistically analyzed using ANOVA function of COSTAT - Cohort software of 2005 - 6 .111 version (USA). Means were separated using the Least Significant Difference (LSD) at a probability level of 5%, the correlation coefficient was also used where necessary.

Results

Performance of low P tolerant bean genotypes on highly acidic and P deficient soils

Results of the first part of experiment, which evaluated the performance of some of the available low P tolerant bean genotypes at the International Center for Tropical Agriculture (CIAT) research centers on the highly acidic and phosphorus deficient soils in Rwanda, are presented in Tables(3 and 4) and Figures (1 and 2).

Soil available P and pH in experimental units under highly acidic conditions

At flowering, soil pH ranged between 5.5 and 3.4 (Table 3). The soils in   pots grown with RWV 1348 and 1873   had the highest soil pH. The lowest value was observed in treatment with genotype 59/1-2. Soil available P ranged between 4.5 and 1.2 mg kg^{-1} soil (Table 3); with the highest value observed in treatment with genotype RWV 1348, and the lowest in treatment of 59/1-2.

Table 3: *Soil pH and available P under different treatments of grown with low P tolerant bean genotypes*

Genotypes	pH (H_2O)	available P (mg kg^{-1})
RWV 1668	4.8	3.42
RWR1873	4.7	2.24
RWV 1348	5.5	6.22
GR 2848	4.8	3.34
[†]59/1-2	3.4	1.27

[†] Local check

Nodulation efficiency

The effect of genotypes on total number of nodules and effective nodules was highly significant ($p < 0.01$) (Figure 1). The variation in effective nodules of low P tolerant bean genotypes was 73-29 %. Genotype RWV 1873 again had the highest proportion of effective nodules (EN) of 73% and a local check 59/1-2 had the lowest (29%) (Figure 1).
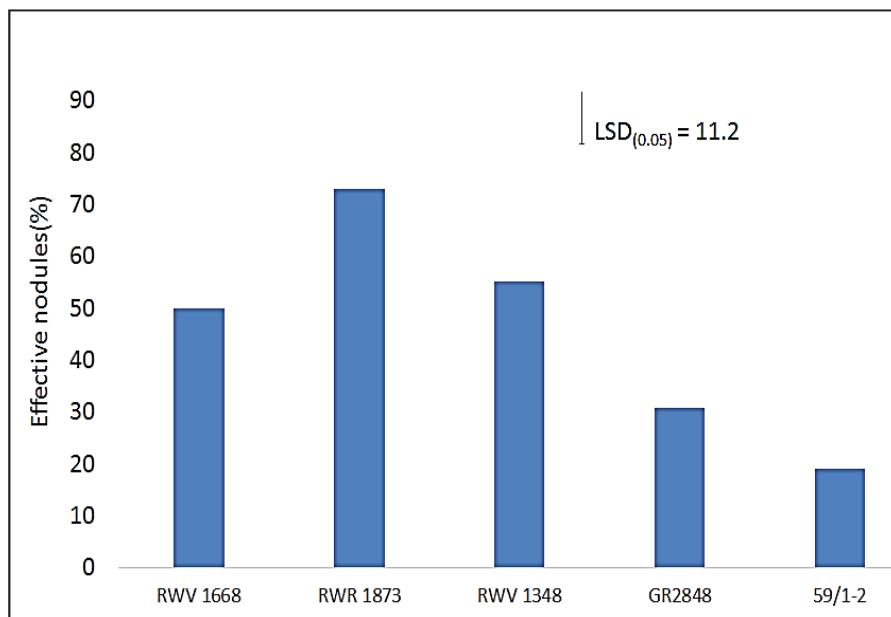
Figure 1: Percentage of effective nodules of low P tolerant bean genotypes on highly acidic soils of Rwanda

Grain yield under acidic soils

Grain yield was significantly different among the genotypes (p<0.05) (Table 1). Grain yield varied between 6.4 to 2.4 g pot^{-1}; with genotype RWV1348 bearing the highest grain yield among the climbers. Both genotypes RWR 1873 and RWV 1668 had statistically similar grain yields.

Table 4*: Grain yield low P tolerant bean genotypes on the acidic soils of Rwanda*

Genotype	Grain yield (g pot^{-1})
RWV 1668	2.5
RWR1873	2.4
RWV 1348	6.48
GR 2848	3.7
59/1-2	3.2
LSD(0.05)	0.9
P < 0.01	***

Performance of low P tolerant bean genotypes at different P levels

Results of the second part of experiment, that evaluated the performance of selected best low P tolerant bean genotypes among available genotypes at different levels of P. Selected genotypes from first part of experiment were RWV 1348, RWV1668, and RWR 1873 and subjected at three levels of P (0, 5, and 10 mg kg^{-1}soil).

Effect of P levels on efficient nodulation

Phosphorus levels significantly affected effective nodulation of the low P tolerant bean genotypes (p >0.05) (Figure 3 and Appendix 1). All genotypes had the higher effective nodulation at P level of 0 mg kg $^{-1}$ of soil and addition of P decreased considerably the efficiency nodulation of RWR 1873 at all levels (Figure 3).
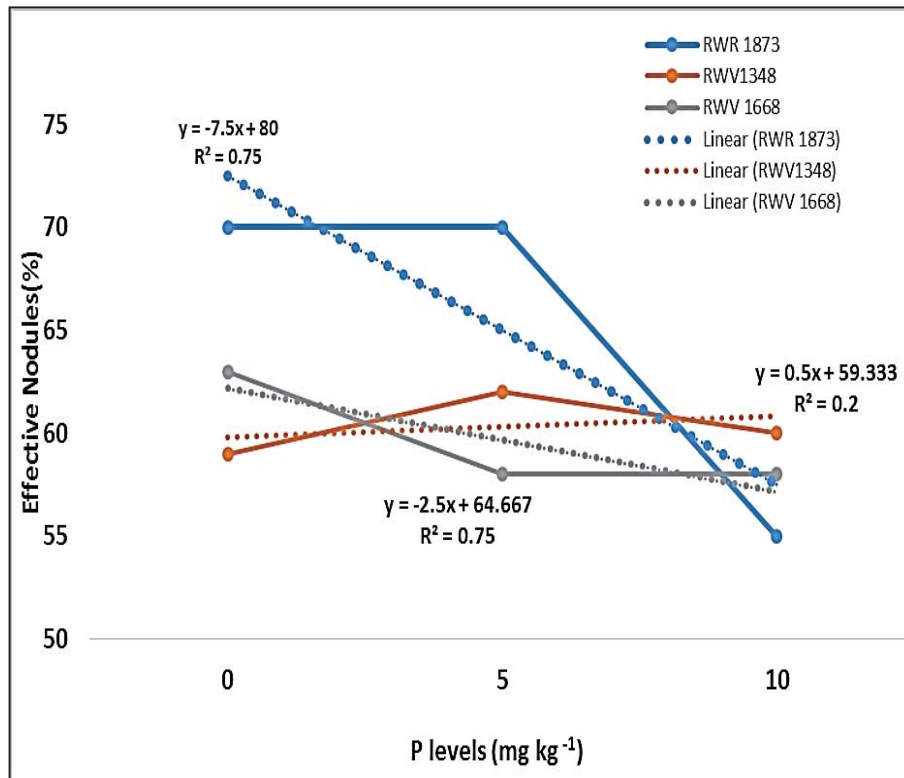
Figure 2: Percentage of effective nodules of low P tolerant bean genotypes at different levels of P

Effect of P levels on grain yield of outstanding low P tolerant bean genotypes

Single factor effect of the bean genotypes and P levels had strong effects on shoot biomass and grain yield (Table 5). However, their interactions were not significant. Grain yields were highest at P level of 5 mg kg^{-1} soil, and decreased at P level of 5 mg kg^{-1} soil. The highest yield reduction of 37% was observed on RWV 1668 genotype. An addition of P to more than 5 mg kg $^{-1}$ soil declined grain yield for all genotypes.

Table 5: Effect of P levels on low P tolerant bean genotypes shoot and grain yield on an highly acid soil of Rwanda

Genotypes	P levels (mg kg^{-1})			
	0	+5	+10	LSD$_{(0.05)}$
	Grain yield (g pot^{-1})			
RWR 1873	14.5	17.5	12.0	**4.4**
RWV 1668	19.5	12.3	14.7	**3.7**
RWV1348	22.9	26.5	22.4	**3.0**
LSD $_{(0.05)}$	**3.6**	1.6	3.9	
Genotype effect	.00***			
P level effect	.00***			
GXP	Ns			

DISCUSSION

Nodulation efficiency

Genotypes RWR 1873, RWV 1348, and RWV 1668 had higher nodulation efficiency under highly acidic and low P conditions than others genotypes (Figure 1). These materials with high number of effective nodules under P deficient conditions were classified as outstanding low P tolerant bean genotypes. This superior efficient nodulation under highly acidic conditions could be due to their ability to secrete organic substances that are released in rhizosphere and solubilize phosphorus, which is very important in biological N fixation. The increase in organic substances of these high nodulating genotypes could have been evidenced by the change of soil pH (Table 3). Thus solubilized phosphorus was useful for N- fixer microorganisms and efficient nodules. It is possible that these low P tolerant bean genotypes, which are high yielding, are also tolerant to low N when compared to others. For instance RWR1873 cultivated in Uganda and Mozambique has shown the outstanding tolerance to low P and low N (Lunze *et al*., 2011). Low P tolerant bean genotypes have improved nodulation efficient under low P conditions, compared to others. The results were in line with Adams and Pate (2002)**,** Ahmad (2011) and Kajumula and Muhamba (2012) findings, which showed that under low P conditions genotypes that are low P tolerant greatly, conserve efficient nodules. Phosphorus is not only essential for plant growth; but its availability has also been noted to affect the functioning of biological nitrogen fixation, by improving nodule number and size (Mahmoud *et al.,* 2008; Adnane *et al*., 2012; Kimani et al.,2012).

On the other hand, application of P has suppressed the nodulation of low P tolerant bean genotypes especially genotype RWR 1873 (Figure 2). This may be due to the antagonism mechanisms for Zn uptake when high amount of P is applied in nodulation legumes. Research conducted by Adelson et al. (1999), Tsvetkova and Georgiev (2003) showed that moderate application of P fertilizer increases efficient nodules by 46%. The results were the same as

results of Brad and Dale (2000), Birhan (2006) and Mahmoud *et al*. (2008) which showed that high P levels affected nodulation especially due to P - Zinc antagonism. More research on efficient nodulation of low P tolerant bean genotypes is required to understand their response to P application.

Grain yield

Among the bean genotypes used in this study, RWV1348, a climber bean genotype, had the highest grain yield. On the other hands two bush beans: RWR 1873 and RWV 1668 had statistically similar yields (Table 4).The significant difference between all low P tolerant bean genotypes for grain yield   means that acquisition and conservation of P from soil by the genotypes under P deficient conditions was different. The genotypes with high grain yield and high grain harvest index at low P treatment imply that they possess enhanced mechanism to acquire phosphorus in P-limiting environments and that they can utilize absorbed P more efficiently to produce relatively large yield (Table 4). The genotypes which had higher grain yield were efficient P utilizers under low P conditions.

White and Wilson (2006), Jonathan and Peter (2011), Kajumula and Muhamba (2012) showed that increased yields in beans are largely attributable to improved partitioning of biomass to the grain. The genotype RWR 1873 was screened for low P tolerance in acidic soil of Madagascar, Uganda and Kenya, and results showed that it was a bush bean with outstanding tolerance, high grain yield and multiple tolerances (Lunze *et al*., 2011). The adaptive research conducted by Baijukya and Vanlauwe (2011) showed that genotype RWV1348 was among 5 outstanding bean climber in Rwanda.

The genotype RWV1348 had the highest grain yield compared to RWR 1873 and RWV 1668, bush bean genotypes at the P level of 5 mg kg^{-1} soil (Table 5). Yet, this rate is still too low to achieve optimum bean yields (Jiambo *et al*., 2011).

The blanket application of lime increased considerably the available P (Table 3) and minimized additional inorganic P source. Lime increased yield of RWR 1783 and RWV 1668 seven times and 9 times respectively. Lime application increased grain yield of RWV 1348 five times. The combined application of lime and low input of inorganic P sources resulted in increased yield of these materials above sole applications of lime.

According to Delbert *et al*. (1993) and Georgia *et al*. (2007), increased soil pH by liming enhances Pi solubilization, making P more available to plants. Research conducted by Fageria *et al*.(2008) on beans cultivated on oxisoil showed that, with P content of 1.9 mg kg $^{-1}$, the application of 12 t lime ha^{-1} increased bean yield about 40% compared with non-amended or control treatment. Gifole *et al.* (2011) showed that the P level of 10 kg ha $^{-1}$ had significantly improved grain yield and biomass. On the other hand, results of Opala *et al*. (2012) showed that combined application of lime and low input of inorganic P sources generally resulted in increases in Olsen P above sole applications of lime or inorganic P sources. In this study, the addition of greater than 5 mg kg^{-1} soil caused a decline in grain yield (Table 5). Yield reduction at P level of 10 mg kg $^{-1}$ could have been due to excessive available P to the crops that led to the excessive

vegetative growth and delayed maturity. On the other hand, the high amount of P might have caused antagonism in Zn uptake which affected yield and efficient nodulation (Brad and Dale, 2000).

The results were in line with research results of Gifole *et al.* (2011) on beans, which showed that P levels (20 and 30 kg ha^{-1}) slightly increased the days to physiological maturity, compared to the control, and a pronounced delayed maturity at above 40 kg P ha^{-1}. They concluded that the reduction was due to increasing P supply. Brady and Weil (2002) and Marschner (2002) also showed that application of P in excessive amount influence excessive vegetative growth and delays maturity, thus reduce grain yield.

Conclusion and recommendations

Conclusion

Performance under highly acidic conditions
The genotype RWV 1348 is the best performing under low P conditions of highly acidic and low P deficient soils such of Rwanda. The bush genotypes (RWR 1873 and RWV 1668) have shown the same performance under acidic and p deficient conditions. They are outstanding low P tolerant bean genotypes because of their improved yield and efficient nodulation in acidic and P deficient soils. Yield is the best indicator for performance for economic aspect and nodulation is very important in integrated soil fertility management (ISFM) where nodules stored Nitrogen (N) should be used by a cereal under rotation. Without the performance in these two aspects, they should also be eliminated as less performing. The two genotypes RWR 1873 and RWV 1668 also perform better than other bush genotypes grown in acidic conditions which yield less than 700 hg ha^{-1} have under highly acidic conditions. They should be grown by farmers who are still growing bush bean genotypes.

Performance at different levels of P
The high grain yielding low P tolerant bean genotypes have shown different responses at different levels of P, and they are efficient and responsive at moderate P level or 5 mg kg^{-1} soil. Thus, the high performance was applied at moderate P level of 5 mg kg^{-1} soil when local lime is applied. The RWV 1348 is highly efficient and responsive compared to RWR 1873 and RWV 1668. The genotype RWV 1668 is higher responsive than RWV 1873. The combined application of lime and low input of inorganic P sources results in highest yield of low P tolerant bean genotypes in highly acidic soils.

Recommendations
The findings of this study suggest the following: more genotypes should be tested for low P tolerance under field conditions and avail them to farmers. A separate and deep BNF study of these materials should be conducted for integrated soil fertility management purpose. Separate research on low P tolerant bean genotypes response to different local agricultural lime should be

conducted to evaluate compared responsive to inputs that may promote the use of locally available lime with minimum inputs.

References

Adams, M.A. & Pate, J.S. (2002). Phosphorus sources and availability modify growth and distribution of root clusters and nodules of native Australian legumes. *Plant, Cell and Environment* 26: 837–850.

Adelson, P.A., Marcelo, G.T. & Dejair, L.D. A. (1999).Growth and yield of common bean cultivars at two soil phosphorus levels under biological nitrogen fixation. Ph.D. Thesis. Brazil.

Adnane, B., Mustapha, F. & Neila, A. (2012). Low soil phosphorus availability increases acid phosphatases activities and affects P partitioning in nodules, seeds and rhizosphere of beans (*Phaseolus vulgaris). Agriculture Journal*. Retrieved January 17, 2013 from www.mdpi.com/journal/agriculture.

Ahmad,R.G. (2011). Genetic Diversity Assessment for Improvement of Nitrogen Fixation ability and seed production in Iranian Common Bean Genotypes (*Phaseolus vulgaris* L.). . Soil sci. 22(3): 289 – 301

Ann, V. & Eric, V.R. (2006). The soil information system of Rwanda: a useful tool to identify guidelines towards sustainable land management. *Soil Survey*. Ministry of Agriculture, Kigali, Rwanda.

Baijukya, F. & Vanlauwe, B. (2011).Adaptive research in N$_2$Africa impact zones**:** Principles, guidelines and implemented research. *N2Africa* Country Report. *Rwanda.*

Birasa, E.C., Bizimana, I., Boucaert, W., Deflandre, A., Chapelle, J., Gallez, A., Maesschalck, G. & Vercruysse, J. (1990). *Carte Pédologique du Rwanda*. Ministry of Agriculture, Kigali. Rwanda.

Birhan, A. (2006). Response of haricot bean (Phaseolus *vulgaris L.*) to nitrogen, phosphorus and inoculation of Rhizobium *Leguminosarum* on yield and yield components at Melkassa. *MSc. Thesis*. University of Hawassa. Awassa College of Agriculture. Ethiopia.

Brad, B. & Dale, W. (2000). Soil Fertility and Bean Production. Review Article. Agriculture Extension. Washington State University. USA.

Buruchara, R. C, Sperling, L., Mukankusi, C., Rubyogo ,J.C., Muthoni , R., & Abang, M.M.,(2011): Development and delivery of bean genotypes in Africa: The Pan- Africa Bean Research Alliance (PABRA) Model. *African Crop Science Journal*, 19(4) : 227-245

Corbin, E.J. Brockwell, J., People, D.R., & Gault, R.R. 1977. Nodulation studies on chickpea (Cicer arietinum). *Australian Journal of Experimental Agriculture and Animal Husbandry*, 17: 126-134.

Delbert, D., Hemphill, J.R. & Jackson, T.L. (1993). Lime fertilizer interactions affecting vegetable crop production. *Annual fertilizer conference report No.34*. Portland –Oregon, USA.

Fageria, N.K., Baligar, V.C. & Li, Y.C. (2008) [b]. The role of nutrient efficient plants in 520 improving crop yields in the twenty first century. *Journal of Plant Nutrition*31: 1121-1157.

Frederick, R. T. & Thompson, L. (2005). Soil and Soil Fertility (6th Eds.). John Wiley & Sons, Inc., Hoboken, N.J.USA.

Jiambo, S., Lixing, Y., Junling, Z. & Haigang, L. (2011). Phosphorus Dynamics: From Soil to Plant. *Plant Physiology*156: 997–1005. Retrieved August 13, 2012 from www.plantphysiol.org.

IITA. (1979). International Institute of Tropical Agriculture. Selected methods for soil and plant analysis. Oyo Road, PMB 5320, Ibadan, Nigeria.

Gee, G.W. & Bauder, K. (1986). Particle size analysis, In: Klute, A (2^{end} Eds.) Methods of soil analysis part 1. *Soil Science Society of America* 9: 383–412.

Georgia, H., Mario, R. & Oswaldo, V. (2007). Phosphorus stress in common bean: Root transcript and metabolic responses on phosphate. *Plant Physiology Article*. *American Society of Plant Biologist*s144: 752–767. Retrieved February 2, 2013 from www.plantphysiol.org

Gifole, G., Sheleme, B. &Walelign, W. (2011).The Response of Haricot Bean (*Phaseolus vulgaris L.*) to phosphorus application on ultisols at Areka, Southern Ethiopia. *Journal of Biology*, *Agriculture and Healthcare* 1(3). Retrieved July 4, 2012 from www.iiste.org.

Gunasekhar, N., Peter, L., Chris, G. & Paul, K. (2009). Phosphorus uptake in faba bean, field pea, and corn cultivars from different sources: Preliminary studies of two options for organic farmers. *Crop and Pasture Science* 60 (2) 183–189.

Kajumula, S.M. & Muhamba, G.T. (2012). Evaluation of common bean (*Phaseolus vulgaris L.*) genotypes for adaptation to low phosphorus. *Agronomy Research Article*. International Scholarly Research Network. 309614: 9.

Kamprath, E.J. (1970). Exchangeable aluminum as a criterion for liming leached mineral soils. Soil Science of American Proceedings 24: 252–254.

Karen, A.C., Matthew, W.B., Carlos, H.G., Sieglinde, S.S. & James, D.K. (2009). Analysis of root architecture traits and low phosphorus tolerance in an Andean bean population. Crop Science 49(1):59-68.

Lunze, L., Kimani, P.M., Ndakidemi, P., Rabary, B., Rachier, G.O., Ugen, M.M. & Nabahungu, N. L. (2011). Selection of bean lines tolerant to low soil fertility conditions in Africa. *Journal* of Alternative Agriculture 16:161-167. Retrieved February 4, 2013 from www.intechopen.com.

Mahmoud, J., Abayomi, Y.A. & Aduloju, M.O. (2008). Comparative growth and grain yield response of soybean genotype to phosphorus application. *African Journal of biotechnology* 8(6): 1030-1038.

Marschner, H. (2002). *Mineral Nutrition of Higher Plants*. Second edition, Academic Press, Amsterdam.

Moberg, J.R. (2000). Soil and plant analysis manual. The Royal Veterinary and Agriculture University, Chemistry Department, Copenghagen, Denmark. 133.

Mukuralinda, A., Tenywa, J.S., Verchot, L.J.O., Nabahungu, N.L. & Chianu, J.N. (2010). Phosphorus uptake and maize response to organic and inorganic fertilizer inputs in Rubona, Southern Province of Rwanda. *Journal of agroforestry system*. Springer. Science+Business Media B.VDOI 10.1007/S10457-010-9324-9.

Mutijima, A. (2004). *Plan stratégique de transformation de l'agriculture au Rwanda. Analyse thématique des productions végétales*. Ministry of Agriculture, Kigali, Rwanda.

Nabahungu, N.L., Semoka, J.M. & Zaongo, C. (2007). Limestone, minjingu phosphate rock and Kihara, J. & Kimetu, J. (Eds.). Advances in Integrated Soil Fertility in Sub-Saharan Africa: Challenges and Opportunities. Springer, Dordrecht, pp. 691–703. ISBN 13978-1-4020-5759-5 (HB).

Kimani, P.M., Gicharu, G.K., Mburugu, N., Boga, H. & Cheruiyot, R. (2012). Nodulation and yield of bush and climbing beans inoculated with rhizobia strains. *Bean Improvement Cooperative*. Annual Report. Volume 50 pp.198.USA

Opala, P.A., Okalebo, J.R. & Othieno, C.O. (2012). Effects of organic and inorganic materials on soil acidity and phosphorus availability in a soil incubation study. *Journal of Agricultural and Food Research* 148: 38–101.

Page, J.R., Miller, R.H., Keeney, D.R., Baker, D.E., Roscoe, E.J. & Rhoades, J.D. (1982). *Methods of Soil Analysis*. II. Chemical and microbiology properties (2nd Eds.). American Society of Agronomy, Madison, WI, USA.1159.

Rhoades, J.D (1982). Cation exchange capacity. In: Page AL, Miller RH, Keeney PR (eds) Methods of Soil Analysis Part 2. Chemistry and mineralogical properties, agronomy mono- graph No. 9. American Society of Agronomy, Madison, WI, pp 149–169

Tsvetkova G E , Georgiev GI. (2003). Effect of phosphorus nutrition on the nodulation, nitrogen fixation and nutrient -use efficiency of Bradyrhizobium Japonicum – soybean (*glycine max* l. *merr*.) symbiosis. Plant Physiology. Bulgalia. SPECIAL ISSUE 2003, 331–335

Yamoah, C.F., Burleigh, J.R. & Malcolm, A. M. (2003). Application of expert systems to study of acid soils in Rwanda. *Soil Survey* 28:417-424.

Appendix
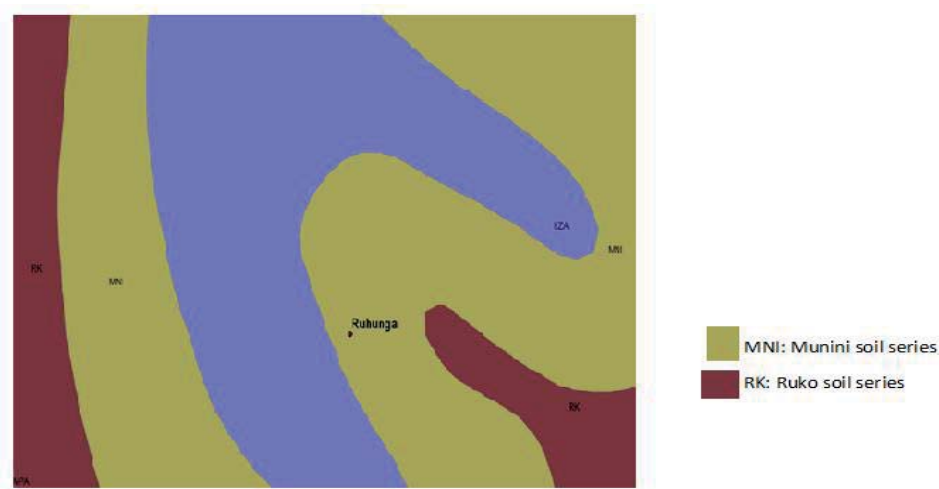
Figure 3: Map representing soil series of soil used in pots during the study
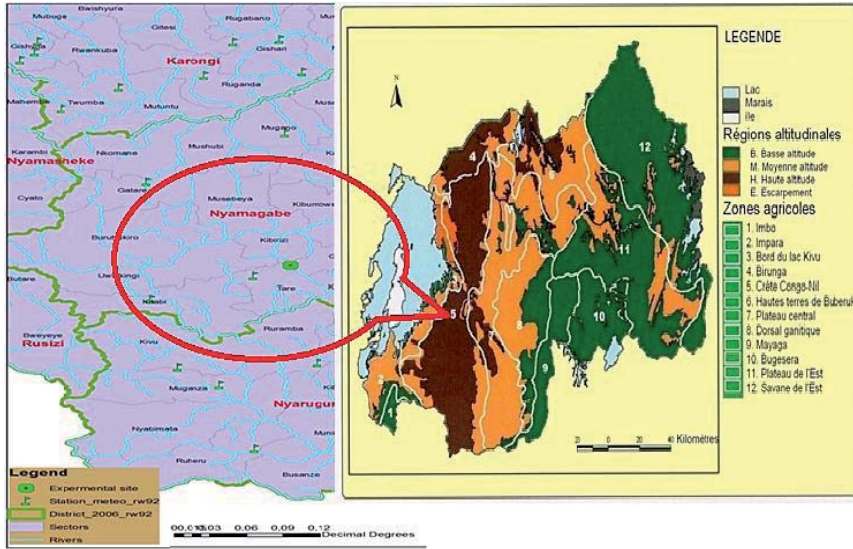
Figure 4: Map showing soil site and its agro ecological zones in Rwanda

Figure 5: Experiment layout

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Figure 6: Nodulation efficiency at different levels of P

1.2.0 COMPARATIVE STUDY OF THE INFLUENCE OF TWO LAYERS LEGUMES (LIGNEOUS AND HERBACEOUS) ON SORGHUM YIELD IN NAFANGA (KOUTIALA), MALI

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Abstract
The study was conducted in the Sudanese region of Mali. The aim was to find a solution that would balance the interests of producers and protection of the environment through agroforestry. The activities concerned four rural villages of Nafanga (Koutiala). The plant material was: sorghum, ligneous nitrogen-fixing legumes (*Gliricidiasepium*, *Leucaenaleucocephala*) and herbaceous nitrogen-fixing legume (*Stylosantheshamata*). Both agroforestry components (ligneous and herbaceous) were planted in the first year and sorghum the following year. The experimental plan used was Fisher's block dispersed at 16 peasants' fields, thus each farmer constituted one replication. The five treatments were sorghum, ligneous and herbaceous legumes association. Results showed that ligneous and herbaceous diversity in the nitrogen-fixing unit area contributes to the increase in soil productivity. *Gliricidiasepium* and *Leucaenaleucocephala* with or without *Stylosantheshamata* contributed to the development of sorghum yield of about 755 kg (*Gliricidiasepium* with *Stylosantheshamata*) and 1 615 kg (*Leucaenaleucocephala* without *Stylosantheshamata*).

Keywords: Agroforestry, nitrogen fixation, sorghum, yield

Introduction

The majority of African countries in south of the Sahara have economies based primarily on agro-forestry-pastoral sector that provides most of the Gross Domestic Product (GDP) and import revenues. In most of these countries the primary sector employs over 70% of the labor force (FAMANTA, 2014). With one (the highest in the world) growth rate of about 3%, the population was estimated at 46 0000000 in 1985 will exceed one billion in 2020 (FAMANTA, 2014). It follows then a continuous increase in the deficit of food (especially cereal products), which is a long time ago, the most difficult problem for developing countries (Romantchenko and Larin, 1971). The import of grain and other commodities is a heavy burden for developing countries. It is for these countries to create their own food base and thus change the character of their traditionally unequal economic links with the outside market (RATNADASS et *al.,* 1997). Cereals and more particularly sorghum constitute the commodity which is the staple diet of many people in the West African country. In Mali, sorghum is the most important since the other cereals have very little input because of climate risks and are not considered cash crops (RATNADASS et *al.,* 1997). The study Rural Struc (SAMAKE and al. 2007) On four areas of Mali (Diéma, Tominian, Macina and Koutiala) thus showed that the use of fertilizers for sorghum average was 7,25%, against 20,5% for maize and 43% for rice.

The present study was conducted to test on-farm agroforestry technology on the combination of culture.

Materials and methods

Rootstock

Gliricidia sepium : Ligneous legume nitrogen-fixing deciduous ;
Leucaena leucocephala : Ligneous legume nitrogen-fixing with perennial leaves ;
Stylosanthes Hamata : Herbaceous legume nitrogen-fixing ;
Sorghum bicolor : Variety of Sorgho CMI 6.

Method

A participatory and multi-disciplinary approach was carried out in three stages :
1.   Surveys
2.   Installation legumes
3.   Installing the cereal crop

The rural town of Nafanga has six villages. Four of these six villages were chosen for agroforestry demonstrations following a field investigation.

Four people were selected by the village on the basis of the criteria listed in Table 1. A total of 16 farmers were selected for the realization demonstrations.

Table 1: Key selection of villages and peasants employees.

No.	Villages	Peasantry
1	Accessibility	Availability of land
2	Magnitude of the Problem	Magnitude of the Problem
3	Spirit of commitment to honor the village and commune	Availability
4	Spirit of commitment of conquest and / or preserve the credibility of the village and the town	Spirit of commitment to honor the family, village and commune
5		Communicator
6		Spirit of commitment of conquest and / or preserve the credibility of the family, village and commune

Experimental device

Fisher's block scattered among 16 farmers was used; each peasant is a replication.

A replication was composed of five treatments:

1. T1 : Sorghum + *Gliricidia sepium* + *Stylosanthes hamata*
2. T2 : Sorgho + *Gliricidia sepium*
3. T3 : Sorgho + *Leucaena leucocephala* + *Stylosanthes hamata*
4. T4 : Sorghum + *Leucaena leucocephala*
5. T5 : Pure Sorghum

The first year was devoted to the installation of nitrogen-fixing legumes. The treatments T2 and T4 have benefited from the biomass of the corresponding legume. Biomass was cut and slightly buried between the lines of sorghum for use as green manure. This operation was performed at 15 days after planting sorghum. T5 treatment (control) was fertilized according to standard dose of fertilizer popularized for sorghum. Each treatment had a basic plot of 100 sqm or 500 sqm for one replication. The spacing between plants ligneous legume nitrogen fixing was 2 m x 2 m.

Results

Survey results

The results of the survey are shown in Tables 2 and 3.

Legend

- Exploitation type A : Equipped farm with at least two full teams, a drill, a bovine or donkey cart, a herd of cattle at least 10 heads oxen

- Exploitation type B : Equipped with at least one coupling unit

-        Exploitation type C : Partially equipped with an incomplete unit, with experience in animal traction
-        Exploitation type D   : Not equipped, practice the manual cultivation.

Table 2:   Causes of land degradation of the common Nafanga

Causes	Typology of Agricultural Production Unit			
	A	B	C	D
Erosion	x	x	x	x
Shortening of the fallow period	x	x	x	x
Poor soils	x	x	x	x
Lack of fallow	x	x	x	
Overgrazing	x	x	x	x
Other (timber)		x		

Production constraints and farmers' solutions

Table 3: The main constraints of the animal and plant production

Production constraints		Farmers proposed solutions	
Animal	Plant	Vegetable Production	Animal Production
- Difficulty complementation - Poverty pasture - Diseases - Lack of water	- Reduction of soil fertility -Insufficient Surface - Low level of equipment - Poor management of technical	- Crop's association - Crop's Rotation -Input of organic matter and mineral fertilizers - Erosion control	Animal holding

Test results of demonstrations
The measured parameter is the sorghum's yield. The collected data were analyzed using the software SATATITCF. The results are shown in Table 4.

Table 4 : Performance tests demonstrations

Designation plots	Yield (kg / ha)
Gliricidia sepium sans *Stylosanthes Hamata*	1353
Gliricidia septum with *Stylosanthes hamate*	755
Leucaena leucocephala sans *Stylosanthes Hamata*	1615
Leucaena leuccocephala with *Stylosanthes Hamata*	994
T émoin	1370
CV	35,10%
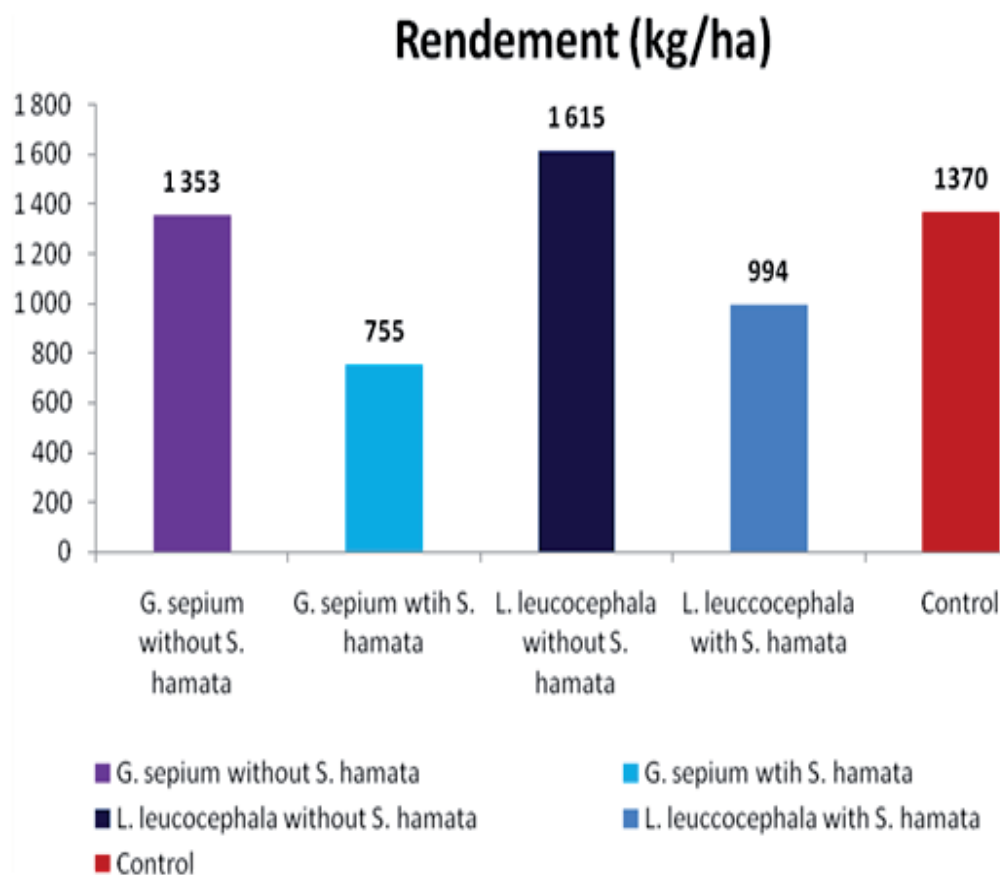
Figure 1: Demonstration of tests yields

Discussion

Leucaena leucocephala gave the best performance. The prunings are applied to crops as green manure or mulch (GANRY and DOMMERGUES, 1993). It is recognized that this practice very significantly improves the yields of intercropping as well as in a semi-arid climate (XU et al., 1993). A portion of the fixed nitrogen is transferred to crops through prunings. SANGINGA

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(1988) found that these prunings provide 110 to 580 kg of nitrogen, but the nitrogen supplied by the prunings is misused by some crops such as corn. VAN KESSEL et al. (1994) indeed showed unambiguously that there is transfer of fixed nitrogen to plants of the undergrowth. Thus another experiment conducted in southern Nigeria showed that in the case of *L. leucocephala* prunings provide 300 kg N / ha, this contribution amounts to only 34-41% of an application of 80 kg / ha of ammonium sulfate. MULONGOY (1993) explains the low efficiency that the leaves and twigs of *L. leucocephala* quickly release their nitrogen, 50% in the first four weeks of their application on the ground and that the mineralized nitrogen is probably lost much by leaching or volatilization (SANGINGA et al., 1988). It is the same for *Gliricidia sepium* with sorghum, which follows the *Leucaena leucocephala* in terms of good results.

As for the organization's three levels (Ligneous legumes, herbaceous legume and sorghum), the sorghum yield decreased compared to all other treatments. FUJITA et al, (1992).; ANDERSON and SINCLAIR (1993) (cited by GANRY and DOMMERGUES, 1993) the transfer of fixed nitrogen in a non-legume does not always seem to happen in the case of annual legumes, suggesting that depend on certain conditions still poorly understood. However it should be noted that: there is more associated more there are sources of cash compensation. Indeed at this association the producer has woody and herbaceous forage to compensate for losses incurred on sorghum.

Figure 2: Biomass slightly buried between the lines of *Sorghum*

Figure 3: Established *Sorghum*

Figure 4: A plant of *Stylosanthes hamata*

References:

ANDERSON L.S., SINCLAIR F.L, (1993), Ecological interactions in agroforestry systems. Agroforestry Abstracts 54 : 57-91.

FAMANTA M. (2014), Module de Méthodologie de Recherche Agricole expérimentale, Koulikoro, Mali.

FUJITA K., OFOSU-BUDU K.G., OGATA S. (1992), Biological nitrogen fixation in mixed legume-cereal cropping systems. Plant and Soil 141; 155-175.

GANRY F., DOMMERGUES Y. (1993), Role des arbres fixateurs d'azote dans le maintien de la fertilité azotée des sols, Extrait de GANRY F., CAMPBELL B.

(Edsl, 1995. Sustainable land management in African semi-aridandsubhumid regions.Proceedings of the SCOPE workshop, 15-19 November 1993, Dakar, Senepl.Montpellier, France, CIRAD, 406 p.

MULONGOY K., 1983. Leaf decomposition. In: Annual report for 1982. Ibadan, Nigeria, International Institute of Tropical Agriculture, p. 126-128.

RATNADASS A., CHANTEREAU J. and GIGOU J. (1998), Amélioration du sorgho et de sa culture en Afrique de l'Ouest et du Centre. Actes de l'atelier de restitution du programme conjoint sur le sorgho ICRISAT – CIRAD (17 – 20 mars 1997, Bamako, Mali), collection Colloques, Montpellier, Cirad-ca, pages 293 - 294 ;

ROMANTCHENKO A. and LARINE G. (1971), L'économie agricole, Editions MIR, 244p.

SAMAKE, A., J.-F. BELIERES, et al. (2007), Les implications structurelles de la libéralisation sur l'agriculture et le développement rural RURALSTRUC PROGRAMME CEPIA, World Bank, French Cooperation 227.

SANGINGA N., MULONGOY K., AYANABA A. (1988), Nitrogen contribution of *Leucaena* Rhizobium symbiosis to soil and subsequent maize crop. Plant and Soil 112; 137-141.

SIDIBE A., DOUMBIA S., DEMBELE M. A., TRAORE B. M., MAIGA H. A. (2008), Production de matière sèche de trois variétés de maïs.

VAN KESSEL C., FARRELL R.E., ROSKOSKI J.P. KEANE K.M. (1994), Recycling of the naturally occur- ring 15N in an established stand of *Leucaenaleucocephala*. Soil Biol. Biochem. 26; 757-762.

XU Z.H., SAFFIGNA P.G., MYERS R.J.K., CHAPMAN A.L. (1993), Nitrogen cycling in *Leucaena* sp. (*Leucaenaleucocephala*) alley cropping in semi-arid tropics. Plant and Soil 148: 63-72; 73-82. YADAV

1.2.1 COMBINING ABILITY AMONG MAIZE INBRED LINES UNDER LOW AND HIGH SOIL NITROGEN LEVELS IN THE BIMODAL HUMID FOREST ZONE OF CAMEROON

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Abstract
Low soil nitrogen causes significant yield reduction in maize *(Zea mays* L.) in the tropics. Understanding the genetic basis of hybrid performance under stress is crucial to designing appropriate breeding strategies for developing low N tolerant hybrids. Thirty nine maize tropical

inbred lines were crossed to three heterotic testers in a line x tester scheme. The resulting 117 F_1 hybrids, along with 4 checks were evaluated for grain yield and yield related traits under low and high soil nitrogen during the minor season of year 2012 and major and minor seasons of 2013 in two sites (Mbalmayo and Nkolbisson).The genotypes were assessed using an 11x11 lattice with two replications. The objectives of the study were to estimate combining abilities among maize inbred lines and the mode of gene action under low N and optimum condition; to identify secondary traits correlated with yield and identify high yielding maize hybrids tolerant to low N. Both additive and non-additive gene action influenced grain yield under low N with predominance of non-additive genetic effects. Hybrid development could therefore be employed to exploit non additive gene action under low N. Under high N, additive gene action was predominant. Leaf area, leaf chlorophyll concentration, plant height and ear height were positively correlated to grain yield under low N while anthesis-silking interval, leaf senescence and ear aspect were negatively correlated to grain yield. These traits could be used as early selection criteria to speed up the development of hybrids adapted to low N environment. TL-11-A-1642-5 x Exp1 24, CLWN201 x 87036, CLYN246 x 87036, J16-1 x Exp1 24 and CLWN201 x Exp1 24 were identified as high yielding hybrids under both low N and high N. These results suggest that good performance across stress and non stress environment can be achieved in tropical maize hybrids.

Key words: Maize, hybrids, low N, Combining ability

Introduction

Maize (*Zea mays*, L.) is one of the most important and widely grown cereals crop in Cameroon. The country experienced an increase in maize production from 966,000 tonnes in 2004.to 1,300,000 tonnes in 2013 (USDA, 2013). Despite of this, there is a deficit between domestic demand and supply. This is because farmers face many biotic and abiotic constraints such as low soil fertility, soil acidity, non-availability or high cost of inorganic fertilizers, inappropriate farming practices, non- utilization of suitable varieties, weed pressure, pest damages, and diseases (Ngoko *et al.*, 2002; Nguimgo *et al.*, 2003; The *et al.*, 2013). Low soil fertility, especially soil nitrogen deficiency is a major abiotic constraint in Cameroon (Hauser and Nolte, 2002; The *et al.*, 2013). Most small scale farmers cannot afford fertilizers due to their high cost. There is therefore a need to develop maize cultivars that can utilize nitrogen efficiently and produce economically in soils with low levels of N.

Most of the maize varieties released in Cameroon are open pollinated varieties with a yield range between 2 to 4 tonnes per hectare, far below the potential yields of hybrids which can yield up to 10 tonnes per hectare.

Breeding strategies to develop stress tolerant hybrids include multi-location testing of hybrid progenies in a representative sample of the target environment and selection under high plant population (Beck *et al.,* 1996). New inbred lines to be used for hybrids development under low N environments needs to be selected within heterotic groups using suitable testers for specific

combining ability. Knowledge of the heterotic groups of inbred lines is necessary to develop superior hybrids (Abrha *et al.,* 2013).

The development of low N tolerant hybrids requires information about heritability, genetic and environmental variances, and the mode of gene action under low N. It is essential for a breeding program to evaluate the breeding value of prospective parental lines to be used for developing new adapted varieties (Ndhlela, 2012). The nature of gene action involved in the expression of quantitative traits can be obtained through the determination of general combining ability (GCA) and specific combining ability (SCA) (Tamilarasi *et al.,* 2010).

The objectives of this study were to identify high yielding hybrids tolerant to low N soils, determine the combining abilities and mode of gene action of intermediate maturing inbred lines to be used in hybrid development under low N soils conditions and identify secondary traits correlated with yield under low N.

Materials and methods

Germplasm

Forty two intermediate to late maturing inbred lines (39 lines and 03 testers) were used in the study. These include inbred lines from IRAD Cameroon, IITA, CIMMYT and lines from other African maize breeding programs (Table 1).

Table 1: Origin, color and main characteristics of maize inbred lines and testers used in the study

No	Lines	Origin	Color	Main characteristics
1	Cla 17	CIMMYT	Y	Tolerant to acid soils. Heterotic to Cla 18
2	9450	IITA	Y	Converted from B73 and tolerant to low N
3	1368	IITA	W	Extracted from pop 21
4	M 131	IRAD	W	Mid altitude adaptation and tolerant to low N.
5	88094	IRAD	W	Mid altitude adaptation and tolerant to low N.
6	J18-1	WACCI	W	Tolerant to drought
7	88069	IRAD	Y	Mid altitude converted to lowland adaptation.
8	Entrada 29	CIMMYT	W	Tolerant to Aluminium.
9	CML 358	CIMMYT	Y	Tolerant to Aluminium.
10	Entrada 3	CIMMYT	W	Tolerant to Aluminium.
11	CML 254	CIMMYT	W	Tolerant to Aluminium.
12	5012	IITA	W	Temperate converted to tropical adaptation.
13	Cam inb gp1 17	IRAD	Y	Tolerant to acid soil
14	9848	IITA	Y	Temperate converted to tropical adaptation.

15	CLA 18	CIMMYT	Y	Tolerant to Al acid soil.
16	ATP S9 30 Y-1	IRAD	Y	Extracted from acid tolerant maize population.
17	ATP S5 26 Y-1	IRAD	Y	Extracted from acid tolerant maize population.
18	KU1414	IITA	Y	Tolerant to low N
19	5057	IITA	W	Temperate line converted: Susceptible to drought, striga.
20	ATP S6 20 Y-1	IRAD	Y	Extracted from acid tolerant maize population.
21	ATP S8 30 Y-3	IRAD	Y	Extracted from acid tolerant maize population.
22	TZMI 102	IITA	W	
23	J16-1	CIMMYT	W	Tolerant to drought
24	CLYN246	CIMMYT	Y	Tolerant to low N
25	CML395	CIMMYT	W	Susceptible to low N
26	CML494	CIMMYT	W	Susceptible to low N
27	CML165	CIMMYT	Y	Susceptible to low N
28	CLQRCWQ26	CIMMYT	W	Susceptible to low N
29	CML451	CIMMYT	W	Susceptible to low N
30	V-351-1/6	CIMMYT	W	Drought tolerant
31	V-481-73	CIMMYT	W	Drought tolerant
32	TZ-STR-133	IITA	W	
33	TL-11-A-1642-5	CIMMYT	W	
34	Ku 1409	IITA	Y	Tolerant to low N and downy mildiou. From Swan pop
35	ATP S6-20-Y-1	IRAD	Y	Extracted from acid tolerant maize population.
36	CLWN201	CIMMYT	W	Tolerant to low N
37	CML444	CIMMYT	W	Tolerant to low N
38	CML343	CIMMYT		Tolerant to low N
39	4001STR	IITA	Y	Tolerant to low N, extracted from population 28

	Testers			
40	87036	IRAD	W	Mid altitude line converted to low land
41	Exp1 24	IRAD	W	Tuxpeno background. Good combiner.
42	9071	IITA	W	Converted from N28 and good combiner

W = white

Y = yellow

Thirty nine inbred lines were crossed to three testers (87036, Exp1 24 and 9071), in a line by tester scheme to obtain 117 hybrids. In addition to the 117 hybrids obtained, 3 hybrids (87036 x Exp1 24, 9071 x Exp_1 24, 87036 x 9071) from crosses among the 3 testers and one other hybrid (88069 x $Caminbgp_1$17) were included as checks to make a total of 121 entries. The hybrid 87036 x Exp1 24 is a high yielding hybrid released in Cameroon and adapted to the Humid Forest Zone of Cameroon. This hybrid is a hybrid between tropical lowland by mid-altitude inbred. Exp_1 24 x 9071 is also a high yielding hybrid, coming from a cross of a tropical lowland x temperate converted inbred.

Experimental sites

The study was done in two locations of the Humid Forest Zone with bimodal rainfall namely Nkolbisson and Mbalmayo. Nkolbisson is located at 11°36 East and 3° 44 North, 5 km from the main capital city 'Yaoundé'. The altitude is 650 m. The annual rainfall is 1560 mm with bimodal distribution. The average daily temperature is 23.5°C. The soil is a sandy clay with pH (water) of 4.52, CEC of 4.79C mol (+) kg^{-1} and AL of 0.30 Cmol (+) kg^{-1} (The et al., 2013).

Mbalmayo is located at 11°30' East and 3°31' North, 45 km from Yaoundé. The altitude is 641m a s l. The mean annual rainfall varies from 1017 to 1990 mm with bimodal distribution. The mean monthly temperature varies from 25°C to 22°C. The soil is sandy clay (Tchienkoua, 1996).

Site preparation and soil analysis

Low N plots were established by soil depletion of available nitrogen. Soil N depletion consisted of planting maize uniformly in the field at a very high density without any fertilizer application for many growing seasons.

Soil samples collected from the two locations before each cropping season were analyzed for selected physical and chemical properties at the soil laboratory of IITA Cameroon.

Experimental design and management

The 121 F_1 hybrids were evaluated during 2012 and 2013 2 years and three cropping seasons under optimum N level (100 kg ha^{-1}) and low N (20 kg ha^{-1}). At each N level, the 121 hybrids were arranged in an 11 x 11 lattice design. The experimental unit consisted in a single row of 5m at Mbalmayo and single 4m at Nkolbisson. Hybrids were planted in 2 replications. The spacing between rows was 0.75m and 0.5m between hills within a row. Three seeds were planted in a hill and thinned after emergence to 2 plants, for a final density of 53,330 plants per hectare.

Split fertilization was done on each plot. On the low N plot, the first application consisted of 10 N, 24 P_2O_5 per hectare and 14 K_2O per hectare, 10 days after planting, and the second dose consisted of 10 N, applied 30 days after planting. On the optimum N plot, the first application consisted of a mixture of 35 N, 24 P_2O_5 and 14 K_2O per hectare, applied 10 days after planting

and the second dose was 65 N per hectare, applied 30 days after planting. The trials were kept clean of weeds throughout the growing cycle by spraying 750g/kg of Atrazine and 40 g/kg of Nicosulfuron at the early stage of maize growth, and later by hand weeding.

Data recorded

Anthesis date (AD) and silking date (SD) were obtained as 'number of days after planting', when 50% of plants were shedding pollen and silking, respectively. The anthesis silking interval (ASI) was calculated as silking date minus anthesis date.

Leaf chlorophyll content was determined in four randomly selected plants from each experimental unit and two measurements were obtained per plant on the ear leaf, using a portable Minolta chlorophyll meter (SPAD-502, MINOLTA) one week after silking.

Ear leaf area was determined after silking from the leaf immediately below the upper ear on four randomly selected plants in each plot, and was obtained by multiplying maximum leaf width by leaf length by 0.75 (Giauffret et al., 1997).

Leaf senescence was scored 10 and 12 week after planting on a scale from 0 to 10, dividing the percentage of the estimated total leaf area below the ear that is dead by 10. A score of 1 = less than 10% dead leaf and 10 = more than 90% dead leaf.

Plant height was measured as the distance from the base of the plant to the height of the first tassel branch.

At harvest, the number of ears per plant was computed as the proportion of total number of ears divided by the number of plants harvested in each experimental unit.

Ear aspect was scored on a scale of 1 to 5, where 1 corresponded to clean, uniform, large, and well-filled ears and 5 was the rotten, variable, small, and partially filled ears. At maturity, each row was harvested separately and ear weight was measured for each plot. Grain yield adjusted to 15% grain moisture was calculated in kg ha^{-1} for every entry from the data of fresh ear weight per plot.

Statistical analysis

Data were analyzed using general linear model (GLM) procedure in SAS (SAS institute, version 9.2, 2008). Entry means adjusted for block effects as analyzed according to lattice design (Cochran and Cox, 1960).

Each environment was defined as year x season x site x nitrogen treatment.The Combined analysis of variance (ANOVA) and the ANOVA for each environment were computed with PROC GLM procedure in SAS using the RANDOM statement with the TEST option. Environment effects were treated as random effects and genotypes as fixed effects. The effects of environment on all the measured traits were evaluated through different interaction estimates.

Combined analysis of variance across environments was done for all the 121 F_1 hybrids evaluated (including checks). This was followed by analysis of variance across low N environment and across optimum environments only for traits which exhibited significant differences between environments.

Line x tester analysis (Kempthrone, 1957) was done for low N environments, optimum and across environments to partition the mean square due to crosses into lines, testers and line by tester interaction effects for traits that showed significant differences among crosses.

The relative importance of GCA versus SCA on progeny performance was calculated as the ratio between sum of square due to GCA or SCA and total sum of squares (GCA and SCA sum of square) (2003b).

Simple linear correlation coefficient was calculated to determine relationships between grain yield and all the measured traits.

Results

Analysis of variance and hybrid mean performance

Across the ten research environments, highly significant differences ($p<0.01$) were observed among the hybrids and between environments for all the measured traits (Table 2). Hybrid x environment interaction was significant for all traits. This suggests that hybrid relative performance was not consistent across environments.

Table 2: Means squares of grain yield and other agronomic traits of hybrids evaluated across research environments at Mbalmayo and Nkolbisson in 2012 and 2013

Source of variation	df	YIELD (kgha⁻¹)	DTS (days)	ASI (days)	LAREA (cm²)	CHLORO (%)	PHT (cm)	EPP	EA (1-5)
Env	9	421826605**	1572.49**	133.37**	1775554.16**	11634.39**	158195.18**	0.40*	23.22**
Rep (Env)	10	22643366**	69.83**	2.95ns	75129.41**	1178.31**	14499.79**	0.13**	2.77**
Bock(Rep x Env)	200	2029263**	14.35***	1.61**	17876.44**	64.22**	729.02**	0.04**	0.56**
Hybrids	120	5390074**	33.69**	1.95**	26687.76**	78.46**	1477.59**	0.04**	1.64**
Hybrids*Env	1080	1565879**	9.94**	1.27**	11685.55**	32.42**	447.50**	0.04**	0.42**
Pooled error	1000	1005416	6.69	1.03	6828.26	23.92	271.38	0.03	0.26
Lsd		1395.6	3.6	1.41	115.85	6.81	22.92	0.23	0.71

*, **, Significant at 0.05 and 0.01probability levels, respectively, and ns, not significant; DTS = days to 50% silking; ASI= anthesis silking interval; LAREA= Ear leaf area; CHLORO = leaf chlorophyll content; LSENE=leaf senescence PHT=plant height; EPP=ear per plant; EA=ear aspect, YIELD=grain yield.

Under low N environments, significant differences were observed among the hybrids for all traits (Table 3). The difference between all low N environments was significant ($p<0.05$) for grain yield and ear leaf chlorophyll content and highly significant for days to silking, anthesis silking interval, leaf area and plant height (Table 3).

Across low N environments, grain yield ranged from 1539.3 kg ha^{-1} for CML 358 x 9071 kg ha^{-1} to 3770.51 kg ha^{-1} for TL-11-A-1642-5 x Exp1 24, with a mean of 2721.9 kg ha^{-1} (Table 4). Days to silking ranged from 62.50 to 71.70 with a mean of 66.98 days. Anthesis-silking interval ranged from 1.9 days to 4.9 days with a mean of 3.18 days. Leaf area varied from 404.93 to 626.59 cm^2 with a mean of 525.59 cm^2. Leaf chorophyll content varied from 31.50% to 46.22%, with a mean of 40.80% and higher values observed among the 20 best hybrids. Means for plant height was 163.46 cm, ranging from 135 cm to 182.92 cm and ear aspect ranged from 2.35 to 4.05 with a mean of 3.05 (Table 4). Across low N stress environment, five hybrids yielded more than 3500 kg.ha^{-1}, these are TL-11-A-1642-5 x Exp1 24 (3770.51 kg ha^{-1}), CLWN201 x 87036 (3609.2 kg ha^{-1}) ATP S6 20 Y-2 x Exp1 24 (3556.47 kg ha^{-1}), J16-1 x Exp1 24 (3516.41 kg ha^{-1}), ATP S9 30 Y-1 x Exp1 24 (3514.44 kg ha^{-1}), CLYN246 x 87036 (3512.06 kg ha^{-1}) (Table 4). The two highest yielding hybrids were TL-11-A-1642-5 x Exp1 24 and CLWN201 x 87036 with means grain yield of 3770.51 kg ha^{-1} and 3609.2 kg ha^{-1} respectively. None of the four hybrid checks was among the 20 best hybrids under low N.

Table 3: Means squares of grain yield and other agronomic traits of hybrids evaluated under low N environments at Mbalmayo and Nkolbisson in 2012 and 2013

Source of variation	df	YIELD (kgha⁻¹)	DTS (days)	ASI (days)	LAREA (cm²)	CHLORO (%)	LSENE (1-9)	PHT (cm)	EPP	EA (1-5)
Env	4	120610253.6*	2610.91**	156.89**	991661.7**	12763.1*	69.10ns	138175.3**	0.43ns	2.21ns
Rep (Env)	5	18954223.1**	71.28*	5.24ns	59589.4ns	2158.68**	28.29**	1861.11ns	0.15**	3.13*
Bock (Rep x Env)	100	19943390.9**	19.31**	2.62**	20918.8**	79.50**	1.47**	681.22	1.09ns	0.68**
Hybrids	120	1898873.4**	23.60**	2.72**	14272.18**	62.69**	1.02**	836.83**	1.31*	0.94**
Hybrids*Env	480	1293549.0**	9.59**	1.90**	9643.81**	33.76**	0.80**	417.99**	1.52**	0.46**
Pooled error	500	729665	7.27	1.5	5921.28	23.15	0.6	236.97	0.03	0.29

*, **, Significant at 0.05 and 0.01probability levels, respectively, and ns, not significant; DTS = days to 50% silking; ASI= anthesis silking interval; LAREA= Ear leaf area; CHLORO = leaf chlorophyll content; LSENE=leaf senescence PHT=plant height; EPP=ear per plant; EA=ear aspect, YIELD=grain yield.

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Table 4: Means for grain yield and other agronomic traits of selected best 20 hybrids and checks across low N environments at Mbalmayo and Nkolbisson in 2012 and 2013

Hybrids	YIELD (kgha⁻¹)	DTS (days)	ASI (days)	LAREA (cm²)	CHLORO (%)	LSENE (1-9)	PHT (cm)	EPP	EA (1-5)	Index (%)
TL-11-A-1642-5 x Exp1 24	3770.51	66.7	2.6	531.77	41.47	2.9	155.78	1.14	2.4	30.42
CLWN201 x 87036	3609.2	66.1	4.2	504.41	41.62	3.8	175.6	1.06	2.35	33.51
ATP S6 20 Y-2 x Exp1 24	3556.47	64.5	2.9	589.33	41.85	3.2	158.67	1.07	2.7	31.00
J16-1 x Exp1 24	3516.41	65.7	3.8	601.41	39.95	3.2	162.07	1.11	2.55	41.87
ATP S9 30 Y-1 x Exp1 24	3514.44	66.4	3.1	585.44	44.16	3.7	167.13	1.05	2.5	22.04
CLYN246 x 87036	3512.06	65	2.7	602.02	41.42	3.28	173.73	1.19	2.65	46.67
ATP S9 30 Y-1 x 87036	3464.15	66.6	2.7	536.29	41.98	3.7	179.73	1.18	2.95	33.34
CLWN201 x Exp1 24	3415.18	65.3	2.5	491.7	41.09	3.5	153.9	1.09	2.75	44.49
ATP S6-20-Y-1 x Exp1 24	3365.33	64	2.7	556.5	34.25	3.4	162.9	1.02	2.9	40.60
Entrada 29 x Exp1 24	3321.12	66.2	3.3	594.61	42.86	2.85	174.23	1.12	2.5	34.40
CML165 x 87036	3319.69	66.5	3.1	585.71	44.38	3.6	174.97	1.09	2.6	36.83
1368 x 87036	3315.63	66.7	3.5	574.84	41.11	3.45	173.83	1.06	2.65	44.03
CML343 x 87036	3306.36	68.5	2.6	568.73	43.41	3.25	172	1.05	2.95	40.59
4001STR x 87036	3290.93	66.5	3.2	543.45	43.25	3.6	163.67	1.13	2.8	41.08
CLQRCWQ26 x 87036	3288.68	64.7	2.9	558.68	38.54	3.55	169.83	1.06	2.7	39.60
CML 444 x Exp1 24	3275.13	71.7	2.6	529.34	40.32	3.65	160.8	1.13	3.05	34.98
V-481-73 x Exp1 24	3255.76	68.9	3.6	559.71	44.1	2.6	165.1	1.06	2.63	27.28
CML343 x Exp1 24	3242.41	68.2	3.6	527.04	40.78	3.25	160.63	1.04	2.75	32.53
Cam inb gp1 17 x 87036	3227.94	66	3.7	556.25	37.12	3.4	169.9	1.01	2.65	43.77
CML343 x 9071	3224.32	69	2.5	509.9	41.94	3.6	171.08	1.19	2.75	41.72
Best checks										
87036 x Exp1 24	2866.47	69.9	3.7	521.43	43.03	3.45	175.1	1.05	2.75	30.42
Exp1 24 x 9071	2336.64	67.3	2.7	548.51	37.71	3.9	160.15	1.09	3.1	
Mean	**2721.49**	**66.98**	**3.18**	**525.59**	**40.80**	**3.53**	**163.46**	**1.07**	**3.05**	
Min	**1539.3**	**62.50**	**1.9**	**404.93**	**31.50**	**2.6**	**135.00**	**0.88**	**2.35**	
Max	**3770.5**	**71.70**	**4.9**	**626.59**	**46.22**	**4.4**	**182.92**	**1.30**	**4.05**	
lsd (0.05)	**1687.9**	**5.32**	**2.42**	**152.05**	**9.51**	**1.53**	**30.42**	**0.33**	**1.07**	

*, **, Significant at 0.05 and 0.01probability levels, respectively, and ns, not significant; DTS = days to 50% silking; ASI= anthesis silking interval; LAREA= Ear leaf area; CHLORO = leaf chlorophyll content; LSENE=leaf senescence PHT=plant height; EPP=ear per plant; EA=ear aspect, YIELD=grain yield.

Under optimum environments, mean yield varied from 3026.5 kg ha^{-1} for J18-1x 9071 to 6588.8 kg ha^{-1} for TL-11-A-1642-5 x 87036, with an overall mean of 4887.18 kg ha^{-1} (Table 5). Days to 50% silking ranged from 61.2 to 60.40 with a mean of 62.4 days. Mean anthesis silking interval varied from 1.6 to 3.1 days with a mean of 2.26 days (Table 5). Leaf area ranged from 472.70 cm^2 to 772.06 cm2 with a mean of 630.63 cm2. Chlorophyll concentration varied from 43.02% to 55.90% with a mean of 49.96%. Mean of plant height was 182.27, ranging from 153.23 to 210.07 cm. Mean of ear aspect ranged from 1.85 to 3.50, with a mean of 2.5 (Table 5).

Five hybrids yielded more than 6000 kg ha^{-1} under optimum environments, these are TL-11-A-1642-5 x 87036 (6588.84 kg ha^{-1}), CLYN246 x 87036 (6584.97 kg ha^{-1}), TZ-STR-133 x 87036 (6393.32 kg ha^{-1}), CLWN201 x Exp1 24 (6152.26 kg ha^{-1}), J16-1 x Exp1 24 (6048.74 kg ha^{-1}) (Table 5).

The highest yielding checks among the four evaluated were 87036 x Exp1 24 (5169.43 kg ha^{-1}) and Exp1 24 x 9071 (5262.24 kg ha^{-1}) but these hybrids were not among the 20 best hybrids selected optimum environments.

Table 5: Means for grain yield and other agronomic traits of best 20 hybrids and checks under optimum Environments at Mbalmayo and Nkolbisson in 2012 and 2013

Hybrids	YIELD (kgha⁻¹)	DTS (days)	ASI (days)	LAREA (cm²)	CHLORO (%)	PHT (cm)	EPP	EA (1-5)
TL-11-A-1642-5 x 87036	6588.84	65.2	1.7	650.86	51.08	193.57	1.13	2.4
CLYN246 x 87036	6584.97	63.4	2.2	740.32	54.19	197.7	1.09	2.05
TZ-STR-133 x 87036	6393.32	62.5	2.5	582.73	51.64	194.03	1.14	2.4
CLWN201 x Expl 24	6152.26	63.1	2	617.83	49.52	174.17	1.07	2.05
J16-1 x Expl 24	6048.74	63	2.2	652.95	47.84	174.97	1.1	2.1
CLQRCWQ26 x Expl 24	5968.82	64.9	2.3	606.8	47.04	174.4	1.08	2.1
1368 x 87036	5923.65	64.3	2	625.94	48.64	195.3	1.07	2.1
CLA 18 x Expl 24	5909.7	64.2	2	635.94	48.63	168.81	1.01	2.05
4001STR x 9071	5792.07	63	2.2	645.79	48.67	177.8	1.08	2.45
J16-1 x 87036	5780.49	63.7	1.9	654.25	51.02	181.73	1.07	2.3
CML395 x Expl 24	5772.47	66.3	2.1	656.09	45.69	177.13	0.93	2.35
ATP S6-20-Y-1 x 87036	5765.88	63.6	1.6	671.13	52.65	198.03	0.98	1.9
Cam inb gp1 17 x 87036	5741.05	64.6	2.9	614.06	55.9	196.33	1.06	1.85
CML451 x 87036	5729.07	66.3	2.7	616.98	47.88	187.5	0.99	2.45
CLYN246 x Expl 24	5708.79	63.4	2.1	677.84	50.52	175.92	1.13	2.15
CML 358 x 87036	5699.02	65.6	2.3	644.87	46.79	197.07	1.08	2.4
CLA 18 x 87036	5694.14	64.2	2.2	663.14	54.1	199.67	1.12	2.15
88069 x 9071	5687.94	62.3	2.4	709.45	53.63	188.73	1.03	2.4
ATP S5 31 Y-2 x 87036	5682.27	63.5	2.3	639.69	51.14	180.47	1.22	2.4
ATP S6-20-Y-1 x Expl 24	5665.37	63.6	2.1	668.94	47.33	178.1	1.09	2.3
Best checks								
87036 x Expl 24	5169.43	64.6	2.5	655.17	49.73	185.6	1.13	2.35
Expl 24 x 9071	5262.24	68.2	2.1	680.24	47.74	176.23	1.16	2.9
Mean	**4887.18**	**64.73**	**2.26**	**630.63**	**49.96**	**182.27**	**1.07**	**2.50**
Min	**3026.50**	**61.20**	**1.60**	**472.70**	**43.02**	**153.23**	**0.92**	**1.85**
Max	**6588.80**	**69.40**	**3.10**	**772.06**	**55.90**	**210.07**	**1.24**	**3.50**
lsd(0.05)	**2236.6**	**4.89**	**1.48**	**176.02**	**9.82**	**34.55**	**0.32**	**0.93**

*, **, Significant at 0.05 and 0.01probability levels, respectively, and ns, not significant; DTS = days to 50% silking; ASI = anthesis silking interval; LAREA= Ear leaf area; CHLORO = leaf chlorophyll content; PHT=plant height; EPP=ear per plant; EA=ear aspect, YIELD=grain yield.

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Combining ability

Under low N environments, there were significant differences between crosses for all traits number of ears per plant (Table 6). Line x tester analysis revealed highly significant (p<0.01) line GCA mean squares for all traits except ears per plant (Table 6). Means squares of tester GCA was significantly different for all traits except days to silking and anthesis silking interval. There were highly significant differences between SCA mean squares for all traits except leaf senescence, plant height and ears per plant (Table 6).

Under low N, the contribution of SCA to the total sum of squares of square of crosses was higher compared to the contribution of GCA for grain yield, anthesis silking interval, leaf chlorophyll content, number of ears per plant and ear aspect, while contribution of SCA was lower than GCA for days to silking, leaf senescence and plant height (Table 6).

Under optimum environments, line x tester analysis revealed significant (p<0.05) line GCA mean squares for anthesis silking interval and highly significant (p<0.01) line GCA for all the other measured traits (Table 7). Tester GCA mean square was significant for all traits except anthesis silking interval and ears per plant (Table 7). SCA mean squares were significant for grain yield, days to silking, leaf area and ear aspect.

The contribution of GCA effect to the sum of square of crosses was higher than the contribution of SCA for all traits except anthesis silking interval and ears per plant (Table 7).

Table 6: Line x tester analysis for grain yield and other agronomic traits across low N environments at Mbalmayo and Nkolbisson in 2012 and 2013 and percentage contribution of GCA and SCA to the total sum of squares

Source of variation	df	YIELD (kg.ha⁻¹)	DTS (days)	ASI (days)	LAREA (cm²)	CHLORO (%)	LSENE (1-9)	PHT (cm)	EPP	EA (1-5)
Env	4	115584228.4**	2565.56**	150.00**	916162.69**	12249.75*	64.57ns	130530.30*	0.34ns	2.24ns
Rep (Env)	5	18845743.3*	57.41ns	4.42ns	59773.79ns	2075.55**	26.63*	1803.32ns	0.15*	2.93*
Crosses	116	1604070.5**	21.31**	2.46**	13004.16**	61.88**	1.06**	660.13**	0.03**	0.84**
Env *Crosses	464	1281639.8**	9.30*	1.91*	9364.79**	31.93*	0.75*	395.42**	1.28*	0.47*
Line (GCA)	38	20332201.1**	38.82**	3.40**	17208.56**	67.92**	1.32**	629.38**	0.04ns	1.06*
Tester (GCA)	2	6836645.8**	0.94ns	4.11ns	16265.33ns	305.68**	10.93**	13490.22**	0.02ns	3.44*
Line*Tester (SCA)	76	1227344**	11.58**	2.08*	11138.17**	48.92**	0.71ns	317.82ns	0.03ns	0.64*
Env*Line (GCA)	152	1586891.9**	8.83ns	2.18**	9477.26**	37.02**	0.79*	365.82*	0.03ns	0.62*
Env*Tester (GCA)	8	1824558.9*	24.08**	1.15ns	15949.62*	59.08**	1.03ns	1509.20**	0.05ns	0.48ns
Env*Line*Tester (SCA)	304	1095883.3**	9.16*	1.74ns	8863.19**	27.85ns	0.72ns	365.70**	0.05ns	0.39*
Error	689	770917	7.56	1.53	6477.74	25.99	0.62	283.15	0.03	0.3
%GCA SS (Line)		41.52	64.95	44.38	43.35	35.96	40.99	31.23	37.28	41.26
%GCA SS (Tester)		7.35	0.11	2.88	2.16	8.52	17.84	35.23	1.00	7.03
%SCA SS (Line x Tester)		50.13	35.48	55.34	56.12	51.80	43.92	31.54	61.04	49.40

Table 7: Line x tester analysis for grain yield and other agronomic traits across optimum environments at Mbalmayo and Nkolbisson in 2012 and 2013 and percentage contribution of GCA and SCA to the total sum of squares

Source of variation	df	YIELD (kg.ha⁻¹)	DTS (days)	ASI (days)	LAREA (cm²)	CHLORO (%)	PHT (cm)	EP P	EA (1-5)
Env	4	11361785.2*	152.37ns	14.48**	1253297.66**	707.94ns	158316.66*	0.43ns	4.12ns
Rep (Env)	5	23958606.9**	63.79**	0.57ns	91730.79**	189.13*	26106.28**	0.10ns	2.19**
Crosses	116	4235566.4**	18.05**	0.72ns	18531.24**	41.88**	877.13**	0.04ns	0.87**
Env *Crosses	464	1840627.2**	10.11**	0.59ns	13091.60**	30.38*	461.43**	0.040**	0.040**
Line (GCA)	38	5735295**	31.32**	0.92*	27262.50*	50.34**	864.85**	0.05**	1.10**
Tester (GCA)	2	27425796**	52.36**	0.95ns	33483.60*	608.21**	17622.32**	0.05**	4.5**
Line*Tester (SCA)	76	2766032.3**	9.89**	0.61ns	13372.88*	22.97ns	401.10ns	0.03ns	0.67**
Env*Line (GCA)	152	2977712.1**	11.97**	0.57ns	16689.71**	30.84ns	492.73**	0.03ns	0.39**
Env*Tester (GCA)	8	3273204.3*	12.61**	0.94ns	9156.18ns	104.76**	1552.15**	0.03ns	0.58*
Env*Line*Tester (SCA)	304	1502318.4ns	8.68**	0.59ns	11064.99ns	28.46ns	403.81ns	0.03ns	0.40**
Error	689	1292975	6.13	0.57	9877.4	26.3	360.33	0.03	0.24
%GCA SS (Lines)		44.36	56.68	42.15	48.19	39.38	32.30	44.25	41.24
%GCA SS (Testers)		11.16	4.98	2.31	3.12	25.04	34.64	1.42	8.88
%SCA SS (Line x Tester)		42.79	35.78	55.45	47.28	35.93	29.96	54.66	49.88

*, **, Significant at 0.05 and 0.01probability levels, respectively, and ns, not significant; DTS = days to 50% silking; ASI= anthesis silking interval; LAREA= Ear leaf area; CHLORO = leaf chlorophyll content; LSENE=leaf senescence PHT=plant height; EPP=ear per plant; EA=ear aspect, YIELD=grain yield.

*, **, Significant at 0.05 and 0.01probability levels, respectively, and ns, not significant; DTS = days to 50% silking; ASI= anthesis silking interval; LAREA= Ear leaf area; CHLORO = leaf chlorophyll content; PHT=plant height; EPP=ear per plant; EA=ear aspect, YIELD=grain yield.

General combining ability effects

Six lines had positive significant GCA for grain yield. These are CML 343 (522.26), ATP S6 20-Y1 (504.46), CLWN201 (483.80), 1368 (468.23), ATP S9 30 Y-1 (436.48) and CLQRCWQ26 (396.45) (Table 8). The line with the best GCA for grain yield was CML 343. The desired line GCA value for days to silking and anthesis silking would be negative, therefore, the best lines GCA for days to silking were V 351-1/6 and CLA 17 with a GCA of -3.23and -2.46 respectively. The same lines V351-1/6 and CLA 17 had the best GCA effects for anthesis silking interval (-0.81 and -0.58 respectively). The two best combiners for leaf area, with positive significant GCA were CLQRCWQ26 (43.97) and ATP S5 31-Y-2 (35.98). The lines with best GCA for plant height were ATP S9 30 Y-1 (9.31) and 5012 (8.10). For ear aspect, three lines had the best GCA of -0.2. These are CLWN 201, CLYN246 and ATP S6 20 Y-2.

Two out of the three testers had positive GCA for grain yield under low N. These are 87036 (72.19) and (59.95). The tester 9071 had a negative GCA value (Table 8).

For days to silking, only 9071 had negative GCA (-0.07) while for anthesis silking interval, 87036 and Exp1 24 had negative GCA (-0.02 and -0.11 respectively), indicating good general combining ability for this trait under low N. The testers 87036 and Exp1 24 also had positive GCA for ear leaf area indicating good combining ability for this trait. For leaf chlorophyll content, 87036 had the best GCA (0.81) while for leaf senescence EXP1 24 was the tester with best GCA (-0.18). For plant eight the tester 87036 had the best GCA (6.75). The testers 87036 (-0.06) and Exp1 24 (-0.06) both had a good GCA for ear aspect.

Under optimum environments, the six best lines with positive significant GCA for grain yield were CLYN246 (982.75), J16-1 (728.75), CLWN201 (720.74), TL-11-A-1642-5 (675.86), CLQRCWQ26 (640.10) and 1368 (546.51) (Table 9).

Specific combining ability for grain yield

The SCA for crosses under low N and optimum environments are presented in Table 8 and 9, respectively. Line and tester GCA are also presented in the same table in order to determine the relationship between SCA and GCA. The cross between line ATP S6 20 Y-2 and Exp1 24 had the highest positive SCA (679.45) for grain yield under low N environments (Table 12). This cross was followed by (648.39) and CML 494 x 9071 (626.40). The first two crosses, ATP S6 20 Y-2 x Exp1 24 and TL-11-A -1642- 5 x Exp1 24, with the best SCA, were among the highest yielding. Under optimum environment, the best crosses with the highest positive SCA (986.82) were 4001STR x 9071, followed by J18-1 x 87036 with an SCA of 905.58 and TZ-STR-133 x 87036 with 893.04 as SCA (Table 13). All these were high yielding hybrids, with two of them (TZ-STR-133 x 87036 and 4001STR x 9071) being among the 20 best yielding under optimum condition.

Table 8: Specific combining ability effects for grain yield and GCA effects of lines and testers under low N environments

Lines	Testers			GCA
	87036	**Exp1 24**	**9071**	**lines**
Cla 17	-157	156.12	0.88	-235.01
9450	176.14	-36.55	-139.59	-865.88**
1368	39.78	-114.17	74.4	468.23*
M 131	-314.4	-141.49	455.89	-471.41*
88094	309.16	-494.04	184.88	-262.54
J18-1	196.68	-317.1	120.42	-355.27
88069	-39.04	-90.83	129.87	275.61
Entrada 29	-721.19*	452.43	268.76	-215.15
CML 358	16.68	506.33	-523.02	-321.81
Entrada 3	265.88	-131.26	-134.62	-158.03
CML 254	162.89	-62.79	-100.1	19.99
5012	-116.73	110.06	6.68	-103.65
Cam inb gp1 17	86.6	-27.92	-58.68	253.52
9848	130.24	-411.97	281.73	-436.20*
CLA 18	155.1	-68.81	-86.29	208.75
ATP S9 30 Y-1	280.4	155.38	-435.78	436.48*
ATP S5 31 Y-2	20.8	-130.12	109.33	106.39
KU1414	313.07	-272.61	-40.46	-123.14
5057	30.32	-98.44	68.13	-334.54
ATP S6 20 Y-2	-507.06	679.45*	-172.39	185.23
ATP S8 30 Y-3	-187.49	-6.86	194.36	-62.55
CLWN201	275.45	-202.25	-73.2	483.80**
TZMI 102	-355.56	344.13	11.44	-88.74
J16-1	-115.2	303.93	-188.73	326.14
CLYN246	503.41	-456.75	-46.67	300.65
CML395	-480.61	229.27	251.34	-283.85
CML494	-198.48	-427.93	626.403*	-299.82
CML165	518.95	-355.12	-163.83	-46.53
CLQRCWQ26	-109.46	159.52	-50.06	396.45*
CML451	187.95	-374.18	186.23	85.04
V-351-1/6	-31.49	-43.26	74.75	-165.15
V-481-73	-594.49	602.76	-8.27	-293.94
TZ-STR-133	-272.85	120.64	152.21	121.22
TL-11-A-1642-5	51.38	648.395*	-699.77*	326.73
Ku1409	28.66	-16.79	-11.86	15.45
ATP S6-20-Y-1	-98.84	65.49	33.35	504.46**
CML343	-23.52	-75.23	98.76	522.26**

Lines	Testers			
	87036	Exp1 24	9071	
CML 444	165.75	468.08	-633.83*	11.67
4001STR	408.16	-645.52*	237.37	75.15
GCA Testers	**72.19**	**59.95**	**-132.13****	

*, **, Significant at 0.05 and 0.01probability levels, respectively, and ns, not significant; SCA: Specific combining ability

Table 9: Specific combining ability effects for grain yield and GCA effects of lines and testers under optimum environments

Lines	Testers			GCA lines
	87036	**Exp1 24**	**9071**	
Cla 17	198.45	293.24	-491.69	-197.43*
9450	97.77	532.12	-629.89	-880.92*
1368	-45.03	101.87	-56.84	546.51*
M 131	-893.42*	301.29	592.13	-867.08**
88094	84.79	-471.23	386.44	-569.49*
J18-1	905.58*	-65.83	-839.75*	-650.35**
88069	-569.85	93.37	476.48	367.32
Entrada 29	-498.58	358.29	140.28	-501.27*
CML 358	570.35	394.44	-964.79*	-146.94
Entrada 3	138.63	-330.23	191.6	-470.78*
CML 254	-643.06	508.75	134.32	84.29
5012	-115.8	254.75	-138.95	-341.08
Cam inb gp1 17	158.46	-166.89	8.43	259.45
9848	27.2	-307.46	280.26	-329.05
CLA 18	213.51	678.56	-892.06*	217.99
ATP S9 30 Y-1	634.38	-89.83	-544.55	-431.89
ATP S5 31 Y-2	173.48	-388.74	215.25	308.32
KU1414	-111.2	-58.53	169.73	274.74
5057	-536.08	394.34	141.74	-235.7
ATP S6 20 Y-2	-795.1*	339.79	455.31	-84.51
ATP S8 30 Y-3	20.04	-9.05	-10.99	185.93
CLWN201	-221.98	143.04	78.94	720.74**
TZMI 102	144.77	-11.23	-133.54	-240.31
J16-1	-337.17	332.91	4.26	728.75**
CLYN246	278.32	-232.95	-45.37	982.75**
CML395	-888.88*	621.06	267.82	125.17
CML494	45	-808.92*	763.92	-16.75
CML165	212.11	-43.25	-168.86	-59.51
CLQRCWQ26	-290.71	409.14	-118.43	640.10**
CML451	548.87	-497.01	-51.85	19.49
V-351-1/6	-285.87	-229.37	515.24	-557.39*
V-481-73	-263.1	309.21	-46.11	-751.85**
TZ-STR-133	893.04*	-624.02	-269.02	339.57
TL-11-A-1642-5	752.27	-176.46	-575.81	675.86**
Ku1409	235.94	-392.6	156.66	-26.32

ATP S6-20-Y-1	66.98	207.6	-274.58	538.19*
CML343	1.66	-516.69	515.03	402.9
CML 444	-140.04	367.64	-227.6	-250.34
4001STR	234.29	-1221.11*	986.82*	190.86
GCA Testers	**262.49****	**21.36****	**-283.84****	

*, **, Significant at 0.05 and 0.01probability levels, respectively, and ns, not significant.

Correlation between grain yield and secondary traits

Under low N environments, grain yield was positively correlated to leaf area (0.47**), leaf chlorophyll content (0.49**), plant height (0.42**) while it was negatively correlated to days to silking (-0.36**), anthesis silking interval (-0.20**) leaf senescence (-0.23**) and ear aspect (-0.58**) (Table 10). Grain yield was also correlated to all these traits under optimum and across environments.

Table 10: Pearson correlation coefficient between grain yield and other agronomic traits under low N, optimum N and across environments

Traits	Grain yield (kg ha^{-1})		
	Low N	**Optimum**	**Across**
DTS	-0.36**	-0.19**	-0.37**
ASI	-0.2**	-0.18**	-0.34**
LAREA	0.47**	0.34**	0.52**
CHLORO	0.49**	0.28**	0.54**
LSENE	-0.23**	-	-
PHT	0.42**	0.29**	0.44**
EPP	0.01ns	0.15ns	0.07**
EA	-0.58**	-0.58**	-0.64**

*, **, Significant at 0.05 and 0.01probability levels, respectively, and ns, not significant; DTS = days to 50% silking; ASI= anthesis silking interval; LAREA= Ear leaf area; CHLORO = leaf chlorophyll content; PHT=plant height; EPP=ear per plant; EA=ear aspect, YIELD=grain yield.
Discussion

Under low N, significant differences were observed among the hybrids for all traits. Five hybrids yielded more than 3500 kg.ha^{-1} under low N condition, these include TL-11-A-1642-5 x Exp1 24, CLWN201 x 87036, ATP S6 20 Y-2 x Exp1 24, J16-1 x Exp1 24, ATP S9 30 Y-1 x Exp1 24 CLYN246 x 87036. The best hybrid among the four checks evaluated was 87036 x Exp1 24, and the performance of this hybrid under low N was similar to that obtained (3 t ha^{-1}) by The *et al.* (2013). Under optimum environments, the five highest yielding hybrids were TL-11-A-1642-5 x 87036 , CLYN246 x 87036, TZ-STR-133 x 87036, CLWN201 x Exp1 24, J16-1 x Exp1 24. Each yielded more than 6000 kg ha^{-1}. Both under low and optimum environments, the best yielding hybrids out-yielded the four checks among which is the commercial hybrid (87036 x Exp1 24) for the Humid Forest Zone of Cameroon. These could be candidate for release.

GCA effects are associated with additive gene action while SCA effects are associated with non-additive gene action. Under low N, means squares of both GCA and SCA were significant for all traits except leaf senescence and plant height. This suggests that except these two traits, all other traits were controlled by both additive and non-additive gene effects. Furthermore, non-additive gene action was predominant in the control of grain yield, anthesis silking interval, leaf chlorophyll content and ear aspect while days to silking, leaf senescence and plant height were influenced mainly by additive gene effects. Similar results were earlier reported by (Betràn *et al.*, 2003a), (Makumbi *et al.*, 2011), (Meseka *et al.*, 2006; Meseka *et al.*, 2013) and (Ndhlela, 2012). However, this result contradicts those of (Below, 1997), (Kling *et al.*, 1997), (Badu-Apraku *et al.*, 2011a), (Badu-Apraku *et al.*, 2013), (Ifie, 2014) and Tamilarasi *et al.* (2010) who reported predominance of additive gene effects compared to non- additive gene effects for grain yield under low N. This contradictory results might be due to the difference in testing environments (N stress level) under which the genotypes were tested or genotypic differences among sets of genotypes included in the studies; or it might be due to the difficulties that statistical models have in predicting non-additive gene effects. The predominance of non-additive genetic effects for grain yield and other traits observed in this set of indred lines suggests that hybrid development could be employed under low N in order to exploit non additive gene action which is based on over dominance and epistasis and more predictive of heterotic potential.

Under optimum environments, grain yield, days to silking, leaf area and ear aspect were controlled by both additive and non-additive gene effects. Additive gene effect was predominant in the control of all traits except anthesis silking interval and ears per plant. The higher magnitude of additive gene effects under optimum N is consistent with the findings of Below (1997; De Souza *et al.*, 2008;Makumbi *et al.*, 2011).

Under low N, the significant correlation obtained between grain yield and all measured traits except ear per plant indicates a relationship between these traits and may justify the identification of some of these traits, especially ASI, leaf chlorophyll content, leaf senescence and ears per plant as selection criteria under low N by many researchers. (Bänziger *et al.*, 2000), (Badu-Apraku *et al.*, 2011a) reported that grain yield, number of ears per plant, anthesis-silking interval and leaf senescence were important in identifying superior genotypes under low N. Even though the relationship between yield and number of ears per plant was not significant in the present study, this trait was identified to be correlated to yield and an important selection criterion in early studies.

Conclusion

This study revealed that there is genetic variability among hybrids and it is possible to identify desirable hybrids for grain yield and other agronomic traits under low N. The hybrids CLYN246 x 87036, TL-11-A-1642-5 x Exp1 24, CLWN201 x 87036, CLYN246 x 87036, J16-1 x Exp1 24 and CLWN201 x Exp1 24 were identified as being high yielding under low N, optimum and across environments and could be released to farmers after undergoing additional evaluations followed by on-farm trials.

Under low N and optimum environments grain yield and most traits were controlled by both additive and non-additive gene action with predominance of non-additive gene effect under low N and additive gene effect under optimum N conditions. The predominance of non-additive additive genetic effects under low N for grain yield and many traits in this set of indred lines could suggest that good hybrid development could be achieved under low N through exploitation of this non additive gene effect, predictive of heterosis.

Due to the influence of non-additive gene effect under low N, SCA of crosses could be used together with means for grain yield to classify inbred lines into heterotic groups. These heterotic groups would be used for line improvement using reciprocal recurrent selection. The reciprocal recurrent selection and allow the development of new inbred lines within each heterotic group. The newly developed lines from opposite heterotic groups would be inter-crossed to produce new high yielding hybrids through exploitation of heterosis.

The best combiners for grain yield under both low N and optimum environments were, CLYN246, J16-1, CLWN201, TL-11-A-1642-5, 1368, 87036, TZ-STR-133 and EXP124. These lines could be used as parents in a breeding program to develop high yielding hybrids for low and optimum N condition.

Days to anthesis, anthesis silking interval, leaf area, leaf chlorophyll content, leaf senescence and ear aspect were correlated to grain yield under low N. Some of these traits could be used as early selection criteria to identify maize cultivars tolerant to low N.

Acknowledgement

References

Abrha, S. W., Habtamu, Z. Z. & Dagne, W. G. (2013) Line x tester analysis of maize inbred lines for grain yield and yield related traits. *Asian Journal of Plant Science and Research,* 3**,** 12-19.

Badu-Apraku, B., Oyekunle, M., Fakorede, M. A. B., Vroh, I., Akinwale, R. O. & Aderounmu, M. (2013) Combining ability, heterotic patterns and genetic diversity of extra-early yellow inbreds under contrasting environments. *Euphytica,* 192**,** 413-433.

Badu-Apraku, B., R.O. Akinwale, S.O. Ajala, A. Menkir, Fakorede, M. A. B. & Oyekunle, M. (2011a) Relationships among Traits of Tropical Early Maize Cultivars in Contrasting Environments. *Agronomy Journal* 103**,** 717-729.

Bänziger, M., Edmeades, G. O., Beck, D. & Bellon, M. (2000) Breeding for Drought and Nitrogen Stress Tolerance in Maize: From Theory to Practice. Mexico, D.F. : CIMMYT.

Beck, D., Betrán, F. J., Edmeades, G. O., Bänziger, M. & Willcox, M. (1996) From landrace to hybrid: strategies for the use of source populations and lines in the development of drought-tolerant cultivars. IN Al., G. O. E. E. (Ed.) *Developing Drought and LowN Tolerant Maize. Proceedings of a Symposium* El Batan. Pp 25-29.

Below, F. E. (1997) Growth and productivity of maize under nitrogen stress. IN Edmeades, G. O., Banziger, M., Mickelson, H. R. & Pena-Valdivia, C. B. (Eds.) *Developing drought-and low N-tolerant maize.* CIMMYT, Mexico City.

, CIMMYT, El Batan, Mexico.

Betràn, F. J., Beck, D., Bänziger, M. & Edmeades, G. O. (2003a) Genetic Analysis of Inbred and Hybrid Grain Yield under Stress and Nonstress Environments in Tropical Maize. *Crop Science,* 43**,** 807-817.

Betràn, F. J., Ribaut, J. M., Beck, D. & Gonzalez De León, D. (2003b) Genetic Diversity, Specific Combining Ability, and Heterosis in Tropical Maize under Stress and Nonstress Environments. *Crop Science* 43**,** 797-806.

Cochran, W. G. & Cox, G. M. (Eds.) (1960) *Experimental designs,* New York, USA, John Wiley & Sons

De Souza, L. V., Glauco Vieira Miranda, Galvão, J. C. C., Eckert, F. R., Mantovani, É. E., Lima, R. O. & Guimarães, L. J. M. (2008) Genetic control of grain yield and nitrogen use efficiency in tropical maize. *Pesquisa Agropecuária Brasileira,* 43**,** 1517-1523.

Giauffret, C., Bonhomme, R. & Derieux, M. (1997) Heterosis in maize for biomass production, leaf area establishment, and radiation use efficiency under cool, spring conditions. *Maydica* 42**,** 13-19.

Hauser, S. & Nolte, C. (2002) Biomass production and N fixation of five *Mucuna pruriens* varieties and their effect on maize yields in the forest zone of Cameroon. *Journal of Plant Nutrition and Soil Science* 165**,** 101-109.

Ifie, B. E. (2014) Genetic analysis of *striga* resistance and low soil nitrogen tolerance in early maturing maize (*Zea mays* L.) inbred lines. *West Africa Centre for Crop Improvement.* Legon, University of Ghana

Kempthrone, O. (Ed.) (1957) *An Introduction to Genetic Statistics,* New York, John Willey and Sons, Inc. .

Kling, J. G., Oikeh, S. O., Akintoye, H. A., Heuberger, H. T. & Horst, W. J. (1997) Potential for developing nitrogen use efficient maize for low input agricultural systems in the moist savannas of Africa. IN Edmeades, G. O., Banzinger, M., Mickelson, H.R. & Pena-Valdivia, C.B. (Ed.) *Developing Drought and Low N Tolerant Maize. Proceedings of a Symposium.* CIMMYT, El Batan, Mexico D.F., March 25-29, 1996.

Makumbi, D., Betràn, F. J., Bänziger, M. & Ribaut, J. (2011) Combining ability, heterosis and genetic diversity in tropical maize (Zea mays L.) under stress and non-stress conditions. *Euphytica,* 180**,** 143-162.

Meseka, S. K., Menkir1, A., Ibrahim, A. E. S. & Ajala, S. O. (2006) Genetic analysis of performance of maize inbred lines selected for tolerance to drought under low nitrogen. *Maydica,* 51**,** 487-495.

Meseka, S. K., Menkir, A., Ibrahim, A. E. S. & Ajala, S. O. (2013) Genetic analysis of maize inbred lines for tolerance to drought and low nitrogen. *JONARES,* 1**,** 29-36.

Ndhlela, T. (2012) Improvement strategies for yield potential, disease resistance and drought tolerance of Zimbabwean maize inbred lines. *Department of Plant Sciences (Plant Breeding).* University of the Free State, South Africa.

Ngoko, Z., Cardwell, K. F., Marasas, W. F. O., Wingfield, M. J., Ndemah, R. & Shulthess, F. (2002) Biological and physical constraints on maize production in the humid forest and Western Highlands of Cameroon. *European Journal of Plant Pathology* 108**,** 893-902.

Nguimgo, K. A. B., Balasubramanian, V., Kaho, F. & Zeukeng, P. (2003) Maize-legume rotation and association for intensive maize production in the humid forest zone of Cameroon. IN Badu-Apraku, B., Fakorede, M. A. B., Ouedraogo, M., Carsky, R. J. & Menkir, A. (Eds.) *Maize revolution in West and Central Africa. Proceedings of a regional maize workshop* IITA-Cotonou, Benin Republic, WECAMAN/IITA.

Tamilarasi, P. M., Arumugachamy, S., Anantha, M. S. & Utharasu, S. (2010) Identification of Nitrogen (N) Stress Tolerant Maize (*Zea Mays* L.) Inbred Lines for Low Nitrogen Input Condition. *Indian Journal of Agricultural Research,* 44**,** 53-57.

Tchienkoua, M. (1996) Soil and land-use survey of the northern section of the Mbalmayo Forest Reserve (Southern Cameroon). A study for the selection of the IITA Humid Forest Station site. IN 24, R. A. C. M. R. M. N. (Ed.) *Humid forest Station report N° 1.* Ibadan, International Institute of Tropical Agriculture.

The, C., Ngonkeu, M. L., Zonkeng, C. & Apala, H. M. (2013) Evaluation and selection of maize (*Zea mays* L.) genotypes tolerant to low N soil. *Optimizing Productivity of Food Crop Genotypes in Low Nutrient Soils.* IAEA-TECDOC-1721.

USDA (2013). United States Department of Agriculture

1.2.2 EFFECT OF THREE COVERING MATERIALS ON VEGETATIVE GROWTH OF CUCURBITS IN KENYA

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Abstract

Different covering materials were compared at Jomo Kenyatta University of Agriculture and Technology, Juja in Kenya on their effect on vegetative growth of cucurbits. Three structures equivalent of main treatments each having ventilation gaps were covered with 50% shade net (T1); glass (T2) and UV stabilized plastic sheet (T3) materials respectively were used. The sub treatments were cucurbits family; cucumber and butternut respectively. In each structure twelve pots were placed, six of each crop type. The experiment was laid out as a random complete block design and replicated three times, each replication consisting of two pots. Dry bulb temperature was highly significant in all the treatments with plastic house having the highest mean temperature of 33.83°C followed by glass house with 32.5 and shade house with 30°C respectively while the wet bulb temperature was not significantly different at $p<0.05$. The relative humidity in all the treatments was not significantly different at $p<0.05$ although plastic house had the highest RH of 91.5%, followed by shade house with 90.5 and glass house with 80%. There were significant differences in weeks 3, 6, 7 and 8 for plant height but no significant influence with the type of covering material. However, shade house treatment dominated cumulatively in plant height. Glasshouse treatment yielded most leaves in week 4 for Cucumber, week 6 and 7 for Butternut and week 8 for both Butternut and Cucumber. Solar rays were more direct to the plant in shade house than in glasshouse or plastic house. There was a positive correlation between light intensity and leaf area (r=0.1) showing that for every unit increase in light intensity, the leaf area increased by 0.1. Considering the temperature and relative humidity

variables and the direct effect of solar rays in the shade house coupled with plant height parameter, shade house is an appropriate structure for cucurbit production in a tropical climate.

Key Words: covering materials, cucurbits, growth, Kenya, vegetative

Introduction

In Kenya, the vegetable sub – sector is important in attaining food security and improving livelihood for smallholder farmers. Smallholders produce 100% of African Leafy Vegetables (ALVs) and up to 70% of the Exotic and Asian vegetables (HCDA, 2013). The production of vegetable crops under structures covered with materials commonly referred to as protected cultivation is gaining popularity in Kenya. Protected cultivation is the production of crops under sheltered structures covered with such materials as glass, plastic films or shade screens (saran cloth) which create a specialized climate inside the structure. Protected cultivation of vegetable crops suitable for domestic and export purposes could be a more efficient alternative for land use and other resources, improve yield, quantity and quality (Sanwal et. al. 2004, Sing et al. 1999, Ganesan, 2004). However, the profitability in protected cultivation depends upon the choice of structures, selection of crops/ varieties, production technology and market price.

Changes in the microclimate inside the structures result in modification of plant growth and development and also incidence of fungal diseases (Beckmann *et al*., 2006; Scaranari *et al*., 2008; Chavarria *et al*., 2007, 2009). In one study, interactions between protected environments and different cucumber hybrids were evaluated by Costa et al. (2010) and found that the seedling growth and dry biomass was affected by the growing environments. In greenhouse tomato production, Gent (2007) found that the use of the screen with 50% shading increased commercial fruit production by 9% compared to the environment without the screen. Comparisons between aluminized shade screens with 40, 50 and 60% shading and polyethylene plastic film painted with lime on tomato production showed that the screens minimize energy consumption during periods of low temperatures (Fernandez-Rodriguez et al. 2001). In acclimatized environment with evaporative cooling, Costa & Leal (2008) found greater accumulation of leaf biomass and greater leaf area of strawberry plants than in non acclimatized environments, regardless of the season. Shading with 40% shade net was beneficial for lettuce production (Queiroz et al. 2009). Cucumber and butternut are members of the cucurbitaceae family. The potential for increased production is immense for these cucurbit crops in the on – going rehabilitation and expansion of irrigation schemes in arid and semi – arid counties in Kenya. In the present scenario of perpetual demand for vegetables and drastically shrinking land holdings, protected cultivation is the best alternative for using land and other resources more efficiently. There is an urgent need to assess the suitability of different covering materials for cultivation of vegetables to meet the growing demand. This study investigated the effect of shade net, plastic and glass covering materials on vegetative growth of cucurbits.

Materials and Methods

Different covering materials were compared for their effect on vegetative growth of cucurbits. Three structures each having ventilation gaps were covered with 50% shade net; glass film and UV stabilized plastic sheet materials respectively. The soil media used was a cocktail of garden soil, manure and sand mixed in the ratio of 3:2:1 and put into poly tubes measuring 19 cm in diameter and 21cm height. Five (5) gms of Diammonium phosphate (DAP) was placed in the soil

media per pot, thoroughly mixed then watered. Seeds of butternut pumpkin (Curcubita *moschata*) variety 'Squash' and Cucumber (Cucumis *sativus*) variety 'Ashley' were sown in thirty six pots; eighteen pots of each crop. The poly tubes were then left in the open field for the seeds to germinate which took approximately seven days before being transferred to the protective structures. Each structure contained six pots of butternut and six of cucumber giving a total of twelve pots. The treatments were thus;

T1 – Shade house which was fully covered with 50% shade net with the door kept open for ventilation during day time

T2- The glasshouse consisted of the entire roof and four sides covered with glass but the sides alternated with glass and wire mesh.

T3 – The plastic house was made up of the four sides and the roof covered with polyethylene film with side ventilation

In each structure, the experiment was laid out as a randomized complete block design and replicated three times. Each replication consisted of two pots. Standard cultural practices for cucurbit production were followed.

Data taking and analysis
Data for solar radiation was taken using a luximeter while humidity and temperature data were taken using a wet and dry thermometer (Fig. 1 and 2). The side for measuring temperature was kept wet everyday by adding water in the container with the wick. Plant height was taken using a ruler and physical counting of leaves was done to determine the number of leaves per plant. Leaf size was determined by measuring the leaf lamina horizontally and vertically thus the leaf area was obtained by multiplying the horizontal and then vertical measurements of the leaf lamina. Horizontal measurements entailed measuring the widest parts of the leaf lamina and vertical measurements were obtained by measuring from the tip of the leaf to where the leaf stalk joined the lamina. Data collected was entered into Microsoft spreadsheets and subjected to computer statistical analysis using Genstat VSN International version 14.

Figure 1: Luximeter   **Figure 2:** Wet and dry bulb thermometer

Results

Temperature

Dry bulb temperature was highly significant in all the treatments with plastic house having the highest mean temperature of 33.83°C followed by glass house with 32.5 °C and Shade house with 30°C respectively at $p<0.05$(Table 1). Similarly, the wet bulb temperature was significantly different for all the treatments. Nevertheless, plastic house still had the highest mean temperature of 32.5 °C followed by glass house with 29.33 °C and Shade house with 26°C respectively.

Light intensity

The luxmeter readings in all the treatments was significantly different at $p<0.05$ with the highest light intensity being in shade house (440 lux) and the lowest was in plastic house (251 lux) (Table 1).

Relative humidity

The relative humidity in all the treatments was not significantly different at $p<0.05$ although plastic house had the highest relative humidity of 91.5%, followed by shade house with 90.5% and glass house with 80% (Table 1). In the glasshouse treatment there were cases of blights on leaves and the fruit that formed aborted due to fungal infection (Fig. 3).

Table 1: Means of the Wet and dry bulb temperature (°c), Luxmeter (Lux) and relative humidity (RH) for the three treatments

Treatment	Wet°c	Dry°c	RH (%)	Lux
Shade house	26c	30b	90.5a	440a
Glass house	29.33b	32.5c	80a	306b
Plastic house	32.5a	33.83a	91.5a	251c
Grand mean	29.28	32.11	87.2	333
CV%	11.5	3.6	15.2	19.4
L.S.D	4.13	1.4	16.32	79.2

Means with the same letters are not significant at $p< 0.05$

Figure 3: Butternut leaf affected with blight

Plant height

There were significant differences within varieties in weeks 3, 6, 7 and 8 but there were no significant differences with the type of covering material. Interaction between variety and treatment was not significant in all the weeks (Fig. 4). Butternut dominated in height in shade house treatment in week 3 and glasshouse in weeks 6, 7 and 8. Cucumber was the tallest in week 4 only although shade house treatment dominated in all the weeks with 2.83, 7, 10.67, 13.7, 28 and 51 cm respectively.
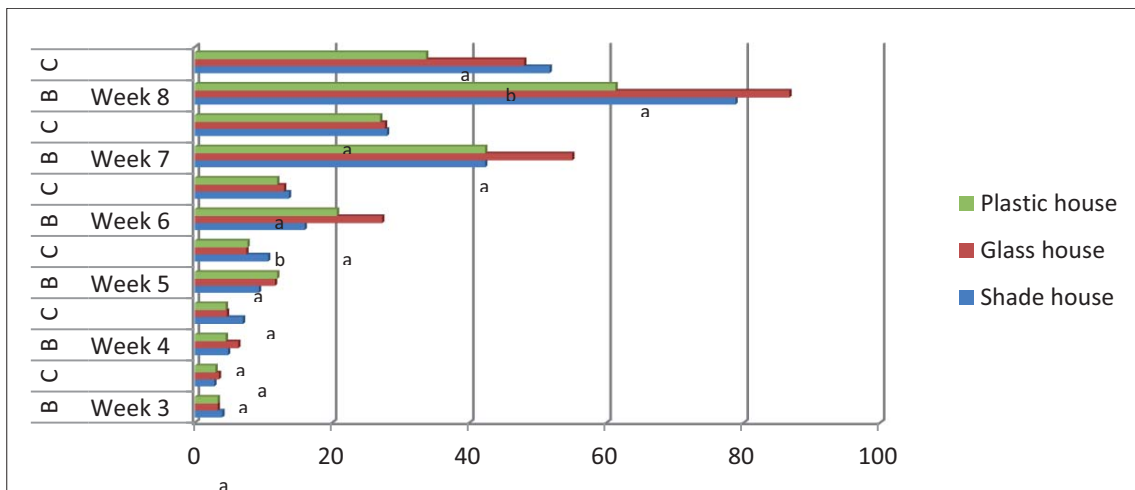
Figure 4: The influence of covering material on plant height increase from week3 to week 8. Means with the same letters are not significantly different at $p<0.05$. Key: B- Butternut; C- Cucumber
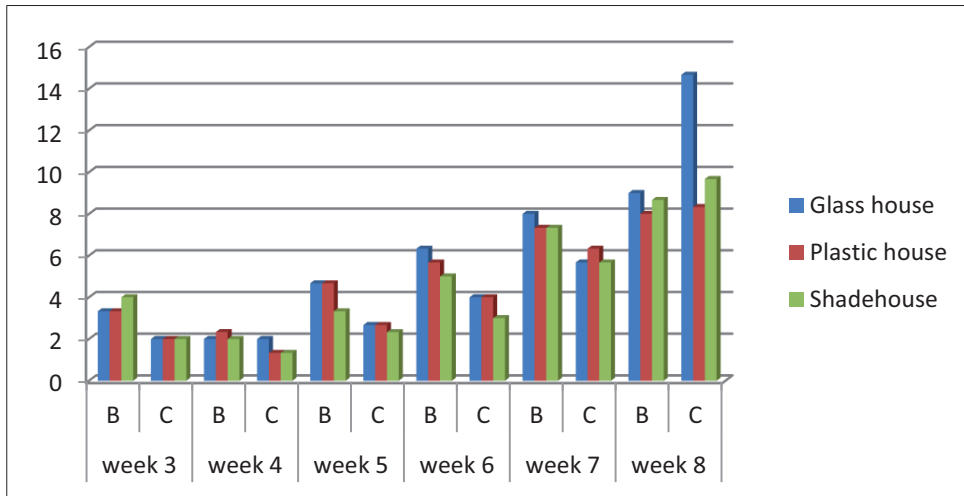
Figure 5: The number of leaves per treatment from week 3 to week 8

Number of leaves

There were significant differences within the varieties of cucurbits in all the treatments as the number of weeks increased at $P<0.05$(Fig 5). But there were no significant differences within the treatments at week level. Butternut had the highest number of leaves from week 3 to week 7 in all the treatments while Cucumber had the highest number of leaves in all the treatments in week 8. Glasshouse treatment yielded most leaves in week 4 for Cucumber; week 6 and 7 for Butternut and week 8 for both Butternut and Cucumber (Fig 5).
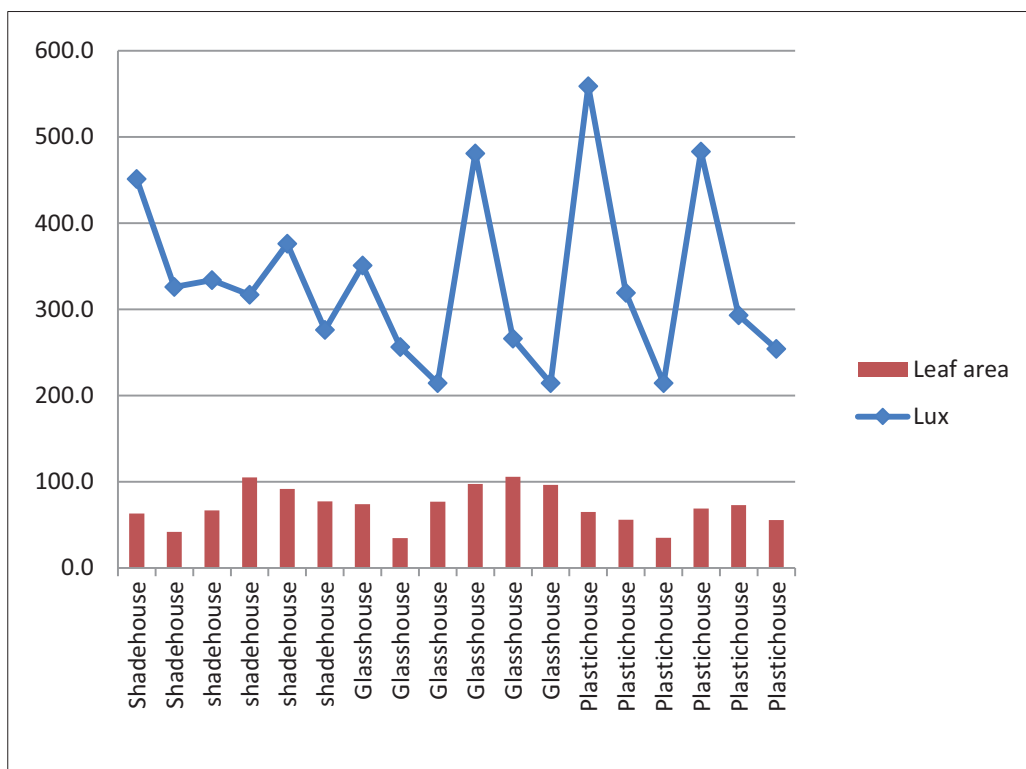
Figure 6: The relationship between Light intensity and Leaf area as influenced by covering material

Leaf area

There was a positive correlation between light intensity and leaf area (r=0.1) showing that for every unit increase in light intensity, the leaf area increased by 0.1(Fig 6). Increase in leaf area directly affected plant growth and hence plant height.

Discussions

Among environmental factors, light intensity, temperature and relative humidity influence crop growth and development in protected cultivation (Rajasekar et. al. 2013). The influence of environmental variables; temperature, relative humidity and light intensity under different covering materials were studied. The temperature in the plastic house was the highest probably due to the thermal transmissivity characteristics of plastic film. Despite plastic house treatment having significant temperatures above shade house and glasshouse respectively, dry matter accumulation that could have resulted into significant plant height was not achieved. This could be explained probably due to the fact that high temperatures could have slowed down the cell metabolic activities thus lowering the growth rate. Similar studies with radish (*Raphanus sativus* L.) showed that higher temperatures had more adverse influence on net photosynthesis than lower temperatures leading to decreased production of photosynthates (Reddy *et al*. 1999). Solar rays were more direct to the plants in shade house than in glass house or plastic house. In plastic house the light was more diffused and opaque as compared to the other two treatments. Despite the Shade house obtaining on average higher light intensity than other treatments (glasshouse and plastic house), the growth rate determined by plant height in this case was not significant.

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A high relative humidity on the one hand encourages fungal diseases (Fig. 3), because under fluctuating temperatures and sharply increasing evaporation during the first morning hours, condensation can easily occur on the crop creating the ideal conditions for fungal spores to germinate rapidly. A high relative humidity can also cause a crop to weaken and become more susceptible to changes in the weather. High relative humidity could have contributed to slower growth rate because the air was almost at the saturation point and thus the respiration rate was slowed down. If the respiration rate is slowed down, there's accumulation of photosynthates within the tissues thus this also leads to lower photosynthetic rate and hence slower growth rate. This explains the reason why there were lower number of leaves in this treatment as compared with glasshouse and shade house (Fig 5) and also lower leaf area despite the high light intensity (Fig 6). Cucumber did not exhibit significant differences in the treatments applied. Shade house treatment dominated cumulatively in plant height because of its optimal temperature of 26°c, high relative humidity of 90.5% and high light intensity that supported growth and development. This observation supports the findings of Marcelis and Baan Hofman – Eijer (1993) which indicated that cucumber require more light intensity and high temperatures for better growth and development. A larger leaf area signified a larger proportion for light interception and since light is the critical energy for photosynthesis, the more the the higher the rate of light photosynthates. These results agree with Papadopoulos and Omrod (1991) that higher leaf area increases leaf physiology and number of stomata and thus photosynthesis. This therefore leads to faster and higher growth rate as is the case in glasshouse (Fig 3). The higher the photosynthetic rate, the faster the phenological events taking place in a plant thus also the better the quality of the plant. Therefore this also could have caused the glasshouse treatment which had a lux of 306 (table 1) to have the highest number of leaves (Fig 5).

Ultimately, this study revealed that the prospect of cucurbits cultivation under shade house is promising. Other structures could also be used but only with sufficient ventilation to regulate the temperature and the humidity. In conclusion, the best protective covering for production of cucurbits and generally vegetables in areas of high temperatures and light intensity could be the Shade net. However, varietal interaction with the type of cover used needs investigation.

References

Beckmann, M. Z.; Duarte, G. R. B.; Paula, V. A.; Mendez, M. E. G. & Peil, R. M. N. (2006). "Radiação solar em ambiente protegido cultivado com tomateiro nas estações verãooutono do Rio Grande do Sul." Ciência Rural, Santa Maria-RS, v. 36, n. 1, p. 86-92,

Chavarria, G.; Santos, H. P.; Mandelli, F.; Marodin, G. A. B.; Bergamaschi, H. & Cardoso, L. S. (2009). "Potencial produtivo de videiras cultivadas sob cobertura de plastic". 44, n. 2, p. 141-147, ISSN 0100-204X.

Costa, E and Leal, P. A. M. (2008). "Avaliacao de alface hidroponica em tres a mbientes de cultivo". Engenharia Agrflola, Jaboticabal, v. 29, n. 3, p. 358 – 369, ISSN 0100 – 6916.

Costa, E; Leal, P. A. M; Gomes, V. A.; Machado, D. and Jara, M. C. 2010. Biomassa de mudas de pepines hibridos conduzidos sob ambientes protegides. *Bregantia,* Campinas, v. 69. N. 2, p. 381 – 386, ISSN 0006 – 8705.

Fernandez – Rodriquez, E. J.; Perez, D., Camacho- Ferre, F.; Fernandez Vadillos, J. and Kenig, A. (2001). "Effects of aluminized shading screens vs whitewash on tomato photochemical efficiency under a non heated greenhouse". Acta Horticulturae, v. 559, p. 279 – 284. ISSN 0567 – 7572.

Ganesan, M. (2004). " Effect of poly – greenhouse on plant micro – climate and fruit yield of sweet pepper". International Symposium on Integrated Management Practice. AVRDC. Taiwan.

Gent, M. P. N. (2007). "Effect of shade on quality of greenhouse tomato". Acta Horticulturae, v. 747, p. 107 – 112, ISSN 0567 – 7572.

HCDA, 2013." Horticulture validated report". Horticultural Crops Development Authority; www.hcda.or.ke

Marcelis, L. F. M and Baan Hofman – Eijer, L. R. (1993). "Effect of temperature on growth of individual cucumber fruits". Physio. Plantarum 87: 321 – 328.

Papadopoulos, A. P and Omrod, D.P. (1991). "Plant spacing effects on growth and development of greenhouse tomato". Canadian J. Plant Sci. 71: 297 – 304.

Queiroz, J. P. S.; Neves, L. G.; Seabra Junior, S and Costa, A. J. M. (2009). "Avaliacao da producao de genotipos de alface em diferentes ambientes, cultivados no period de inverno em caceres/ MT." In Jornada Cientifica da Unemat, Barra dos Burges - MT.

Resumes.. Barra dos Burges – MT; Universidade Estadual de mato Grosso, 2009.

Rajasekar, M, Arumugam, T and Rramash, K. (2013. "Influence of weather and growing environment on vegetable growth and yield." Journal of Horticulture and Forestry. Vol. 5(10); pp. 160 – 167.

Reddy, M. T, Ismail, S and Reddy, Y. N. (1999). "Shade and allelopathic effects of ber on growth, productivity and quality of radish (Raphanus sativus L.) under pot culture." South Indian Horticult. 47: 77 – 80.

Sanwal, S. K, Patel, K. K, Yadav, D. S. (2004). "Vegetable production under protected conditions in NEH region." Problems and Prospects. Indian Soc. Veg. Sci. 3: 120 – 129.

Scaranari, C.; Leal, P. A. M. & Pellegrino, G. Q. (2008). "Estudo de simulações de microclimas em casas de vegetação visando à aclimatação de mudas micropropagadas de bananeira cv

Grande Naine." Revista Brasileira de Fruticultura, Jaboticabal-SP, v. 30, n. 4, p. 1001-1008, ISSN 0100-2945

1.2.3 EFFECTS OF SULPHUR FERTILIZATION ON YIELD RESPONSE OF RICE

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Abstract
Sulphur (S) is an emerging nutrient limiting rice production in Tanzania particularly Kilombero district. Currently there is no a tentative critical level and S recommendations for rice in Kilombero to match with the improved varieties, change in farming practice and soil fertility decline. An experiment was conducted at Sokoine University of Agricultre (SUA) glasshouse to determine the critical level of sulphur (S) and to assess effectiveness of S application on paddy soils of Kilombero district. Sulphur was applied at rates of 0, 20 and 40 mg/ kg soil arranged in a randomized complete block design and rice SARO 5 variety was used as the test crop. Using Cate-Nelson method, the results indicated a critical level to be 6.2 S mg /kg. Seventy-two percent of 20 soils sampled during survey from Kilombero district had low levels of S (ranging from 1.4 to 6.2 mg /kg) which is below the established critical value and therefore need to apply S. Sulphur application significantly increased grain yield for soils with less than 6.2 mg/kg. For most of soils, an application of S at rates of 20 and 40 mg S/ kg soil significantly performed the same. The conclusion was soils with S below 6.2 mg /kg needs application of at least 20 mg S/ kg soil for optimal rice grain under glasshouse experiment.

Key words: Cate-Nelson method, Grain yield, Kilombero district, Sulphur critical level, Rice-SARO 5 variety.

Introduction

Soil fertility evaluation is very important when one need to increase rice (*Oryza sativa* L.) production. There is a need of improving rice production in Tanzania since the crop is an important cereal staple ranking the second after maize. The plan of Tanzanian Government is to increase annual rice production from the current 900 000 to 2.7 million tones in the coming decade and Kilombero district is among the targeted areas (Ministry of Agriculture and Food Security, 2010). However, USDA-EAC (2012) reported increase of area under rice from 905 x 10^3 in 2009 to 1 480 x 10^3 ha in 2012 and decrease in yield from 1.5 to 1.0 t/ha under lowlands rainfed of Tanzania, at the same period. Kilima (2011) reported comparable yield of 971 kg/ha in Kilombero district under rainfed condition. This is far below the yield potential of 4.3 to 6.5 t/ha, for some common rice varieties like SARO 5 (Msomba *et al*., 2002). Several factors such as low soil fertility, imbalanced application of nutrients, pests and diseases, inadequate water for irrigation, and inadequate water management contributed to the low and declining yields (Msolla, 1991; Kilima, 2011; Semoka *et al*., 2012).

Few rice farmers are using inorganic fertilizers in Tanzania and for those applying fertilizer nitrogen is of main nutrient used. Rice growers in Tanzania rarely apply phosphorus, potassium, sulphur and other nutrients. Therefore inherent soil nutrients are gradually declining due to

intensive cropping with high yielding varieties (e.g. SARO 5), little use of inorganic fertilizers and improper management of those nutrients particularly soil organic matter.

Furthermore, low levels of S has been reported in soils of Kilombero (Massawe and Amuri, 2012). Another study by Semoka *et al* (2012) found 40 % of soil samples taken from five rice-producing areas of Kilombero district to have low levels of S. This implies application of S fertilizers is necessary. For fertilizers application to be done soil testing by analyzing a nutrient is very important in reference to the critical level of that nutrient in the soil. Currently, there is neither a tentative critical level nor S recommendations established for rice in Tanzania to match with the improved varieties, change in farming practice and soil fertility decline.

Some researchers worked on establishment of critical values that to be adopted when one assesses soil S in the soil (Landon et al., 1991). However, soil critical level and nutrients availability are affected by several factors like soil type, irrigation and drainage, exchangeable cations and salts. Therefore a need for critical levels to be used in the areas where they were established. Since S deficient is prominent nowadays and rice farmers in Kilombero need to use fertilizers containing S to maintain its optimum levels, this study aimed to establish critical levels and optimal levels for S application in the area.

Methods
Soil samples for the green house experiment conducted at SUA were collected from Kilombero district, Tanzania which is located along the Kilombero valley. The area receives an annual rainfall range between 1200 to 1400 mm falling between December to June and annual temperature ranges between 26 to 32 $^{\circ}$C (Kato, 2007). The study area is located in the elevation between 266 to 318 meters above sea level and coordinates range between longitudes 35.54294 to 36.54863 and latitudes 7.50141 to 8.19438.

Within Kilombero district, 20 villages famous in rice production were chosen randomly during survey and soils were collected for laboratory nutrients analysis. After analysis, soils of nine villages/sites with varied levels of S were collected for the green house experiment at SUA. The experimental units were arranged in a randomized complete block design (RCBD) with three replicates. Sulphur was applied at rates of 0, 20 and 40 mg/kg soil and the details of treatments are in Table 1. Other nutrients were applied at levels assuming they will not limit the response of S and biological yield. Potassium was applied 400 mg K/kg soil as KCl, Phosphorus was applied at 80 mg P / kg soil from triple super phosphate. Zinc was applied at 5 mg Zn/kg soil) as $ZnSO_4$. Calcium was supplied as $CaSO_4$. These fertilizers supplied S. In a treatment that was not applied with S ZnNO3, CaCl2 was used to supply Zn and Ca. Magnesium was applied as MgO. All nutrients were applied at planting except N, which was applied at 21 and 49 days after sowing (DAS). The source of N was urea.

Eight pre-geminated seeds of rice (variety SARO 5) were sown in the plastic pots of five liters capacity potted with 3.8 kg of 8 mm sieved soil. Potted soils were moistened to field capacity and equilibrated for one day before sowing. Water content was maintained close to field capacity for the first 21 days after which urea was applied and potted soils were flooded. Thinning also was done at 21 DAS to remain with two seedlings. Out of two, one was harvested by cutting 1cm above the soil surface at 56 DAS. Shoots were dried at 70C to constant weight ready for dry matter yields and plant tissue analysis. The remaining plant was grown to maturity for yields determination.

Table 1: S treatments

Treatments P mg/kg soil	Description
$P_0N_0K_0Zn_0 S_0$	No any nutrient was applied
$N_{600} P_{80}K_{400}Zn_5 S_0Mg_{24}$	All necessary nutrients applied except S
$N_{600}P_{80}K_{400}Zn_5 S_{20}Mg_{24}$	S was applied at a rate of 20 mg/kg soil
$N_{600}P_{80}K_{400}Zn_5 S_{40}Mg_{24}$	S was applied at a rate of 40 mg/kg soil

Soil laboratory analysis

A representative half kg of soil sample was collected from each site for laboratory analysis. Soil pH was analyzed (1: 2.5 soil: water) by electrode method, total nitrogen by Kjeldahl wet digestion-distillation method, extractable P by Bray-1 because were acid soils, , cation exchange capacity, basic cations (Ca, Mg, K and Na) by NH4Ac saturation method, micronutrients (Cu, Fe, Zn, Mn) by DTPA method, texture by hydrometer method after dispersion with Na hexametaphosphate. Page *et al*. (1987) has detailed procedures followed during laboratory soil analysis. Extractable SO_4-S was analyzed by $BaCl_2$ turbidity method.

Soil pH for the soils used in the experiment ranged from 4.5 to 6.1 termed acidic to strong acid.

Phosphorus ranged between 1.9 and 12.6, soil with low P it was adjusted by applying TSP. Some soils had low levels of K and were adjusted by applying KCl. Seventy-two percent of 20 soils sampled from Kilombero for the experiment (only nine mentioned) had low levels of S (ranged from 1.4 to 6.2 mg /kg). These soils are expected to show S fertilizer response.

Table 2: Selected agrochemical characteristics of soils used in the green house experiment

Site	pH	P (mg/kg)	Ca	K	Mg	Zn	SO4 –S (mg/kg)
Kisawasawa-2	5.1	12.6	4.7	0.3	2.8	2.6	1.9
Signali-2	6.1	20.7	10.0	0.5	3.0	3.4	7.6
Mbasa-1	4.5	1.9	0.9	0.1	0.1	0.4	1.3
Magombera-2	4.9	1.9	1.6	0.1	0.7	1.3	2.4
Mkula-1	5.3	2.3	4.3	0.2	1.5	2.1	6.2
mkula-2	5.9	2.2	8.0	0.2	4.5	1.6	4.5
Mangula -1	5.6	2.0	6.7	0.2	2.9	0.2	12.1
Mangula -2	5.6	11.3	6.0	0.2	2.4	1.5	11.6
Mngeta-1	5.8	7.1	6.7	0.5	2.6	3.0	4.1

Critical levels establishment by Cate and Nelson Procedure

Critical levels of sulphur availability was determined by (Cate and Nelson, 1965) graphical method following several steps as follows: (1) making the distribution diagram of the relative

percentage yield on the Y axis and S soil test values on the X axis, (2) drawing the distribution diagram and put the two lines intersect (cross axis) which divides quadrant into four parts. The lower left quadrant and right upper quadrant as positive and the left upper quadrant and lower right quadrant as a negative (3) then cross slide axis in a fixed position until the number of points in the positive quadrant as much as possible, while at the quadrant negative as little as possible (4) the intersection of the cross axis with X axis is a critical level nutrient value of S. Positive quadrant left of the critical threshold is low class and can respond with S while the positive quadrant area to the right of the critical threshold is high class and no response of S application expected.

Relative grain yield % calcuated as:

Grain yield of S control treatment x100 …………………………………..(i)

Maximum yield of treatment with all nutrients

Results

Critical Sulphur Level in Soils

Estimates of critical concentration of $S-SO_4$ by turbidmetric procedure using the Cate and Nelson graphical method (Cate and Nelson method, 1965) is given in Fig.1.The tentative critical S levels under pot condtions were 6.2 mg/ kg. The lowest relative yield was obtained at 1.9 mg S/kg and the highest relative grain yield was obtained at 12.1 mg/kg. It was assumed treatments with relative yield higher than 80 percent will not respond with S application.
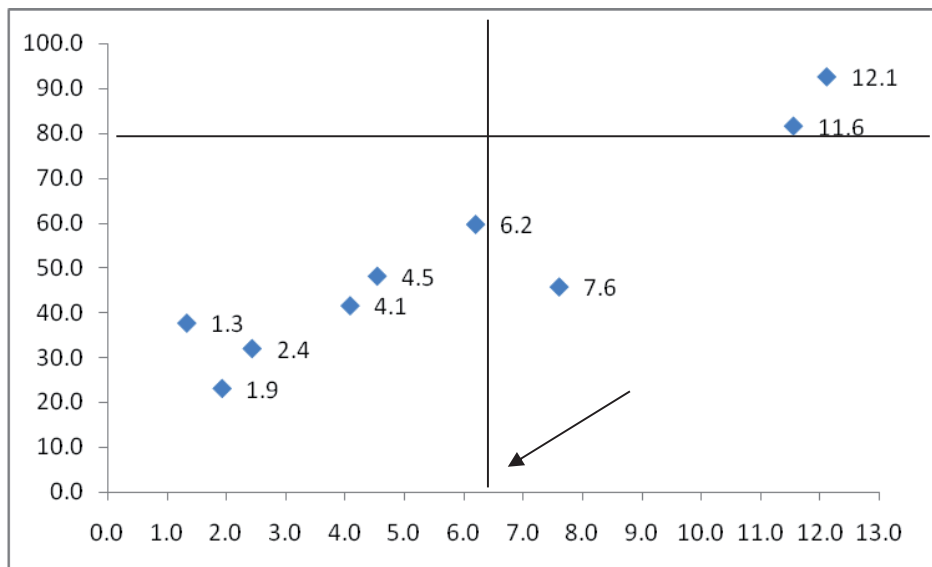
Figure 1: Relative Yield Grain weight (%) Vs   Sulphur concentration (mg/kg)

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Grain yield

Perusal of data revealed that minimum rice yield was recorded in the absolute control treatment while the highest grain weight was recorded in the treatment with the rate 20 mg S/kg soil. Absolute control grain yields ranged between 5.3 to 12.1 gm per pot.

Table 3: Grain yield response to S applied to soils from different villages of Kilombero district

Nutrients	applied (mg/kg soil)				
Village/ site	$P_0N_0K_0Zn_0 S_0$	$N_{600}P_{80}K_{400}Zn_5 S_0Mg_{24}$	$N_{600}P_{80}K_{400}Zn_5 S_{20}Mg_{24}$	$N_{600}P_{80}K_{400}Zn_5 S_{40}Mg_{24}$	L.s.d.
Grain yield (gm)/plant					
Mngeta-1	8.3 a	27.97 b	67.4 c	50.13 c	17.76
Signali	9.9 a	30.23 b	60.83 c	66.17 c	18.83
Kisawasawa	4.5 a	11.7 a	45.53 b	50.87 b	25.54
Mkula-2	12.1a	26.07 b	54.2 c	46.37 c	8.60
Mbasa-1	4.5 a	17.7 a	46.33 b	47.07 b	8.50
Magombera	4.6 a	15.13 b	46.67 c	47.4 c	5.54
Mangula -2	7.5 a	47.2 c	51.47 c	57.83 c	8.97
Mangula -1	10.8 a	63.17 b	68.2 b	59.73 b	11.23
Mkula-1	8.63 a	30.5 b	39.87c	51.13 d	7.90

Mean in the same row followed by the same letter are not significantly different at $P \leq 0.05$ using New Duncan Multiple range test.

l.s.d. = least significant difference

Treatment abbreviations with subscript numbers on each element indicating nutrient rates applied in kg/ ha

Discussion

Grain Yield

There was no nutrient that was applied in the absolute control treatment, then S was not necessarily a limiting nutrient but various nutrients influenced the grain yield according to Liebig's law of nutrient concentration. Application of S at different rates was significant in increasing grain yield for most of soils. There was no a significant response in increasing grain yield when S was applied for the two soils collected from Mangula-1 and Mangula-2 over the control S treatment. These soils had higher S-SO4 concentration i.e. 12.1 and 11.6 mg/kg respectively. There was a grain yield significant increase due to application of S for eight soils namely Mkula-1, Magombera, Mbasa-1, Mkula-2, Kisawasawa, Signali and Mngeta-1over the S control treatment. These soils had S level below 6.2 mg/kg which is set as a critical level. It indicates in these areas application of S is necessary for increasing yields. Rahman (2009) reported a significant increase of grain yield when S was applied in a field experiment with soil sulphur 10.73 ppm in the Brahmaputra floodplain of Bangladesh.

No significant difference observed for S application at rates 20 and 40 mg/kg soil for eight soils. Excluding Mkula -1 where significantly S applied at 40mg/kg, increased grain yield compared to 20 mg/kg soil. Singh (2012) recorded increase of grain yield when S was applied above 20 kg/ha but the increase was lower to 30 and 40 kg/ha rates. Rasavel and Ravichandran (2012) indicated the increase in the grain yield when S was applied at 20 and 40 kg/ha on neutral and alkali soils.

For soils with S less than 2 mg/kg soil given that other nutrients were applied no significant difference observed between the absolute control treatments and S control treatments, implying that for farmers in Mbasa and Kisawasawa an application of other nutrients without S will not change grain yields compared to those applied nothing. The explanation was S is a limiting nutrient in these two areas collected from Kilombero when consider Liebigs law of minimum (Ploeg *et al*., 199). The law states "if one crop nutrient is missing or deficient, plant growth will be poor, even if the other elements are abundant".

Critical S level in Soils

According to Cate and Nelson graphical method six soils (67 %) had S concentration low to the response level and application of S will result on grain yield increase while two of them were in the class of no response. Considering 20 soils sampled during survey when establishing this study about 72 % were below the S critical level. This implies that majority of soils in Kilombero, S application is very important when one is targeting higher grain yield. These results are similar to those of Landon, (1991) who suggested S critical level to be betweeen 6 - 12 mg/kg) for most of crops. Dobermann and Fairhust (2000) suggested the critical level of less than 5 mg/kg using 0.05 M HCl extractant.

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Conclusion

Sulphur is among of the deficient nutrient in most soils of Kilombero district. Critical level using Cate-Nelson method, the results indicated a critical level to be 6.2 S mg /kg, therefore response to S application is expected when it is applied to soils with S concentration below to that level. Soils with less than 2 mg S/ kg, an application of other nutrients will not improve yields at all until S is applied.

Recommendations

Validation of these results under farmers fields is necessary such that an appropriate recommendation is achieved.

References

Dobermann, A. and Fairhust T. (2000). Rice Nutrient disorders and Nutrient and Nutrient management. International Rice Research Institute. P 191.

Kato, F. (2007). Development of major rice cultivation area in the KilomberoValley, Tanzania. *African study Monograph* 36: 3- 18

Kilima, F.T M. (2011). *Scaling up Minjingu Phosphate Utilization for Balanced Fertilization of Crops in Tanzania.* Participatory socio-economic and agronomic baseline survey Report. Sokoine University of Agriculture, Morogoro 51pp.

Landon, J.R. (1991). *Booker Tropical Soil Manual:* A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics. John Wiley and Sons, New York. 474pp.

Massawe, B. H. J. and Amuri, N. (2012). *Soil Fertility and Agronomic Practices Evaluation for Improved Rice Production in Lowland rice Producing areas Kilombero and Wami Valleys.* A Report for ACDI/VOCA Project. Morogoro, Tanzania. 255pp.

Ministry of Agriculture and Food Security (2010). *Serikali kuongeza uzalishaji Wa Mpunga.* In: Kilimo Ushirika Tanzania. Jarida la Wizara ya Kilimo Chakula na Ushirika.Toleo Na.1-2. Desemba 2010.

Msomba, S. W., Kanyeka, Z. L., Kihupi, A. N., Penza, M.S. and Alluri, K. (2002). Rice Ecosystem in Tanzania. *International Research Notes* 20:1-13.

Msolla, M.M. (1991). Response of rice to Zinc in Igunga and Nzega Districts. Dissertation for Award of MSc Degree at Sokoine University of Agriculture,, Morogoro, Tanzania, 152pp.

Msomba, S. W., Kanyeka, Z. L., Kihupi, A. N., Penza, M.S. and Alluri, K. (2002). Rice Ecosystem in Tanzania. *International Research Notes* 20:1-13.

Page, A.L. Miller, R.H. Keeney, D.R. Baker, D.E. Roscoe E. Ellis, J. and Rhodes, J. D. (1982). *Methods of Soil Analysis. II. Chemical and Microbiological properties.* Second Edition. Madison, Wisconsin, USA. 1159pp.

Rahman M.S.Ahmed M. U. Rahman M.M Islam M.R and Zafar A.(2009). "Effect of different levels of sulphur on the growth and yield of BRRI Dhan 41". Bangladesh Research Publication Journal. Vol. 3 No.1 pp 846 -852.

Rasavel, M. and Ravichandran M. (2012). "Effect of zinc phosphorus and sulfur interactions on growth and yield of rice under neutral and alkali soils", International Journal of Material Sciences and Chemistry, Vol. 1, No. 1, pp. 12-14.

Semoka, J.M.R, Ikerra, S.T., Nyambilila, C. Msuya – Bengesi, C. and Kullaya, I. (2012). *Scaling Up Minjingu Phosphate Utilization for Balanced Fertilization of Crops in Tanzania.* Technical Report for the Project on 2010 -2011. Sokoine University of Agriculture, Morogoro. Tanzania. 16pp.

Singh A. K., Manibhushan M. K. Meena and Upadhyaya, A. (2012). "Effect of sulphur and zinc on rice performance and nutrient dynamics in plants and soil of indo gangetic plains" Journal of Agricultural Science, Vol. 4, No. 11; 2012. pp 162 – 170.

United States of America- East African Community Rice Report (2012). USDA review of policy constraints on competitive EAC rice production. Informed analysis, expert opinions. [http://agritrade.cta.int] site visited on 20/3/2013.

van der Ploeg, R.R., W. Böhm, and M.B. Kirkham. (1999). "On the origin of the theory of mineral nutrition of plants and the Law of the Minimum." Soil Science. Society. American . Journal. Vol. 63 pp. 1055-1062.

1.2.4 RESOURCE USE EFFICIENCY IN RICE BASED FARMING SYSTEMS: A CASE OF UPLAND AND PADDY RICE IN NAMASAGALI SUB-COUNTY KAMULI DISTRICT

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Abstract
Rice is an emerging and one of the increasingly important cereal crops grown in Uganda. Being a relatively new crop, farmers are faced with a challenge of effectively utilising resources and their combination for maximum productivity and therefore profit. Therefore the study identified the determinants of efficient rice production in Namasagali sub-county with a backdrop of ensuring food security and enhancing the sustainable use of wetlands. The factors assessed were land size devoted to rice farming, motive of the farmer, education level, family size, labour, and use of ox-plough, farmer's experience, gender, rice type, fertilizer application and land ownership. A logistic regression and the Cobb-Douglas production function model were used to find the determinants and the level of technical efficiency respectively. Results show that out of the 11 factors assessed, 7 were found significant at 5% level of significance. Land size devoted to rice cultivation was the most significant factor determining technical efficiency in the area. Others are education level, experience, motive of the farmer, family size, labour and use of ox-plough. However, rice type, fertilizer application, gender and land ownership were insignificant. The Cobb-Douglas results show that the farmers in Namasagali sub-county are generally technically inefficient due to decreasing returns to scale of production, implying that key factors of production are over-utilized. It is therefore recommended that farmers should shift to upland rice cultivation especially NERICA 4 which is high yielding one so as to divert attention and ensure limited exploitation of wetlands.

Keyword: Resource use efficiency, Rice, Technical efficiency, Uganda, Upland, Wetland,

Introduction

According to (27), rice is an emerging crop with foreseen positive benefits towards the livelihoods of farm households and processors in Uganda. It is a major intervention identified in the Ministry of Agriculture Animal Industry and Fisheries (MAAIF) development Strategy and Investment Plan (DSIP) 2009/10 -2013/14 for food security and poverty reduction in Uganda (11). Introduced in 1942, rice is mostly grown in wetlands by small holder farms mostly located in eastern Uganda. The current consumption estimate of 225,000 metric tons is way above the total production of 165,000metric tons. In view of the current population growth rate of 3.2%, the gap between production and demand for rice is expected to increase even more. Uganda adopted NERICA 1, 4 and 10 varieties in addition to the old lowland varieties. Since the introduction of upland rice in 2002, rice farming has grown from 4,000 farmers to over 35,000. From the earlier releases of three upland rice varieties in Uganda in 2002, farmers were able to reap $9 million (14.9 billion) in 2005. In the process, the country has seen rice imports drop between 2005 and 2008. This trend of events according to the National Agricultural Research Organization (NARO) saved the country about $30 million in foreign exchange earnings.

However, with continuous cultivation farmers are experiencing low and declining rice yields-greatly affecting their income and food security (27). Rice yields as low as 0.9-1.1 metric-tons per hectare have been recorded on farmers fields (27). Rice production is constrained by low and declining nutrient and water availability, various pests and diseases, lack of information on the optimal use of resources for rice production, ineffective marketing and extension system and inadequate policies on agricultural inputs and finance (27; 11). These factors are exacerbated by undesirable effects of climate change. Furthermore, the inappropriate rice cultivation practices have affected wetland biodiversity and water conservation functions of the wetlands. Upland rice varieties are promoted to reduce pressure on wetlands and thus sustain wetland ecological functions amidst rice cultivation. This study identified the economic benefits and determinants of efficient rice production in Namasagali sub-county with a backdrop of ensuring food security and enhancing the sustainable use of wetlands.

Materials and Methods

The study Area

Namasagali sub- County is bound on the east by Nile River in Kamuli district, and 60 km north of Jinja town in Uganda. It is endowed with land resources of which wetlands and floodplains are prime for rice cultivation. The area is characterized by a bi-modal rainfall with peaks in March – June and August – November with the March - June peak being the major one. The annual average rainfall is 1,350 mm with a mean monthly rainfall of 75 mm - 100 mm (19). There has been a trend of pronounced dry seasons in this sub county over the recent years. Temperatures in most areas of the sub county range from 19^0C to 25^0C
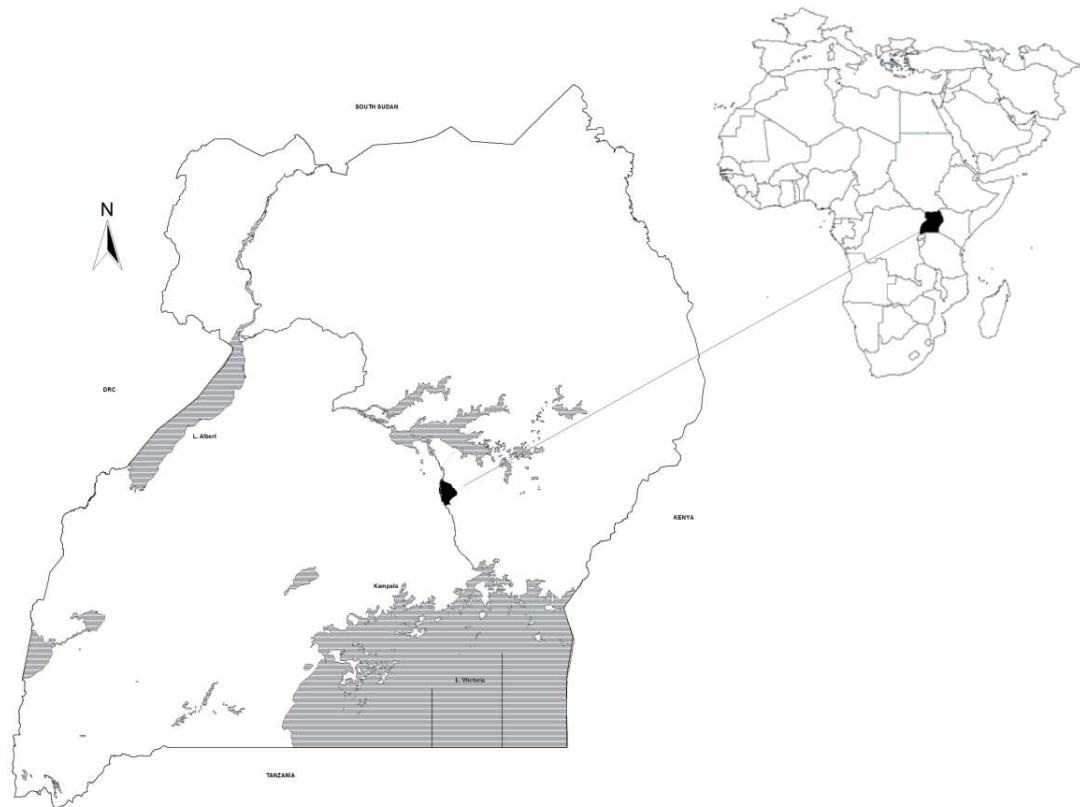
Figure 1: Location of Namasagali sub-county

In Namasagali sub-county, maize is a staple and most widely grown crop. Therefore the analysis of rice as a source of food security was made in comparison to maize. Rice cultivation is a new enterprise that is picking up fast. Rain-fed upland and paddy rice varieties are grown with an increasing tendency of farmers growing upland rice in wetlands especially during the dry seasons. Upland varieties grown include NERICA 1& 10, NERICA4 and NARIC 1 while the paddy varieties include *Kaiso* and *Super* with *Kaiso* dominating. *Kaiso* variety was considered in this study.

Both qualitative and quantitative data was collected using crop yield surveys, individual interviews using a pre-tested structured questionnaire. Parameters collected and analysed included crop yield, the cost of purchasing or hiring land, cost of planting materials, labour (Ploughing, weeding, bird chasing, harvesting, bush clearing), sun-drying, cost of drying material, transport costs from fields to homes and from homes to processing mills, bio data, aspects related to sustainable wetlands use and food security.

Both purposive and snowball sampling techniques were used to collect data from rice growers. A sample size of 50 households was sampled from the villages of Bwizza, Kakaanu, Nalwekomba, Kapalaga, Kisaikye, Namakoba, Malugulya, Kabbeto and Mutukula.

Field plots of 2m x 2m were diagonally established in farmer's plots during the April – August season of 2012. Quantities of grain from these plots were translated in crop yields with averages used for statistical analysis. STATA11 and MINI TAB 15 programs were used to analyse data.

Descriptive, cross tabulations, cost-benefit analysis, logistic regression model and Cobb-Douglas production function models were used to analyze the data.

Logistic regression model:

A logistic regression model was used to analyze the factors that determine rice yields as well as the technical efficiency in rice production especially the socio-economic factors that could not be analyzed by the Cobb-Douglas production model. It was preferred to other models such as Probit and logit because of its mathematical simplicity. The logistic regression model was chosen because its dependent variable is binary and can only take two values. Also, it allows one to estimate the probability of a certain event occurring. The general operational model was as follows

Logit $(P_i) = \ln(P_i / 1 - P_i) = \alpha + \beta_i X_i + \cdots + \beta_k X_k + \gamma$

Where -The ratio Pi/1-Pi is the odds ratio, Pi - probability that a farmer is efficient, 1-Pi - probability that a farmer is not efficient, Xi - various independent variables, B$_I$- estimated parameters, V - stochastic term.
Therefore the model for analysis is as stipulated below
YIELD = β_0 + β_1VARIETY + β_2Fsize + β_3Landownership + β_4Rlandsize + β_5 Rexperience + β_6Rmotive + β_7Hirelab + $\beta_8$oxplough + β_9Fertilizer + β_{10}Education + B$_{11}$Gender
Cobb-Douglas production function model:

This production function was used to analyze the factors that influence rice production especially those that are concerned with technical efficiency. The reason behind using this type of production function is that it is linear in its logarithmic form, and allows for the usage of Ordinary Least Squares (OLS) which was also applied in the above specified linear regression model. It has been also widely used for production function analysis by many researchers world-wide. In theory it is expressed as below:

$$Y = AL^\alpha K^\beta$$

Where; Y= output; A- constant; L- labour; K-capital; U- error term α and β - elasticizes of production

For constant returns to scale, the sum of the coefficients, β and α must be equal to one (K=1). For increasing returns to scale, they must be greater than one (K>1), and for decreasing returns to scale they must be less than one (K<1).
The model was used mainly because of its mathematical simplicity, secondly it has limited effect on empirical efficiency measure and not exclusive to labor and capital alone but also other production inputs. Short-comings of this function model include the inability to represent all the three stages of the Neo-classical production function thereby representing one stage at a time and lastly the elasticities in this model are constant regardless of the amount of inputs used. The specific model for this study relating to the production of Y, to a given set of inputs X, and other conditioning factors is presented as follows:
Y =a $X_1^{b1}X_2^{b2}X_3^{b3}X_4^{b4}X_5^{b5}X_6^{b6}$ v

Where; Y- total yield of rice produced (kg), X_1- land devoted to rice (acre), X_2- quantity of seeds used (kg), X_3- fertilizers used (kg), X_4- pesticides used (in kg), X_5- labour used (in days), X_6- capital/ Ox plough, β1…..β5 are parameters to be estimated and v-error term.
To allow for use of the Ordinary Least Squares procedure, the Cobb-Douglas production function was linearised using logarithms. Taking logarithms on both sides, the model would be:

$$\ln a + \ln \beta_1 X_1 + \ln \beta_2 X_2 + \ln \beta_3 X_3 + \ln \beta_4 X_4 + \ln \beta_5 X_5 + \ln \beta_6 X_6 + V$$

Results

Social characteristics
Rice is a new introduction in this part of the country with about an equal number growing upland and low land rice type. With an average household size of 6(Table 1) and the youthful majority of rice farmers who use an average of 1.3 acres (Table 1), the rice enterprise is sure of a reliable supply of labor mostly literate to support the rather labor intensive rice enterprise. This observation is in line with the country's population structure that is dominated by youths (35).

Analysis of rice production as a source of food security

According to (17), it requires 1700kg of maize to feed a single family of 6 people annually and 0.63ha of land is required to produce the equivalent maize grain. Therefore it costs USD 816 to feed a family of 6 people with maize flour for a period of one year. Table 2 shows that the net returns from rice grown on land equivalent to 0.63 ha of all the rice varieties are paddy (USD 963.46), NERICA 1(USD 884.77), NERICA 10 (USD 884.77), and NERICA 4(USD 1,171.93). It is evident that rice growing can serve to ensure food security in the area since the farmer can be in position to buy food and remain with surplus income to invest in other economic activities including saving for future investment.

Costs-Benefit Analyses for the different rice varieties
Results in Tables (3) indicate that the benefits of growing paddy rice are generally close to upland rice varieties with the exception of NERICA 4 that portrays superior benefits. This therefore implies that farmers as well can start growing upland rice varieties instead of the paddy rice varieties. This will enable them to enjoy the benefits of upland rice while conserving the wetlands to ensure flood control, sinking functions, resource base, among others; this was also noted by other researchers (18).

Logistic regression model result
The results indicate that the 7 significant variables; family size, farmer's experience in farming, land size devoted to rice, use of ox plough, education level, cost hiring labour and the motive of growing rice. It does indicate the importance of these factors in rice cultivation.

Farmer's farming experience (years)
It is positively significant at 5% level of significance (p>t =0.043), (Table 5), with the implication that there is a positive relationship between the farmer's experience in farming and the rice output that is likely to be harvested. It is known that the more experience a farmer has, the better the use of available resources. It is a pointer to the improvement of productivity and

technical efficiency. According to (16), many rural rice farmers have low levels of education but with much experience in rice production that enables them to harvest rice yields since they are versed with the field practices.

Education level

There is a positive significant linear relationship between the efficiency in rice growing and the level of the farmer's education. Greater schooling could enhance farm efficiency, either through acquisition of knowledge relevant to agriculture and the usage of available resources efficiently or enhanced adoption of technology

Land size devoted to rice

The variable land size devoted to rice (table 5), is positively and highly significant at 1% level (p>t =0.000), which is the most significant variables found. The implication is that there is a positive relationship between land size devoted to rice and rice yield.

Family size

Family size is highly significant at 1% level (P>t=0.001), which happens to be one of the most significant variables, but negative. Labour input replaces capital input and the majority of family labour is applied to rice, so access to family labour is an important catalyst for increasing yield. Therefore, it eases the labour constraint faced by most rice farmers in Namasagali sub- County. However, the result implies that there is negative relationship between family size and yield of rice produced implying an optimum amount must be selected for an acre because too many of them impose a negative relation and too little affects the output as well.

Use of Ox plough

Using an Ox plough by the farmer has a positive relation with the output of rice, and is significant at 5% level (p>t= 0.017). There its use helps to improve on the efficiency other than using the traditional means of ploughing that are time consuming and inefficient, according to one respondent, it takes 2 days to plough an acre of land using the oxen and it takes a minimum of 2 weeks for two energetic men to plough an acre of land. Therefore as regards efficiency in rice production use of Ox plough is very paramount.

Hiring of labour

This variable has a positive relationship with rice production, and significant at 5% level (p>t=0.045). This implies that as regards rice production efficiency in this area care should be taken when determining the number of laborer's to hire for use. This appears like that that's slightly significant because in this area farm production is highly dependent of family labour as shown by the significance on family size towards rice production.

Motive of growing rice

This is another key variable identified as very significant in determining rice yields in Namasagali sub-county with a positive and significant relationship. This implies that the mindset and aim of a farmer determines very much his/her levels of action towards ensuring high yields and efficiency in production as a farmer will endeavor to allocate the resources optimally to ensure profitability

Cobb-Douglas production function model results:
The main reason for using Cobb-Douglas production function is to determine the technical efficiency of rice growing of the farmers in Namasagali sub-county. There are a number of variables that are usually known to affect agricultural production for cereals rice in particular. As a result, it is important to use a model that relates production to those variables for a better understanding of the functional relationships. The results indicate that out of 6 variables used in the Cobb-Douglas, 5 were identified to be significant with one being negatively significant. This implies that there is an input to output relationship.

Elasticity of production
The results (Table 6) indicate that the estimation of the production function resulted in adjusted R- squared of 0.67, indicating that the independent variables included in the model account for about 67% of the variation in rice production in Namasagali

Land size devoted to rice
The result shows that the size of land devoted to rice is an important factor in rice production. With a positive and highly significant elasticity, an increase in one acre of land devoted to rice can result in 31.0% increase in the total yield of rice.

Ox plough use
Cost of hiring the Ox plough was used as a proxy for capital. The elasticity coefficient of Ox plough is significant but negative, which indicates that the input is paramount but farmers are over-utilizing it in the production of rice.

Seeds used per farm (kg)
The elasticity of seeds is positive, and also one of the highly inputs significant at 5%. The results indicate a 1%change in the quantity of seeds is associated with a 28.1% change in the total rice yield ceteris paribus.

Labour
The elasticity of labor is significant but negative where a decrease by one unit of this variable results in 9 % decrease in the rice yields.

Fertilizer used (kg)
According to the results in table 6 a 1% increase in the quantity of fertilizer applied is associated with a 25% increase in the total yield of rice.

Pesticides
This variable is negatively related and not significant at all as regards production of rice in this area. It should be noted that few farmers apply pesticides to their rice crops. This is based on the reason that rice is relatively a new cereal crop in this area and therefore the case of pests and diseases infestation is still low and hardly reported by many farmers in this area.

Return to scale

For constant return to scale, the sum of the technical coefficients β and α must be equal to one (K=1), for increasing return to scale, they must also be greater than one (K>1), and for decreasing return to scale they must be less than one (K<1).The regression results indicate that the sum of b`s is less than one (K<1), where K is the sum of the coefficients a and b, thus simply indicating decreasing return to scale. This serves to indicate that the output of rice is priced below the marginal costs of production. It also serves to imply that the factors are over utilized which result in them being technically inefficient in the cultivation of rice.

Discussion

The socio-economic characteristics displayed in Table 1 favor the production of rice, a labor intensive crop. In line with the country's population structure (35), a youthful family of 6 does present the labor to support rice production. Labor is a critical factor in rice production as observed by several studies (10 and 1).The labour scenario shows situations of disguised un-employment and therefore farmers have to be very keen when determining the number of worker for matters of productivity and profitability. Farmers contend that upland rice yields highest in wetlands and this coupled with the available labor is likely to ensure a continued production of rice in wetlands. This presents a challenge to conservationists to devise proper mechanisms of striking a balance between rice production levels and wetlands conservation. Access to land is one of the most important variables, explaining the differentiation in output (Table 5and 6). This is in line with the findings of many scholars (1, 7, and 10), Land as one of the primary factors of production is very important and because of its limitedness in supply it has always accelerated a number of aspects such as migration from upland areas to low land wetlands. Use of Ox plough in this area is a common practice but many of these farmers fail to cost it and thus end up operating in phase 3 of the neo- classical production function. Therefore this serves to imply that any further increase in the use of this input yields diminishing returns of rice production. The variable "seed" (Table 6) is sensitive to the total output of rice, meaning that there is an input to output relationship. The species of the seeds used is very important in ensuring productivity of the rice crop since various seed varieties yield differently for example NARIC 1yields about 3.5-4t/ha, NERICA 4 yields about 4-5t/ha (33). The use of good seeds in crop production is one way of increasing productivity in terms of quantity and quality (10 and20). The variable "fertilizer used" plays a big role in improving productivity and in the intensification of agricultural production as a whole especially where the scarcity of farm land is a big problem (1 and 10). However, the appropriate use of these fertilizers is very important in achieving farm efficiency (13). It should be noted that very few farmers have access to fertilizers and that they are not readily available at affordable prices in this area. Therefore according to the returns to scale, it indicates that the per unit cost of the inputs used in production process of an output of rice exceeds the returns from that output rice. Thus showing inefficiency as they spend more on inputs than they should in the view of the yield, given the fact that their livelihood is majorly dependent on farming. In addition to this they in many cases underestimate the inputs more especially labour, time, land especially where it's freely accessible (12).

Returns to scale
This indicates that per unit cost of the input used in the production of an output of rice exceed the returns from that output of rice. Thus showing inefficiency as they spend more on inputs than they should in the view of the yield, given the fact their livelihood is majorly dependent on farming. In addition to this they in many cases underestimate the inputs more especially labour, time, land especially where its freely accessible. Similar studies in Uganda regarding *matooke* growing indicate the same decreasing returns to scale.

Conclusions
There was a significant difference between the paddy rice yields and NARIC 3 species of the upland varieties. The farmers of paddy rice had slightly higher yields than those of NARIC 3.
On the other hand there were significant differences between the yields of paddy rice and NERICA 1, 10 and 4 where the yields of paddy rice were more than those of NERICA 1 and NERICA 10; however the yields of NERICA 4 were significantly greater than those of paddy rice. This implies rejection of the hypothesis that there is no significant difference between the yields of paddy and upland rice.

The following inputs were found to be key determinants of technical efficiency in rice production and rice output in general: these are land size devoted to rice growing, quantity of seeds (kg) used, use of fertilizers (kg), labor (man days), Ox plough (cost of hiring); and Ox plough and labor were found to be over-utilized, thus if farmers are to improve on production they have to take note of these inputs. The following socio-economic factors were seen as very paramount: family size, farming experience and motive of the rice farmers. It is noteworthy that the returns to scale for the rice farmers are decreasing, suggesting that rice cultivation by farmers in Namasagali is not technically efficient.

Although upland rice is quite promising, the hindrance to its full adoption and therefore a switch out of the wetlands is the use of wetlands during the rather long dry seasons. The performance of upland rice is rather an attractive during the dry season- a reason why farmers grow both paddy and upland rice in the wetlands. Otherwise NERICA 4 is superior to all varieties and therefore a promising variety for integration into the upland crop enterprises. To realize efficiency and avoid the technical inefficiency portrayed by decreasing returns to scale of rice production, there is need to adopt modern agricultural farming practices such as use of fertilizers, planting of recommended and good rice seeds that are high yielding in companion with improved institutional support, and human resource improvement. This will serve to form bedrock for improving the livelihood and standards of living of the many rural farmers

Appendix

Table (1): Descriptive statistics of some social characteristics

Variable	Observation	Mean	Std. Dev.	Min	Max
Age	50	36.2	9.2	22	56
Family size	50	6.1	2.4	2	14
Experience	50	6.5	3.6	2	16
Seeds	50	42.1	25.2	14	140
Rice acreage	50	1.3	0.8	0.5	4

Table (2): Rice net revenue versus the price of maize meal required to annually support a family of six

Variety	Land size(ha)	Milled (kg)	Net revenue (USD)
Paddy	0.63	2028	963.46
NERICA 1	0.63	1825.2	884.77
NERICA 10	0.63	1825.2	884.77
NARIC 3	0.63	1926.6	956.56
NERICA 4	0.63	2230.8	1,171.93

Maize flour of 1700kg produced from 0.63ha cost 2040000; 1700kg of maize flour is the quantity required to annually support a family of 6people in the study area (17).

Table (3): An economic analysis for cultivating one acre of rice

Parameter	Varieties			
	Paddy	**Upland**		
		NERICA 1 & 10	NERICA 4	NARIC 1
Net Income per acre(USD)	617.6	567.16	751.24	613.18
Benefit – cost ratio	1.54	1.50	1.90	1.60

1700 kg of maize flour x 0.48 (mart price) = USD 816

Table (4): Logistic regression model results

Yield	Coefficient	Std. err	T	P>|t|
Variety	323.6	328.4	0.99	0.330[ns]
Family size	-219.1	63.7	-3.44	0.001[**]
Landownership (acre)	-117.8	136.9	-0.86	0.394[ns]
Land size(acre)	1482.2	87.3	16.9	0.000[**]
Experience (yrs.)	84.9	40.8	2.08	0.043[*]
Motivation	68.4	189.7	3.63	0.001[**]
Labour (days)	40.0	408.1	2.06	0.045[*]
Ox plough	931.4	376.3	2.48	0.017*
Fertilizer (kg)	301.2	426.5	0.71	0.484[ns]
Education level	42.0	2.9	14.37	0.04[*]
Gender	329.6	243.6	1.35	0.182[ns]

Number of observations = 50, Prob>F =0.0158, R-squared=0.682, Adjusted R-squared=0.668; *= Significant at 0.05 level,   ** = highly significant at 0.01, ns= not significant at all levels

Table (5): Cobb-Douglas production function model results

Variable	Coefficient of elasticity	Std error	t- ratio	Significance
Land size(acre)	0.310	70.3	10.23	0.000
Seeds (kg)	0.281	2.0	9.32	0.002
Fertilizer (kg)	0.250	40.4	9.32	0.024
Ox plough	-0.194	376.2	-2.48	0.017
Pesticides(kg)	0.066	251.5	1.35	0.182
Labour (days)	-0.099	40.0	-3.04	0.044
Constant		49.1	2.36	0.008

Adjusted R- squared = 0.67, Sum of b's = 0.543, Sum of obs = 50

References

AA. Tijani (2006) Analysis of the Technical Efficiency of Rice farms in Ilesha Land of Osun State, Nigeria vol 45, No 2

Africa Rice Centre (WARDA), (2009). The growing NERICA Boom in Uganda. WARDA publication: Catonou, Benin.

Agribusiness Development Center (ADC) (2001), Upland rice Production and Marketing Feasibility Study. ADC Publication, Kampala Uganda

Agricultural Research Council (ARC) (2002) Food and Agricultural research council. Proceeding of the fifth annual meeting of Agricultural Scientists; Pretoria

Ahmad, M.C., Ghulam, M. and M. Igbal (2002) Wheat productivity, efficiency, and sustainability: A stochastic production frontier analysis, The Pakistan development review, 41: 4

Alice Nakiyemba Were (March, 2013), Stakeholders' Perspectives on the Governance of Natural Resources in Ugandan Lake Victoria Catchment: a Case of Upper River Rwizi and Iguluibi Water Catchments

Amos, T.T. (2007), Analysis of Productivity and Technical Efficiency of Smallholder Cocoa Farmers in Nigeria, Journal of social science, 15: 127-133

Battese, G.E. and T.J. Coelli (1995), A model for technical inefficiency effects in the stochastic frontier production functions for panel data. Empirical economics, 20: 325-332

Binam, J.N., Tonye, N.W., Nyambi, G. and M. Akoa, (2004) Factors affecting the technical efficiency among smallholder farmers in the slash and burn agriculture zone of Cameroon Food policy, 29: 531-545

Gabriel S. Umoh (October, 2005), resource use efficiency in urban farming: an application of a stochastic frontier

Government of Uganda (2009), Agricultural census

Heshmati, A. and Y. Mulugeta, (1996), Technical efficiency of the Ugandan Matooke farms, Applied economic letters, 3: 491-494

Hopper, W.D. (1965). Allocation efficiency in a traditional Indian agriculture, Journal of Farm Economics, 29: 175-398

http://www.infoplease.com/encyclopedia/science/rice-history-rice-cultivation.html#ixzz2Ubj4wmCV

http://www.infoplease.com/encyclopedia/science/rice-other-uses.html#ixzz2UbjQINDn

Huynh Viet Khai and Mitsuyasu Yabe (2011), Technical Efficiency Analysis of Rice Production in Vietnam, J.ISSAAS Vol, 17, No, 1:135-146

Isabirye Moses (2005), Land Evaluation around Lake Victoria: Environmental Implications of Land use Change.

Joseph Oonyu, (2011), Upland rice growing a potential solution to declining crop yields and degradation of the Doho wetlands, Butaleja district- Uganda

Kamuli district local government (2010), Kamuli district environmental report

Kiplang`at, J. (2003), Does agricultural extension have a new beginning because of ICTs? Reflection on experience in Sub-Saharan Africa, Keynote paper, presented at the 6th Consultative Expert meeting on CIA`s observatory on ICTs. Wageningen University, Netherlands. Sept 23-25

Luzi-kihupi A (1998), Inter-relationships between Yield and some Agronomic Characteristics in Rice Afri Crop sci. J., 6(3): 323-328

Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) (2009), agricultural production statistics, ministry of agriculture, animal industry and fisheries; Kampala, Uganda

Ministry of Finance, Planning and Economic Development (MOFPED), Uganda, (2009) Background to budget Ministry of finance, planning and economic development; Kampala Uganda

Ministry of natural resources (MoNR) (1996), the National Wetlands Conservation and Management Program; Wetlands Status Report for Pallisa, Ministry of Natural Resource, Kampala Uganda

Ministry of trade and industry (MOTI), (2008), Rice Production in Uganda

Obwona M (2000).Determinants of Technical Efficiency Differentials amongst Small and Medium scale Farmers in Uganda: A case of tobacco growers. A final report presented at AERC bi-annual workshop at Grand Requency Hotel, Nairobi, Kenya

Odogola R. Wilfred (2006), Final Survey Report on the status of Rice Production, Processing and Marketing in Uganda.

Ogolla, B.D. and J.W. Mugabe (1996), Land tenure system and natural resource management In land we trust: Environment, private property and constitutional change. Juma, C. and J.B. Ojwang: 79-120. Nairobi, Kenya initiatives publishers

Shapiro K.H. and J. MULLER, (1977), Sources of technical efficiency: The role of modernization and information. Economic Development and Cultural Change, 25: 2.

Spencer D.Doward A., Abalu G., and Phillips D., Ogungbile D. (2006): Evaluation of adoption of NERICA and other improved upland rice varieties in Nigeria. Report submitted to the Gatsby and Rockefeller Foundations

Stefan Bäckman, K.M. Zahidul Islam, John Sumelius (2010), Determinants of Technical Efficiency of Rice Farms in North-Central and North-Western Regions in Bangladesh

Sushil Pandey, Derek Byerlee, David Dawe, Achim Dobermann, Samarendu Mohanty, Scott Rozelle, and Bill Hardy (2009), Rice in the Global Economy: Strategic Research and Policy Issues for Food Security

Tatsushi TSUBOI (2010), Upland Rice Cultivation Guide, Promotion of Rice Development Project, NaCRRI, NARO, Uganda

Tiamiyu S.A., Akintola J.O., Rahji M.A.Y. (2010), Production Efficiency among Growers of New Rice for Africa in the Savanna Zone of Nigeria.VOL. 43 (2) 2010

Uganda Bureau of Statistics (2010) Uganda Census of Agriculture for 2008/2009, volume iv, Kampala

WEIR, S. (1999), The effects of education on farmer productivity in rural Ethiopia, Working paper, CSAE WPS99-7, Centre for the Study of African Economies, Oxford University.

Wetland Inspection Division (WID)(2001), Guidelines for smallholder Paddy Rice Cultivation in seasonal wetlands, Ministry of Water, Lands and Environment, Kampala, Uganda

WMD (2011), Submission for the State of Environmental Report 2010, Wetlands Management Department, Ministry of Water and Environment, Kampala

SUBTHEME 2: ANIMAL PRODUCTION

2.1.0 OPPORTUNITIES AND CHALLENGES OF INTEGRATING BIOGAS TECHNOLOGY IN SMALLHOLDER DAIRY FARMING IN NYERI COUNTY, KENYA

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Abstract
Generating and using Biogas from zero-grazing systems is one way of enhancing green agriculture. Despite the readily available raw material from the many zero-grazing units, and also aggressive campaigns by Government and Non-Governmental Organizations to promote biogas technology, its adoption among smallholder dairy farmers in Mukurwe-ini, Nyeri County remains low. This paper reports on this scenario based on a survey research that targeted 120 dairy farmers, who were selected by random sampling from a list of 1204 households that had zero-grazing units. Purposive sampling was also used to obtain data from few key informants (stakeholders) in dairy farming. Results indicated that low adoption was attributed to high initial investment costs, lack of financial credit facilities devoted to biogas technology, marginalisation of women in household decision-making, and absence of locally trained technicians. Attempts to disseminate biogas technology by both the public and private biogas promoters were constraint majorly by poor promotional strategies, limited support by the government, and inadequate operational funds. A comprehensive awareness campaign on the appropriateness and sustainability of biogas technology, including creating a critical mass of local technicians in biogas technology is critical for the up and out-scaling of this technology. This calls for strategic partnerships involving government, private sector and civil society organisations in this endeavour.
Key Words: Biogas Technology, Zero-grazing, Small-scale Farmers, Nyeri

Introduction
In people's daily lives, energy provides essential services for cooking and heating, lighting, food production and storage, education and health services, industrial production, and transportation. People in developing countries rely heavily on biomass, such as firewood, charcoal, agricultural waste and animal dung, to meet their energy needs for cooking.

In Kenya, firewood and charcoal remain the primary sources of cooking energy and accounts for 80% of the total primary energy consumption in rural areas. This scenario explains the reason behind Kenya's low forest cover of 1.7 % (Masinde and Karanja, 2011). In addition, the livelihoods of the people in Kenya will continue to significantly be impaired by energy poverty thus affecting the social, economic and environmental spheres of the people.

As such as there is need to use alternative sources of energy such as biogas. Biogas is an energy technology that has the potential to counteract many adverse social, economic, health and environmental impacts connected with over reliance of firewood and charcoal. The use of biogas as energy source has proven itself to be an important strategy in solving the problems of energy usage in rural areas of developing countries (Biogas for better life, An Africa Initiative, 2007).

The important role played by biogas technology cannot be over looked. According to Tafdrup (1995), biogas systems can yield a whole range of benefits to the users including production of heat, light and electricity, transformation of organic waste into high quality fertilizer, improvement of hygienic condition and environmental advantages through protection of soil, water and woodlots. Biogas as renewable energy can improve livelihoods of people in a sustainable way. As such, there is need to enhance the use of biogas energy to improving the lives of people especially in the rural setting.

In Mukurwe-ini, firewood remains the dominant sources of cooking energy However, problems relating to environmental degradation, deforestation, land clearance, population increase and drought are placing more and more pressure on dwindling forest and woodland resources. Several mitigation strategies have been used in the past to avert the situation such as on-farm agro-forestry to provide wood fuel. However, this has not been successful as the rate of planting (supply) and rate of consumption (demand) is unmatched, given the number of years trees take to mature before they could be used as wood fuel. Nonetheless, Mukurwe-ini is a high potential area for dairy cattle production with the small holder farms keeping between 2 and 6 dairy cows under zero-grazing units. It was envisaged that these households are all potential adopters of biogas plants. However, observations at the farm level indicate that very few farmers have adopted biogas technology. The challenges that dairy farmers face in adopting biogas technology for energy provision has not being fully evaluated and accordingly appropriate recommendations made, for massive adoption to take place. This scenario prompted the current study to assess the challenges of adopting biogas technology for energy provision among dairy farmers in Mukurwe ini- a high potential area in dairy farming under zero grazing units.

Research methods

Study area
The survey was done in Mukurwe-ini sub-county in the current Nyeri County. The sub county lies within latitude 36 ^{0} 34'' E and longitude 0º 42'S. Mukurwe – ini is a humid zone with an average annual rainfall of 1250-2500mm (Jaetzold and Schmidt, 2007). The rainfall pattern is bio modal and determines seasonality. The long rains begin in March and end in May while short rains start in October and end in December. The annual average temperature ranges from below freezing point on top of Mount Kenya to over 34 degrees in the lower areas. The mean annual temperatures are 25 Degrees. These climatic regimes give rise to a warm tropical climate ideal for intensive dairy farming. The majority of the farmers in the sub county are small scale mixed farmers with zero grazing units for dairy cattle production.

Study approach

Farm household and key informant selection
Random sampling technique was used in this study. The population of the study consists of 1204 (N= 1204) respondents. This involved obtaining a list of dairy farmers from Wakulima Dairy Group limited in Mukurwe-ini. A total of 120 respondents were chosen randomly from the target population of this study to form the sample size representing about 10% of the population. Simple random sampling was used because it is a technique in which every member has an equal chance of being selected. Key informants were purposive selected for this study.

Data collection and analysis

A self administered questionnaire involving face to face interview was administered to household heads for all selected households to gather information on household demographic characteristics, relative importance of household cooking energy, challenges facing farmers in adopting biogas technology and measures to be adopted to increase the uptake of the technology among potential farmers.

Key informant interview schedule was particularly used to gather data from both public and private biogas promoters, which verified information, obtained through questionnaires and gave additional information, which could not be captured in the questionnaires, as it is more flexible than questionnaires (Mugenda and Mugenda, 2003).

Data was analysed by use of descriptive statistics. The collected data was coded, entered and checked for consistency before keying into SPSS software for further processing to generate descriptive statistic, percentages of challenges influencing the adoption of biogas technology among dairy farmers.

Results and Discussions
Household energy sources and relative importance

Analysis revealed that 76 % and 6.7% of the households use wood fuel and charcoal as their primary source of cooking energy (Figure 1).

	Woodfuel	Charcoal	Kerosene	Electricty	LPG	Biogas
■ Percentage	76.7	6.7	0.8	0.8	9.2	5.8
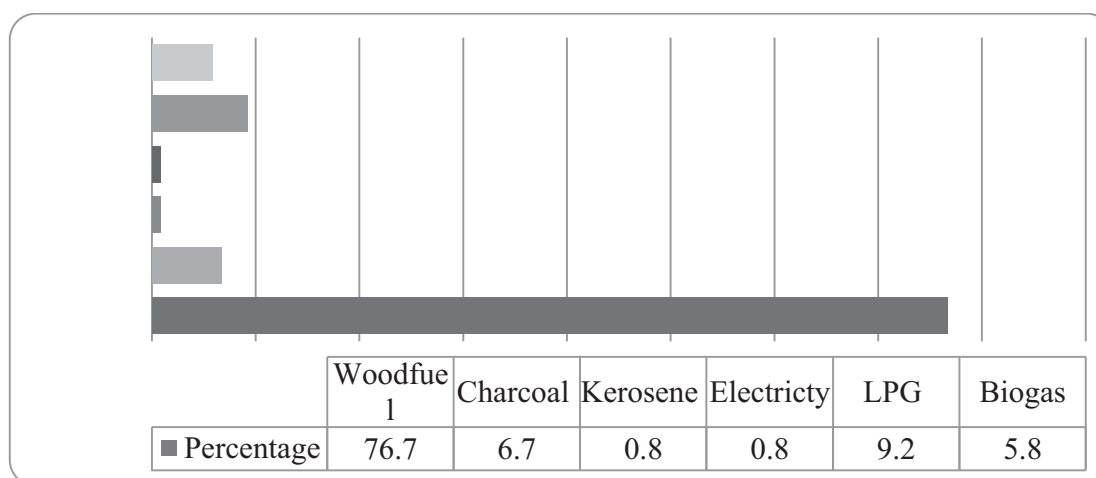
Figure 1. Sources of cooking energy among the respondents in Mukurwe-ini

These results are further backed by the findings of a recent KHIBS study that revealed that wood fuel remained the predominant fuel for cooking with 80% of household in rural areas and 10% in the urban centres (KIHBS, 2009). The impacts of this reliance are vast and while some effects are immediate, the full strength of many may not be felt until far into the future. This implies that there should be concern on the environment, as more trees have to be felled to provide wood fuel and charcoal for the growing population and societal transformation. The consequences of the country's reliance on biomass fuels are far reaching, while the environmental impacts are most notably discussed. Effects of deforestation such as soil erosion and decreasing water tables have

lasting impacts, while consequences of climate change are predicted to exacerbate poverty and strongly affect those who are most vulnerable (FAO, 2009). The use of wood fuel for cooking is a major cause of health problems in developing countries due to indoor air pollution. These biomass fuels are burnt using smoky and inefficient traditional stoves with very poor combustion in unventilated kitchens producing a high concentration of dangerous pollutants: primarily carbon monoxide and particulate matter, and also nitrogen oxides and polyaromatic hydrocarbons (Muchiri, 2008)

Only about 0.8% of the respondents used kerosene and electricity as their main source of cooking energy. This may due to the fact that kerosene is mostly used as common source of light for many rural households and only about 4% of rural population has been connected to the national electricity grid (Rural Electrification Authority, 2009). In addition, the other reason for the rare use of electricity is that it is very expensive. The study further showed that 9.2% of the households used LPG as their main source of cooking energy while 5.8 % used biogas.

A comparison of households with and without biogas facility, showed wood fuel is still the main source of energy for both. However, among the respondents with biogas digesters, reliance on wood fuel is on the decline where (53.5%) of the respondents with biogas still use wood fuel as their main source of energy for cooking compared to (76.6%) of those without biogas (Table 1).

Table 1. Comparison of household cooking energy sources between households with biogas digesters and those without the digesters

Characteristic	Description	With biogas N=43		Without biogas N=77	
		Frequency	%	Frequency	%
Main Household Cooking Energy source	Wood	23	53.5	59	76.6
	Charcoal	2	4.7	6	7.9
	Electricity	-	-	1	1.3
	Kerosene	-	-	1	1.3
	LPG	4	9.3	10	13
	Biogas	14	32.5	-	-

A study conducted by Dahoo (2011) in Kenya produced similar findings regarding biogas energy use and the reduced reliance and use of wood fuel. The amount of wood consumed per day was lower by 40% for the group of women using biogas digesters (average consumption of 14 lbs/day) compared to the referent group (25 lbs/day). This shows that there might be a drastic reduction on the use of wood fuel if biogas technology is embraced at the household level. From an environmental point of view, the use of biogas at the household level reduces utilization of wood fuel as an energy source therefore contributes to reducing woodland degradation and deforestation. The use of charcoal was also on the decline with only 4.7 % of the respondents with biogas energy using it as their main source of cooking energy compared to 7.9% of those respondents without biogas facilities. The above results suggest that the presence of biogas facilities reduces the demand for wood fuel (firewood and charcoal), electricity and kerosene as sources of energy for cooking within households. The money saved from reduced demand would improve the economic status of households hence improving their livelihoods and reducing their vulnerability.

Status of biogas technology

Types of biogas digesters adopted by households
The study results showed that only 35.8 % of the dairy farmers had adopted a biogas plant at the household level. According to the findings of the study, the types of biogas digesters in use in the study were fixed dome (28%) and the plastic tubular digester (PTD) (72%) bio digesters (Table 2).

Table 2. Types of Biogas Digester adopted in Mukurwe-ini

Type of Biogas Digester used	Frequency	Percentage (%)
Plastic Tubular Digester	12	28%
Fixed Dome	31	72%
Total	43	100

The popularity of the Plastic Tubular Digester (PTD) may be attributed to the lower costs incurred in installation and unlike the masonry types such as floating drum and fixed dome that are capital intensive. This means that if the cost of installing the floating drum and fixed dome digesters is lowered or subsidized then more potential non biogas users may take up the technology.

Challenges faced by farmers in adopting biogas technology
The study showed that farmers faced various challenges while adopting biogas technology. The main challenges were high installation costs (70%), social-cultural factors (46%), negative attitude towards biogas energy (17%), lack of interest, (10%), inadequate skilled technicians (26%) and lack of credit facilities (70%) (Figure 2).
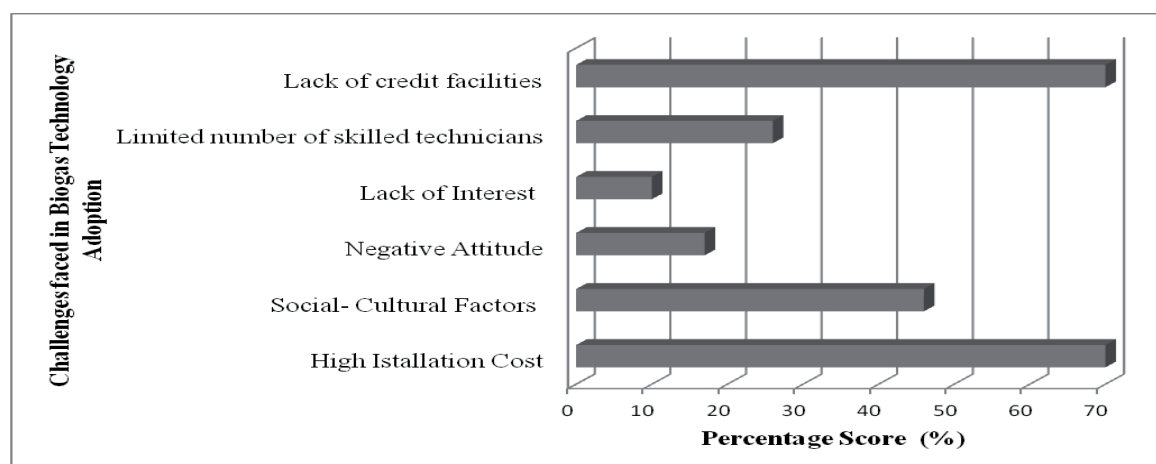
Figure 2. Challenges facing farmers in adopting biogas technology

Majority of the farmers (70%) were in the view that the high upfront cost of installing biogas units was one of the major barriers that have hindered adoption among potential biogas users in the study area. This scenario may explain why the plastic tubular digester was more popular than the masonry types of fixed dome and floating drums. According to Mwirigi *et al*., (2014), high investment costs in installing biogas units have be blamed for the low adoption rates in many developing countries.

Another major challenge was social-cultural factors. This was mainly as result of marginalisation of women in decision making in biogas digester procurement and installation. In the traditional Kenyan families, the prevailing social structures on land tenure system dictate men as the sole decision maker in matters pertaining development and use of land. As such, women efforts and willingness to own a biogas unit without the support from their husbands remain elusive as they denied access and control of land. All these notwithstanding, women may also not be in a position to access financial credits from financial institutions due to lack of collateral.

Study respondents indicated that negative attitude towards the biogas technology and lack of awareness was other challenges that emerged from the findings. Some of the respondents had the notion that biogas was a dirty technology as it used animal waste to cook. These study support findings of Mwakaje (2008) who reported that a number of people who have not accessed biogas technology had the perception that biogas is a dirty thing; however, on seeing physically the functioning of bio latrine, many households were motivated to adopt the technology. The potential biogas users need biogas oriented training through demonstrations and dissemination of information on how biogas digesters work; the importance and viability of biogas energy in improving livelihoods and environmental management.

About 26% of the farmers reported that the absence of locally skilled biogas technicians posed a challenge. As this forced farmers to seek experienced biogas installers located outside the outskirts of the sub county. This scenario translated to increased costs of an already capital intensive project due additional costs related to consultancy. This trend tallies with Amigun *et al*., (2008) views that biogas technology adoption in many African countries has remained low due to lack of locally trained biogas technicians.

The other major challenge is the lack of credit facilities (70%). According to the respondents, the high initial cost and lack of credit financing arrangements have hampered the uptake of the technology among the potential clients. This clearly indicates that some of the potential biogas users may not have the cash to pay for biogas plants upfront, thus they cannot benefit from biogas. In Tanzania, 95 % of the dairy farmers reported that lack of credit facilities was one of the major factors for the low adoption status of biogas technology among potential users (Mwakaje, 2008).

Opportunities for increasing biogas technology uptake in Mukurwe-ini

Types of biogas extension agents
The biogas extension agents in the study area were drawn from both private and public sector. The public actors were those from the core government ministries while the private biogas promoters were drawn mainly from self help groups, private biogas technicians, local nongovernmental organization and individual farmers. The extension officers from the government provided extension services on biogas technology through the Home Economics Extension wing and sensitized the farmers about biogas under the auspices of the National

Agriculture and Livestock Extension Programme (NALEP) and during farmers' field days. This was done through the provision of extension services on good management of livestock waste through conversion to biogas to foster recovering of energy and improving waste management at the farm level. The private actors in the Mukurwe-ini promoted biogas technology by establishing demonstration farms, sourcing for funds from development partners and provision of subsidies and incentives to attract potential dairy farmers to install biogas plants in their farms.

Constraints facing Public Extension Agents in Biogas Promotion
According to the findings of the study, public extension agents from the public sector faced a number challenges while promoting biogas technology in the study area (Figure 3). Some of the key challenges were few extension agents (20%), delayed disbursement of funds at (38%), poor promotion strategies at (15 %) lack of demonstration space at (10%), high installation costs at (40%), lack of credit facilities at (16%) and low interest among farmers at (10%.).
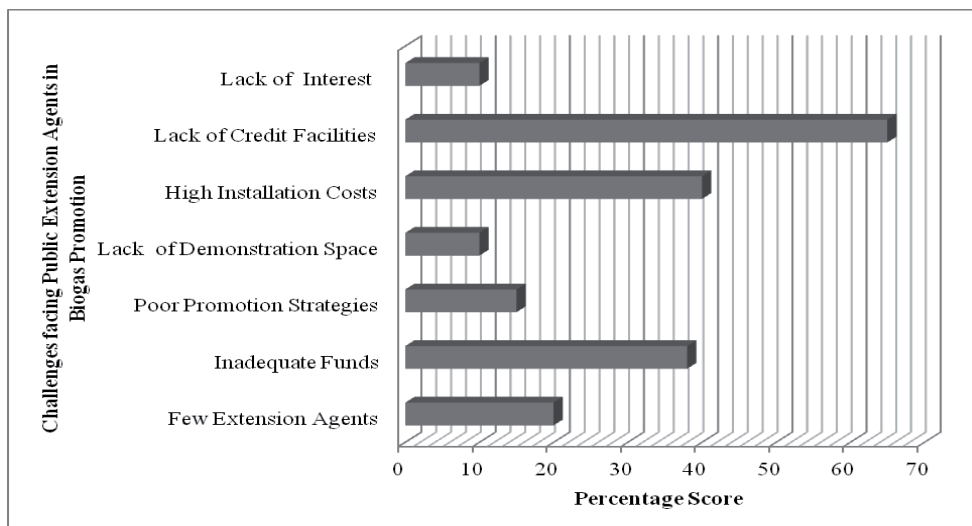
Figure 3. Constraints facing Public Extension Agents in Biogas Promotion in Mukurwe-ini.
The public biogas extension respondents reported that they are understaffed. This prevents them from giving individual attention to farmers often preferring to meet farmers in groups during farmers' field days. In addition, they reported that government had poor promotional strategies of biogas technology. For instance, no funds are specifically set aside to promote biogas instead, it is treated as a cross cutting issue, moreover, disbursement of funds are normally delayed thus hampering the promotion of biogas technology in the study area.

Another challenge that public biogas promoters faced was lack of a biogas demonstration unit at the local level. According to the promoters they normally issued supportive statements to farmers during farmer's field days, farmer's workshops and meetings on the potential of biogas technology in energy provision and waste management. With very little practice to show case to their potential biogas users, as the one nearest to farmers was located about 30 kilometres in the county headquarters. This shows that the institutional framework for popularization of biogas technology at the grass root level is lacking and needs to be strengthened.

The extension agents also reported that the high initial costs, coupled with inadequate financial credit facilities are some of the barriers to effective biogas technology adoption in Mukurwe-ini. The researcher probed further on the issue of access of credit facilities, it became vividly clear that there are no any existing credit or subsidy facilities for procurement of biogas

from the government. The Kenyan government has in the past provided credit facilities to farmers to purchase seeds, fertilisers, machinery among agricultural utilities through Agricultural Finance Corporation. However, it has not offered specific loan services on biogas installation to farmers.

Challenges facing the private biogas actors in disseminating biogas technology
Findings indicated that private biogas actors faced a number of obstacles in biogas technology promotion. According to Figure 4, negative publicity at 15%, limited government support at 20%, gender issues at 28%, and lack of trained installers at 30% were some of the issues that affected biogas promotion activities in Mukurwe-ini. Other challenges cited were high installation cost at 68% and ignorance and lack of knowledge on the value of biogas technology in energy provision at 15%. (Figure 4)
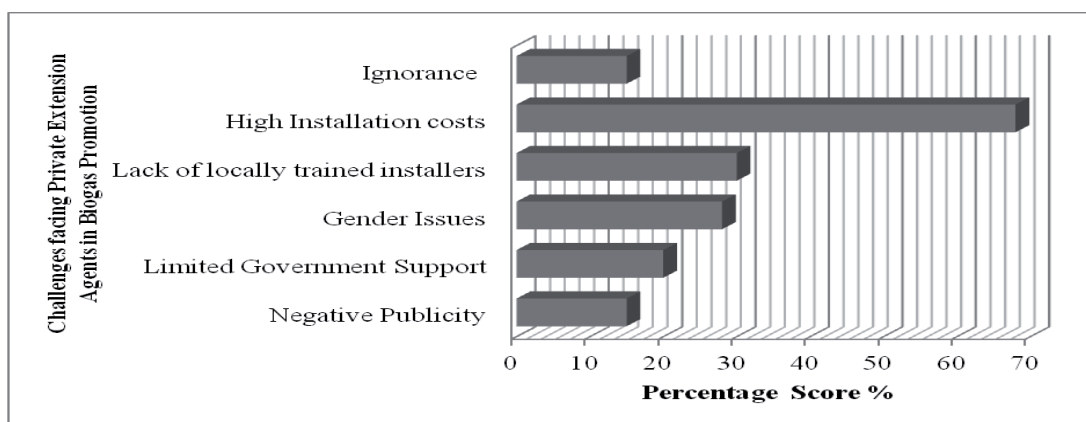
Figure 4. Constraints facing Private Extension Agents in Biogas Promotion in Mukurwe-ini

Negative publicity of biogas technology as a result of poorly functioning biogas digesters was a major hurdle faced by the private biogas technology extension agents. According to the extension agents, some of the dairy farmers did not feed the digesters as advised by the technicians resulting to low gas production hence creating a negative image on the technology. In this regard, there is need for biogas technicians to inform the dairy farmers the number of times and adequate feedstock in order to ensure that gas production is not affected.

Another challenge faced by private biogas promoters was limited government support. According to the private actors, some of the government policies did not promote the uptake of the technology. For instance, there is no duty posed on generators whereas all imported biogas appliances are charged a duty of 25% and a VAT 16%. This makes the purchase of biogas appliances very expensive forcing some of the farmers to modify and improvise giving room for inefficiency. This shows that some of the government policies do not promote the use of biogas energy technology and need to be revised. The National Energy Policy needs to enforce rebates, waivers and promote local manufacture of biogas plants and equipment's in the country. This would reduce costs and hence making the technology affordable.

The private biogas promoters felt that the high installation costs incurred while putting up a biogas plant especially the masonry types such as the fixed dome and floating drum posed a challenge in their promotion activities. This, together with lack of credit facilities from the local banks, Saccos' and micro finance institutions put off potential farmers who may be willing to invest in a biogas unit if credit facilities were available. There is need for a forum to sensitise

financial institutions to provide loans services on biogas procurement just like they provide loans services for purchase of LPG gas appliances, water tanks and other farm machinery.

Gender issues mainly related to the prevailing social structures on land tenure systems in Kenya where land belongs to the man have inhibited the adoption and installation of biogas plants by willing women. According to the private biogas promoters, their promotion activities were hindered where willing women were denied permission to put a biogas unit on the basis it is costly and returns are not tangible. Additionally, without their husbands' approval they cannot access credit facilities to procure biogas units for lack collateral facilities.

Conclusions and Recommendations

These results of this study corroborated those of other studies in that it confirmed that farmers as well as public and private biogas actors faced a myriad of challenges in the uptake and promotion of biogas technology respectively in the study area. It is evident that high costs of biogas installation coupled with the absence of credit facilities hindered the uptake of the technology among potential dairy farmers. The promotional activities of both public and private biogas actors were hindered by poor promotional strategies, limited support from the government, absence of existing credit financial facilities and locally trained biogas technicians.

The solutions to the identified challenges call for a comprehensive and multifaceted approach. The government should play its rightful role in creating an enabling environment by creating biogas loans services under Agricultural Finance Corporation, review the existing Energy Policy and address areas that act as barriers to the uptake of the technology. Additionally, the government should increase its budgetary allocation to biogas promotion activities under its programmes. The private sector and the civil society should also assist and partner with the government by introducing programmes on training biogas technicians to create a pool of well trained technicians. In addition, the government, private sector and civil societies should partner and sensitise the public on the benefit of biogas technology especially to both genders. The campaigns should be well planned, more aggressive and properly targeted. Such a move would create an enabling environment to see massive uptake of the technology among potential farmers.

References

Biogas for better life, An Africa Initiative, (2007). A Feasibility Study by Shell Foundation, Nairobi, Kenya.

Dahoo, C. (2011). The Impacts of Bio-digesters on Kenyan farm women. MSc. Thesis: Dalhousie University, Canada.

Food and Agricultural Organization (FAO), (2009). Enabling agriculture to contribute to climate change mitigation. FAO, Rome

Jaetzold, R. and Schmidt, H. (2007). Farm Management Handbook of Kenya, Natural Conditions and Farm Information. Vol.11B Central Kenya, Ministry of Agriculture, Nairobi, Kenya.

Karanja, G.M. and Kiruiro E.M. (2004). Low-cost On-farm Biogas Production. KARI Technical Publication Note No. 25 KARI, Nairobi.

Kenya Population and Housing Census Highlights. (2009). Kenya National Bureau of Statistics, The Government Printer, Nairobi, Kenya.

Masinde, S. and Karanja, L. (2011). *Global Corruption Report 2011: Climate Change, The Plunder of Kenya's Forests.* 280-282

Rural Electrification Authority (REA) (2009). Kenyan Electricity Expansion Project (EASRural Electrification Authority (REA), *Resettlement Policy Framework 2*.

Muchiri, L. (2008). Gender and Equity in Bio Energy Access and Delivery in Kenya. Practical Action Eastern Africa.

Mugenda,M.O. and Mugenda, A.G. (2003). Research Methods Qualitative and Quantative Approaches. African Centre for Technology Studies (ACTS), Nairobi, Kenya.

Mwakaje, A.G. (2008). Dairy farming and biogas use in Rungwe district, south-west Tanzania: a study of opportunities and constraints. Renewable and Sustainable Energy Reviews, 12, 2240–2252.

Mwirigi, J.W., Makenzia, P.M. and Ochola, W.O. (2009). "Socio-economic constraints to adoption and sustainability of biogas technology by farmers in Nakuru Districts, Kenya" *Energy for Sustainable Development* Vol. 13(2): pp. 106 – 115.

2.1.1 EFFECT OF FEED RESTRICTION ON GROWTH PERFORMANCE CHARACTERISTICS OF BROILER CHICKENS

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Abstract

This study was carried out to examine the effect of feed restriction on growth performance characteristics of broiler chickens. A total of sixty (60) Anak broiler chicks were used. The birds were allotted into four dietary treatments in a Complete Randomized Design (CRD). Each treatment was replicated three times with five birds per replicate. The dietary treatments were identified as T_1, T_2, T_3 (which was commercial diet from Vital feed industry) and T_4. The study lasted for a period of 8 weeks which includes 2 weeks of acclimatization prior to the starting of experiment. Birds on T_1 were on *ad libitum* feeding throughout the experimental period, T_2 were on 70% ad libitum for first 21 days followed by *ad libitum* feeding for the last 21 days, T_3 were on 70% *ad libitum* throughout the experimental period and T_4 were on 70% of commercial diet + 30% sun-dried maize *sievette* throughout the experimental period. Analysis of data showed that the final body weight of T_1 and T_4 were significantly difference among other treatments ($P<0.05$). Feed intake value of T_1 and T_4 was significantly ($P<0.05$) higher than T_2 and T_3. Feed efficiency did not differ between treatments. Result on carcass quality revealed that there was a significant difference between the slaughtered weight of T_1 and other treatments. But similarities existed between T_2 and T_4. No significant differences were found between T_1, T_2 and T_4 for the breast, drum stick/thigh, wing and gizzard weight but T_3 remains the lowest among the treatments .From the result, birds on T_1 had the highest feed intake followed by T_4, T_2 and T_3. T_3 had the least net return. Based on this experiment, T_4 was found to be of more economic value.
Key words: Feed restriction; Growth performance; Maize sievette

Introduction

Poultry feeding has changed more than the feeding of any other species. Originally, it was strictly a backyard enterprise, the mother hen did her own incubating and raised her young, and the farmer's wife fed the chickens on table scraps and the unaccounted-for grain from the crib.

Reproduction was confined to the spring months when green feeds, insects and sunshine were all available to contribute to nutrition of baby chicks (Ensminger, 1991). Feeding was largely an art rather than a science and as such commercial feeds were sold largely "secret formula and patented portion". But all these have changed. Today, the vast majority of commercial poultry is produced in large units where the maximum of science and technology exist (Crouch *et al.,* 2000).

Poultry (broiler chicken) nutrition is more critical than that of other farm animals with regard to a number of factors. This is so because birds are quite different from four footed animals, their digestion is more rapid, their respiration and circulation are faster, their body temperature is 8 to 10 degree higher (about 107^0F), they are more sensitive to environmental influences, growth takes place at a fast rate and birds mature at an earlier age (Crouch *et al.,* 2000). The economic importance of poultry feeding becomes apparent when it is realized that 65% to 75% of the total production cost of poultry is from feed. For this reason, the efficient use of feed is extremely important to the poultry producer (Austic, 1985). Furthermore, confinement production is common place and well balanced rations containing adequate source of all known nutrient materials are fed for maximum production. The current trend in poultry production is towards controlled environment, which usually results in lowered consumption. Under such condition, the daily feed consumption must be taken into consideration and the nutrient content of the feed (energy, amino acids, vitamins and minerals) increased so as to compensate for the reduced feed intake and meet the requirements (Lilbum, 1997).

It is clear that the performance of poultry has improved dramatically over the last decade and potential for similar improvements over the next decade exists. Whether they are corrected to actual level of performance will however depend very much on whether to adjust standard of control over the environment, disease control and most importantly nutrition and practice of feeding to keep pace with the next work of the geneticist (Yahav, 2000).

Feed restriction is becoming a more common commercial treatment employed in poultry breeding industry to reduce the cost of production. Several methods of feed restriction among broiler breeders have been reported. They include skip-a-day feeding, diet deficient in protein, or amino acids, quantitative feed restriction, use of distasteful chemicals in diet, high fiber diets and combination of these methods (Nester *et al.,* 1981).

Maize processing waste (sievette) variously called in Nigeria as 'Esususoka' in Igbo, 'Dusa' in Hausa and 'Eeriogi' in Yoruba is the waste from 'akamu' (pap) production. The waste is relatively available in large quantities both in rural and urban communities in Nigeria. This can be use to increase bulk as in qualitative feed restriction and increase the fiber content of feed. It is very cheap and available at all time. Most of the backyard poultry farmers use it as a source of feed.

The objectives of this study was to evaluate the growth performance and carcass quality of broiler chicks placed on different levels of feed restriction, the efficiency of utilization of dietary treatments and also to determine the economy of production under the different feeding regimes.

Materials and methods

Location and duration of the study
The experiment was carried out at the poultry unit of the department of Animal Science and Fisheries of Ebonyi State University, Abakaliki located at 6^0 15'N and 8^0 05' E. The study lasted for a period of 8 weeks.

Housing and management
The experimental house measured 6.40m x 10.96m. The floor of the house used for the experiment was divided lengthwise into two rows of pens. There were 11 pens along each length and a common passage in between the rows. Each pen measured 1.04m x 2.74m to suit the design at the study. The wall and floor were thoroughly washed and disinfected while the surroundings were cleared of bushes in order to scare away snakes and other predators and for easy access to the site. Litter materials used was wood shavings and was laid to a depth at 2 inches and replaced when wet or caked. Standard feeding and drinking equipments were used at various stages of development.

Experimental diet
The feed used was commercial broiler starter and finisher mashes from Vital feed industry. Proximate Analysis of feed was done. The starter mash was fed from day-old to 5 weeks and finisher mash was given from 5 weeks to 8 weeks.

Table 1: Proximate Analysis of Vital Feed and Maize Sievette (Yellow maize) according to Banigo *et al.,* 1974

Feed component	Starter feed (%)	Finisher feed (%)	Maize sievette (%)	Starter diet + Maize sievette (%)	Finisher diet + Maize sievette (%)
Crude fiber	5.00	5.40	7.00	6.50	6.60
Crude protein	21.00	19.00	13.90	17.40	16.40
Ash	2.90	3.50	4.92	4.41	4.50
Moisture	2.00	2.50	9.75	3.50	2.10
NFE	60.50	61.0	63.20	63.00	64.40
Ether extract	8.5	8.6	1.22	5.00	5.80

Note: maize sievette (maize chaff got from pap processing)

Experimental chicks and procedures
A total of sixty (60) Anak day old broiler chicks with an average initial weight of 42.50g were used. The birds were obtained from Ebonyi State Poultry Farm Nkaliki. The birds were acclimatized for 2 weeks prior to the starting of experiment. The birds were allotted to four

dietary treatments in a Complete Randomized Design (CRD). Each dietary treatment was replicated three times with five birds per replicate. The dietary treatments were identified on the table below.

Table 2: Dietary treatments

Treatment	Description
T_1	*Ad libitum* feeding throughout the experimental period
T_2	70% *ad libitum* for the first 21 days followed by *ad libitum* feeding for the last 21 days
T_3	70% *ad libitum* throughout the experimental period
T_4	70% of commercial diet + 30% sundried maize filtrate waste (got from pap sellers) throughout the experimental period.

Sanitation measures/medication

Strict sanitary measures were adhered throughout the period of the study and disinfectant was always available in the foot dip at the entrance to the pen. Drinking troughs were washed with detergent daily and faeces removed from the feeders. The litter was kept dried throughout the experimental period. Necessary vaccinations were given to the birds according to schedule/prescription. Proximate analyses of the diets were done. Vitamin (vitalyte) and antibiotics were given via drinking water to enhance growth at intervals especially from their 1st week to 4th week of age according to the manufacturer's description.

Data collection
The average day old weights of the birds were determined on arrival of the birds to the farm. Subsequent body weight measurement of individual bird/replicate was taken weekly and daily feed intake was taken by differences between the quantity of feed given and the quantity left using nutri-scale weighing balance of error margin of 0-10gram. Also data collection on the carcass quality was collected. At the end of the experiment, weekly body weight gain was calculated by the following formula:

$$\frac{Final\ body\ weight - initial\ body\ weight}{Number\ of\ weeks}$$

Where:
Initial body weight = weight of bird at 14th day (2nd week) when the study began
Number of weeks = number of weeks when dietary treatment was given.
The feed efficiency/bird was determined by dividing average weight gain by average feed consumed.

Statistical analysis
Data collected on growth performance traits viz: final body weight, average weekly feed intake, average weekly body weight gain, feed efficiency and carcass characteristics, were analyzed using a one way ANOVA (Analysis of Variance) in a Completely Randomized Design (CRD)

where the means were found to be significantly different were separated using Duncan's New Multiple Range Test.

Economic Analysis

A cost benefit (Gross margin) analysis was carried out for the four groups to ascertain whether the restriction applied had some economic benefits. The cost of production included the cost of feeding, procurement of birds, labour and medication. The revenue was based on 5.26 USD per kg live weight of broilers. The following parameters were obtained.

(i) Feed Cost (USD)/g feed consumed/bird/treatment $= \dfrac{Total\ cost\ of\ feed\ (USD)}{Total\ feed\ consumed\ (g)}$

(ii) Feed Cost (USD/g) weight gain/bird/treatment $= \dfrac{Total\ cost\ of\ feeding\ (USD)}{Total\ weight\ gain\ (g)}$

(iii) Total revenue generated = Final body weight x number of birds x cost per g live weight.
(iv)

Result and Discussion

Results

Growth Performance traits viz; initial body weight, final body weight, weekly weight gain, average weekly feed intake and feed efficiency.

The initial body weights of the treatments were similar and the final body weight of T_1 and T_4 were similar. Also T_2 and T_3 were the same for final body weight. Average weekly weight gain of T_1 and T_4 were significantly difference between T_2 and T_3. Average weekly feed intake of T_1 and T_4 were higher followed by T_2 and T_3. No significant difference among treatment for feed efficiency.

Table 3: Main effects of Treatment on Growth Performance of Broiler Chickens

Parameters	Treatments T_1	T_2	T_3	T_4	SEM
Initial body weight (g/bird)	320	290	310	320	0.03
Final body weight (g/bird)	2220[a]	1890[bc]	1830[c]	2060[ab]	0.06
Average weekly weight gain (g/bird)	320[a]	250[b]	250[b]	290[a]	0.01
Average weekly feed intake (g/bird)	930[a]	770[b]	680[d]	850[a]	0.23
Feed efficiency	0.37	0.39	0.41	0.36	0.01

[ab] means on the same row followed with different superscripts are significantly different (P<0.05)
SEM: Standard error of mean

Carcass quality of broiler chickens

The mean values of slaughtered weight of T_1 was significantly difference among treatments while T_2 and T_4 were similar, T_3 remain the lowest. Among treatments the drum stick and thigh and wing weight were similar except T_3. The abdominal fat weight of T_1 and T_4 were greater than T_2 and T_3.

Table 4: Main effect of Treatment on Carcass Quality of Broiler Chicken

Parameters	Treatments				
	T_1	T_2	T_3	T_4	SEM
Slaughtered weight (g/bird)	1950[a]	1780[b]	1480[c]	1800[b]	0.04
Defeathered weight (g/bird)	1730[a]	1560[b]	1340[c]	1590[b]	0.04
Dressed carcass weight (g/bird)	1290[a]	1130[bc]	1080[c]	1220[ab]	0.04
Breast muscle weight (g/bird)	350[a]	320[a]	290[b]	350[a]	0.01
Drum stick and thigh weight (g/bird)	180[a]	180[a]	160[b]	180[a]	0.00
Wing weight (g/bird)	90[a]	80[a]	70[b]	90[a]	0.00
Gizzard weight (g/bird)	50[a]	40[a]	30[b]	40[a]	0.00
Abdominal fat weight (g/bird)	67[a]	30[b]	20[b]	60[a]	0.04
Dressing %	58	60	59	59	

[ab] means on the same row followed with different superscripts are significantly different (P<0.05) SEM: Standard error of mean

Economy of production

Cost of feed/kg weight gain per bird ranges from T_4 = USD 0.88, T_3 = USD 1.05, T_2 = USD 1.12 and T_1 = USD 1.16. T_1 was higher among treatments on feed intake, total cost of feeding and total feed consumed/g/bird and while T_4 has highest net returns (USD) per bird.

Table 5: Economy of Production

Parameters	Treatments			
	1 4	2	3	
Total feed consumed (g/bird)	5580	4640	4130	5120
Total cost of feeding (USD/bird)	2.13	1.77	1.57	1.53
Total cost of bird/(USD)	0.99	0.99	0.99	0.99
Feed cost (USD)/g commercial feed consumed	0.38	0.38	0.38	0.38
Labour and exigencies (USD)/bird	0.66	0.66	0.66	0.66
Total cost of production (USD)/bird	3.76	3.41	3.22	3.17
Total weight gain/g/bird	1840	1590	1500	1740
Feed cost (USD)/g weight gain/bird	1.16	1.12	1.06	0.88
Revenue (USD)/bird	9.67	8.35	7.88	9.18
Net returns (USD)/bird	5.89	4.93	4.67	6.00
Cost/benefit ratio	0.64	0.69	0.69	0.53

Cost per 25000g of feed based on 9.54 (USD); Cost per 1000g of maize sievette based on 0.11 (USD); Cost per 1000g live weight based on 5.26 (USD)

Discussion

Effect of treatments on growth performance traits
Both restriction-realimentation protocols resulted in decreased growth rates (compared with control) during the restriction period. The means of the final body weight shows that there was no significant difference between birds in control group (T_1) (*ad libitum*) and those in T_4 (70% of commercial diet + 30% maize sievette). This may be due to the addition of maize sievette in T_4 which added bulk to the feed. Similarity also existed between those in T_2 and T_4. There is no significant difference between T_2 and T_3.

Weekly weight gain of T_2 and T_3 were reduced during the restriction period. The result coincided with the findings of (Tolkamp *et al.,* 2005). During this time, the chicks were affected by coccidiosis. Zhan *et al*., (2007) and Willis *et al.,* (2007) also observed that restricted birds were prone to coccidiosis during their early period of life. Feed restriction resulted in accelerated growth and at the age of 8th week, the daily weight gain of T_4 and (T_1) full fed birds were similar. The T_2 and T_3 groups produced consistently, the lowest of total weight gain. This may be as a result of 70% of feed restriction, duration, severity and timing of the feed restriction, sex and strain of birds (Yu and Robinson, 1992). Furthermore the final body weight and weight gain of T_1 and T_4 were similar. Compensatory growth resulted in a minimization of difference in the final body weight between restricted and control birds at 8 weeks of age.

Table 3 above shows that feed intake values for T_1 and T_4 was significantly (P<0.05) higher than those in T_2 and T_3. No differences (P>0.05) in feed efficiency was observed among the treatments. Furthermore feed utilization by restricted birds was better than full fed ones. There was no significant difference among the initial body weight of the treatments.

Effect of treatment on carcass quality viz: slaughtered weight, dressed carcass, defeathered weight, breast muscle weight, drum stick and thigh, wing weight, gizzard and abdominal fat weight.

Table 4 shows the main effects of treatment on carcass quality of broiler chickens. The treatments resulted in a slight increase (P<0.05) in slaughtered weight and defeathered weight of birds. There was a significant difference between the slaughtered weight of T_1 and other treatments. This may be as a result of *ad libitum* feeding. But no difference existed between T_2 and T_4. This result may be due to compensatory growth in T_2 following feed restriction, defined as sustained accelerated growth in refed birds compared with T_4 (Lee and Leeson, 2001). T_3 was the lowest among the treatments. There was significant difference in defeathered weight between the control (T_1) and T_2, T_3, T_4. But similarity existed between T_2 and T_4 where T_3 remains the lowest. There was a progressive increase in abdominal fat weight of T_1 and T_4 compared with T_2 and T_3.

The result of this experiment shows that there was no difference between the dressed carcass weight of T_1 and T_4. This finding is in line, showing that broiler chickens may be switched to a less nutrient-dense grower diet or qualitative feed restriction in which T_4 undergone and still gave good growth performance and carcass yield. But there exist similarity between T_4 and T_2 and also when compared T_2 and T_3 there was no difference. No significant difference were found between T_1, T_2, and T_4 for breast muscle weight, drum stick and thigh, wing weight and gizzard weight but T_3 also remain the lowest among the treatments. This was as a result of treatment effect during the experimental period. But differences existed between the abdominal fat weights among the treatments where T_1 and T_4 were greater than T_2 and T_3.

Effect of treatments on economy of production

Table 5 gives the effect of feed restriction on the economy of production. Cost of feed/g weight gain per bird ranges from USD 0.88 to USD 1.16, with bird on T_1 having the highest cost total feed consumption followed by T_2 and T_3 while the lowest was T_4. Total feed cost was lower for the restricted groups than *ad libitum*. The cost of production existed in the same way as that of cost of feed consumed per bird. The net returns (gross margin) were found to be as: T_1 = USD 5.89, T_2 = USD 4.93, T_3 = USD 4.67 and T_4 = USD 6.00. Although higher feed cost/kg was observed in T_1 than other treatments. But the gain/bird was higher in T_4 than other treatments due to the introduction of maize sievette which is cheaply and available. This may be as a result

of qualitative method of feed restriction known as full feeding of deficient diets (Friedman and Sklam, 1989). Similarly, qualitative restriction of nutrient intake by appropriate dietary dilution of appetite suppression, with free access to food, has been suggested as less stressful (Tolkamp *et al*., 2005). The information in the table shows that restricting feeding of broiler chickens had significant effects in the cost of production. Zhan *et al*., (2007) suggested that early feed restriction of birds and later returned to *ad libitum* made higher profit than control but in this study it may be as a result of 70% feed restriction and duration. In this study, T_4 had higher revenue than other treatments and qualitative feed restriction or nutrient dilution provides more profit margins and least cost of production.

Summary and conclusion

Summary
The results shown in the table 1, 2, 3, 4 and 5 were obtained from the experiment which was the effect of feed restriction on growth performance characteristics of broiler chickens. Sixty (60) two week old of Anak broiler randomly assigned to four treatments identified as T_1 = *ad libitum* feeding throughout the experimental period, T_2 = 70% *ad libitum* for the first 21 days followed by *ad libitum* feeding for the last 21 days, T_3 = 70% *ad libitum* throughout the experimental period and T_4 = 70% *ad libitum* + 30% sun-dried maize sievette throughout the experimental period which lasted for a total of 8 weeks. The feed used was Vital feed.

The parameters measured were final body weight, average weekly weight gain, weekly feed intake, feed efficiency, initial body weight, carcass quality and economy of production. There was no significant difference between the final body weight and weight gain of T_1 and T_4. But similarity existed between T_2 and T_3. Data collected were analyzed using one-way ANOVA in CRD.

Conclusion
From the result, birds on T_1 had the highest feed intake followed by T_4, T_2 and T_3. T_3 had the least net return. Based on this experiment, T_4 was found to be of more economic value. The method of feed restriction both quantitative and qualitative methods have great influence on growth performance characteristics of broiler chickens. To buttress this, there is need for addition of maize sievette in a little amount to reduce cost of production. As feed restriction is a common practice in the poultry industry, it is necessary to understand its effect especially on the performance characteristics of broiler chickens. It will also enable the broiler producers to exploit the advantages associated with feed restriction for much improved production of broiler chickens and as well reduce the hazardous effect of feed restriction to birds.

References
Austic, B. (1985). Effect of reduced feeding time using mash or crumble pellet dietary regimes on chicken broiler performance. Poultry science, 16:740-746.
Banigo, E.O.I., Deman, J.M., Duitshaever CL (1974). Utilization of high lysine corn for the manufacture of ogi using a new improved processing system. Cereal Chem. 51(5): 559-572.

Crouch, A.N., Lerner, S.P. and Karunakaran, D. (2000). Influence of feed quality in the brooding period of commercial turkey and its subsequent effect on market performance. Poultry science, 79 (sup.1): 67-68.

Ensminger, M.E. (1991). Animal agriculture series, 9th edition 824-825.

Friedman, A. and Sklam, D. (1989a). Impaired T lymphocyte immune response in vitamin A depleted rats and chicks. British Journal of Nutrition 62:439-449.

Lee, K.H. and Leeson, S. (2001). Performance of broilers fed limited quantities of feed or nutrients during seven to fourteen days of age. Poultry science, 80:446-454.

Lilbum, M.S. (1997). Feeding the male broiler. In "Recent development in poultry nutrition 2, 1999" Eds. P.C. Garnsworthy and T. Wiseman, Nottingham University Press.

Nester, K.E., Cantor, A.H., Bacon, W.L., and Brown, K.I. (1981). The influence of body weight restriction during the growing and holding period on reproduction of turkey females from strains differing body weight. Poultry science, 60:1458-1460.

Tolkamp, B.J., Sandilands, V. and Kyriazakis, I. (2005). Effect of qualitative feed restriction during rearing on the performance of broiler breeders during rearing and laying. Poultry science, April 1, 2005; 235-252.

Willis, W.L., Isikhuemhen, O.S. and Ibrahim, S.A. (2007). Performance assessment of broiler chickens given mushroom extract alone or in combination with probiotics. Poultry science, September 1, 2007; 86(9):1856-1860.

Yahav, S. (2000). Domestic fowl-strategies to confront environmental conditions. Avian and Poultry biology revised, 11:81-95.

Yu, M.N. and Robinson, F.E. (1992). The application of short-term feed restriction to broiler chicken production. A review J. Appl. Poult. Res. 1:147-153.

Zhan, A., Wang, M., Ren, H., Zhao, R.Q., Li, J.X and Tan, Z.L. (2007). Effect of early feed restriction on metabolic programme and compensatory growth in broiler chickens. Poultry science, April 1, 2007; 86(4): 654-660.

SUB THEME 3: BIOTECHNOLOGY

3.1.0 HETEROSIS OF (*Coffea arabica* L. x *Coffea canephora* P.)INTERSPECIFIC HYBRIDS

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Abstract

The principal objective of coffee breeding and selection is to develop high yielding, excellent bean quality and disease resistant cultivars. Fertile inter-specific hybrids between *C. arabica* and *C. canephora* have been produced through crosses between allotetratploid *C. arabica* with induced autotetraploid forms of *C. canephora*. Heterosis is a powerful force in the evolution of plants and has been exploited extensively in crop production leading to commercial success of plant breeding and widespread use of hybrids in several crops. This study was carried out to determine the standard heterosis (SH) of 9 *Coffea arabica* x *Coffea canephora* inter-specific F_1 hybrids due to five biochemical attributes of caffeine, oil, trigonelline, total chlorogenic acids (CGA) and sucrose. These biochemical compounds are important in coffee beverage quality as they are aroma precursors. SL28 was used as a standard variety. The laboratory experiment was carried out in a complete randomized design in four replicates each representing different extraction time. The biochemical characteristics were analyzed in green coffee samples using recommended methodologies. The means were subjected to ANOVA and the results revealed significant ($p<0.05$) variations for caffeine, oil and sucrose, among genotypes but was not for CGA and trigonelline. The means obtained were used to determine the SH. The hybrids exhibited a positive SH ranging from 16.7% to 83.3% for caffeine; a negative and positive heterosis ranging from -4.2% to 33.6% for trogonelline, -25.0 to -1.5% for oil, -5.0% to 13.0% for CGA and – 20.2% to 15.2% for sucrose. SL28 x UT8 was superior among all the other hybrids in this study as it exhibited the lowest caffeine content, high trigonelline, the highest oil content and the lowest CGA content with moderate amount of sucrose and therefore recommended for further studies for other attributes in different agronomic conditions for possible release as a variety.

Key words: Coffee, F_1 inter-specific hybrids, biochemical attribute, standard heterosis.

Introduction

The principal objective of coffee breeding and selection is to develop high yielding, excellent bean quality and disease resistant cultivars which are adapted to specific growing conditions (Kumar et al, 2014). *Coffea arabica* L. is tetraploid ($2n = 4x = 44$) and is known for the production of high quality beverage (Gichuru et al., 2008) but susceptible to Coffee Berry Disease (CBD) and Coffee Leaf rust (CLR). *C. canephora P.,* is diploid ($2n = 2x = 22$) with inferior cup quality but less susceptible to CBD and CLR. CBD epidemics can quickly destroy 50–80% of the developing berries (6–16 weeks after anthesis) on susceptible Arabica cultivars during prolonged wet and cool weather conditions (Van der Vosen & Walyaro, 2009). CLR is a major disease which greatly limits Arabica coffee production in almost all growing countries around the world and whose economic damage to world Arabica coffee production has been

estimated to be between US$ 1 billion and 2 billion per year due to crop losses of 20– 25 % (Prakash et al., 2004).

Fertile interspecific hybrids between *C. arabica* and *C. canephora* have been produced (Lashermes et al., 2011) through crosses between the allotetratploid *C. arabica* with induced autotetraploid forms of *C. canephora* obtained through doubling of the chromosome number by colchicine treatment (Owour and Van Der Vossen, 1981). These hybrids have been used in coffee breeding programmess to introgress genes for resistance to coffee Coffee Leaf Rust (*Hemileia vastatrix*) and Coffee Berry Disease (*Colletotrichum kahawae*) from *C. canephora* into *C. arabica* or to improve the quality of Robusta coffee by direct use of the F_1 inter-specific hybrids (Owour and van der Vossen, 1981; Gimase et al, 2014). Exploitation of natural inter-specific hybrids like S.26 and Devamachy in India and introduction of such hybrids like Kalimas, Kawisari and Hibrido-de-Timor from other countries have encouraged the helpless coffee growers to revive their coffee plantations and support the coffee industry in India after severe destruction by CLR in the 19th century (Kumar and Mishra, 2014).

Production and supply of coffee with excellent quality is important for coffee exports and success of a new coffee variety depends to a great extent on its bean and beverage quality (Gichimu et al., 2012). Despite of the persistent demand for quality coffee in the world, coffee producing countries have been emphasizing more on yield increase and less on quality and its until recently that many coffee growing countries started giving emphasis for quality coffee production (Mohamed, 2011). Both non-genetic and genetic variations contribute to determine the quality of coffee. Significant genetic variability for bean chemical composition and organoleptic characteristics exists between and within species levels (Mohamed, 2011). Genetic gains for quality are assumed to be achieved either by interspecific or within species hybridization strategies. Different levels of biochemical components in coffee contribute variously to the final quality of the cup (Buffo and Freire, 2004). The presence of those biochemical components could have a favorable effect on the coffee beverage quality, as for trigonelline and sugars, or an unfavorable one, as for CGA and caffeine (Clifford, 1985; Macrae, 1985; Kathurima, 2013).

Heterosis (or hybrid vigor) is a phenomenon in which an F_1 hybrid has superior performance over its parents (Parvez, 2006; Garcia *et al*, 2008). It has been observed in many plant and animal species. The utilization of heterosis is responsible for the commercial success of plant breeding in many species and has leads to the widespread use of hybrids in several crops and horticultural species (Garcia *et al*, 2008). Heterosis is expressed in three ways, depending on the criteria used to compare the performance of a hybrid (Rabiei *et al*, 2010). These three ways are mid-parents heterosis (the performance of a hybrid compared with the average performance of its parents), better parent heterosis or heterobeltiosis (the performance of a hybrid compared with that of the best parent in the cross) and standard heterosis (the performance of a hybrid compared with the standard commercial variety in the region) (Nadarajan and Gunasekaran, 2005; Rabiei *et al*, 2010). From practical breeding programmes, standard heterosis is the most important of the other two levels of heterosis because it is aimed at developing desirable hybrids superior to the existing high standard commercial varieties (Parvez, 2010; Rabiei *et al*, 2010).

Heterosis has been a powerful force in the evolution of plants and has been exploited extensively in crop production (Parvez, 2010). It was exploited in the Kenyan Arabica composite cultivar Ruiru 11, one of the cultivars whose major source of CBD resistance is Robusta coffee introgressed through HDT and Catimor (Gichimu et al, 2014). Ruiru 11 cultivar planted at a density 3300 trees/ha produces between 2.5 and 3.0 tons ha^{-1} year^{-1} (Gichimu et al, 2013).

This study was carried out with an aim of assessing the level of standard heterosis in inter-specific F_1 hybrids. SL28 was selected as standard variety due to its very fine cup quality and high yields. The standard heterosis in the *C. Arabica* x *C. canephora* F_1 hybrids was based on their five biochemical profiles of caffeine, trigonelline, oil, CGA and sucrose

Materials and methods

Description of the study site
The study was conducted at the Kenya Agricultural and Livestock Research Organization (KAL RO) - Coffee Research Institute (CRI) that lies within the upper midland (UM2) at latitude 1° 06' S and longitude 36° 45'E and is approximately 1620m above sea level. The area receives a bimodal rainfall of 1063mm annually with mean temperature of 19° C (min.12.8° C, max. 25.2°C). The soils are classified as complex humic nitisols and plinthic ferrasol (Jaetzold and Schmidt, 1983). They are well drained, deep, reddish brown, slightly friable clays with murram sections occasionally interrupting. The soil pH ranges from 5 to 6 (Jaetzold and Schmidt, 1983).

Test materials
The coffee genotypes in this study comprised of nine *C. Arabica x C. canephora* inter-specific F_1 hybrids and a commercial variety, SL28 that was used as a standard check (Table 1)**.** The F_1 hybrids are inter-specific crosses between four Arabica varieties (SL28, SL34, N39 and Caturra) and four induced tetraploid Robusta accession, UT3, UT6, UT8 and UT10 (Ex France) introduced from Uganda. A uniform agronomic condition was applied to the field prior to sample collection. Cherry samples for biochemical analysis were collected during the peak harvesting period of October to December, 2012 and processed using wet processing procedures (Mburu, 2004). The processed samples were then hulled to produce green coffee beans for biochemical analysis (Kathurima et al, 2010).

The laboratory experiment was carried out in a complete randomized design (CRD) in four replicates each representing different extraction time. Five biochemical profiles namely, caffeine, trigonelline, oils, sucrose and CGA were analyzed. Portions of the green coffee samples were placed in small plastic bottles and stored under -80°C. After 24 hours of freezing, the samples were ground in liquid nitrogen using an analytical mill (Model A10, IKA work inc., USA). Caffeine, trigonelline and CGA were extracted from green coffee powder by refluxing in distilled water. Caffeine, trigonelline and CGA were analysed using a HPLC system (KNEUR) equipped with a Supel Co. discovery diode array detector at three wavelengths, 278nm for caffeine, 266nm for trigonelline and 324nm for CGA. Sucrose was analysed using a HPLC system (KNEUR) equipped with a Eurospher 100-5 NH_2 column and a refractive index detector. Caffeine, trigonelline CGA and sucrose were identified by comparing the retention times of standards and their concentrations calculated from peak areas using calibration equations. Coffee oil was analysed using the method outlined in the AOAC (1995).

Data analysis

The biochemical data were subjected to Analysis of Variance (ANOVA) using COSTAT statistical software to obtain means that were used to determine the standard heterosis. The percentage standard heterosis (SH %) was estimated as in Nadarajan and Gunasekaran, 2005; Parvez, 2008 and Mohamed, 2011; i.e.

$$\text{Heterosis \%} = \frac{F1 - \text{Standard check}}{\text{Standard check}} \times 100$$

Results and discussion

Nine *C. arabica* x *C. canephora interspecific F₁ hybrids* were analysed for biochemical characteristics. The ANOVA results are given in Table 1. The genotypes revealed significant ($p<0.05$) differences in the levels of caffeine, oil and sucrose while CGA and trigonelline did not show significant differences among the genotypes (Table 1). These biochemical compounds are important in beverage quality since they are aroma precursors (Kathurima, 2013).

The hybrids revealed a SH of 16.7% to 83.3% for caffeine. Only one hybrid, SL28 x UT8 recorded low SH of 16.7% as all the other hybrids recorded 50% and above (Table 2). Higher caffeine contents is associated with less quality samples as it accounts for 10-30% of the bitterness of coffee brew detected by taste (Viani, 1985, Kathurima, 2013). This therefore implies that high positive SH% for caffeine is undesirable. SL28 x UT8 had the lowest SH% for caffeine content of all the F_1 hybrids.

The hybrids recorded SH% of -4.2% to 33.6% for trogonelline. At roasting temperatures, trigonelline produces pyridines and pyrrole derivatives that are important volatile coffee flavour components (Ky et al., 2001, Kathurima, 2013).Trigonelline is considered to be important for taste and one objective in coffee breeding research programmes is to increase trigonelline content in Robusta green beans (Ky et al., 2001). Therefore, positive SH% is desirable. Three F_1 hybrids, SL28 x UT3, SL28 x UT8 and N39 x UT6 recorded positive SH% for trigonelline.

The hybrids recorded SH% of -25.0 to -1.5% for coffee oil. Coffee beans with higher oil contents give a better roast (Kathurima, 2013). During roasting the oil is expelled to the bean surface, forming a layer which may trap volatile aromas, preventing the immediate loss of these compounds (Clifford, 1985; Arnaud, 1988). The oil therefore, plays an important role in the overall presentation of coffee flavour (Kathurima, 2013). All the hybrids scored negative SH% for oil contents.

The hybrids recorded SH% of -5.0% to 13.0 % for CGA. CGA play a great role in the formation of pigments, taste and flavor of coffee beans, which determine the quality and acceptance of the beverages. CGA contribute to the final acidity of the beverages and the formation of lactones and other phenol derivatives responsible for flavor and aroma. The large difference in CGA content of these species has been considered as one of the factors responsible for flavor difference between the *C.arabica* and *C. canephora* species (Belay, 2011). *C. canephora* species have low quality beverage and are known to produce more CGA than *C. arabica* (Guerrero *et al*., 2001, Kathurima, 2013). Two F_1 hybrids, SL34 x UT6 and SL28 x UT8 recorded negative SH% for CGA.

The hybrids recorded SH% of -20.0% to 15.2 % for sucrose. Sucrose acts as aroma precursors that affect both taste and aroma of the beverage (Maria, *et al,* 1994). Higher sucrose contents in Arabica green have been shown to partially explain its better cup quality (Ky *et al.,* 2001). Five hybrids, SL28 x UT3, SL28 x UT8, SL34 x UT6, Caturra x UT8 and N39 x UT8, recorded positive SH% for sucrose.

Table 1. Mean caffeine, trigonelline, oil, sucrose and total chlorogenic acids (CGA) for the coffee genotypes in this study.

Genotypes	Biochemical components				
	Caffeine	Trigonelline	Oil	CGA	Sucrose
SL34x UT8	2.2	1.2	15.2	5.47	7.95
SL28 xUT3	2.2	1.6	14.5	5.55	9.91
Caturra x UT8	2.1	1.05	13.9	5.52	8.96
Caturra x UT6	2.0	1.15	14.7	5.36	6.92
N39 x UT6	2.0	1.38	14.56	5.25	7.47
SL34 x UT6	2.0	1.16	14.17	4.96	9.99
UT8 N39 x	2.0	1.18	15.25	5.90	8.94
UT6 x SL28	1.8	1.14	14.32	5.74	8.67
Caturra x UT6	1.6	1.46	19.43	5.13	7.61
SL28 x UT8	1.5	1.44	18.26	5.01	8.71
SL28	1.2	1.19	18.53	5.22	8.67
LSD (P<0.05)	**0.054**	**0.422**	**0.502**	**0.805**	**0.746**
P-value	**< 0.0001**	**0.400NS**	**< 0.0001**	**0.200NS**	**< 0.0001**

Table 2: Relative Heterosis for the *C. Arabica x C. canephora* hybrids based on biochemical characteristics

Genotypes	% RH				
	Caffeine	Trigonelline	Oil	CGA	Sucrose
SL34x UT8	83.33	0.84	-17.97	4.78	-8.3
SL28 xUT3	83.33	33.6	-21.75	6.3	14.30
Caturra x UT8	75.0	-11.76	-24.99	5.75	3.34
Caturra x UT6	66.7	-3.4	-20.67	2.68	-20.2
N39 x UT6	66.7	15.97	-21.42	0.57	-13.84
SL34 x UT6	66.7	-2.52	-23.53	-4.98	15.22
N39 x UT8	66.7	-0.84	-17.7	13.02	3.11
SL28 x UT6	50.0	-4.20	-22.72	9.96	0.0
SL28 x UT8	16.67	21.0	-1.5	-4.0	0.46
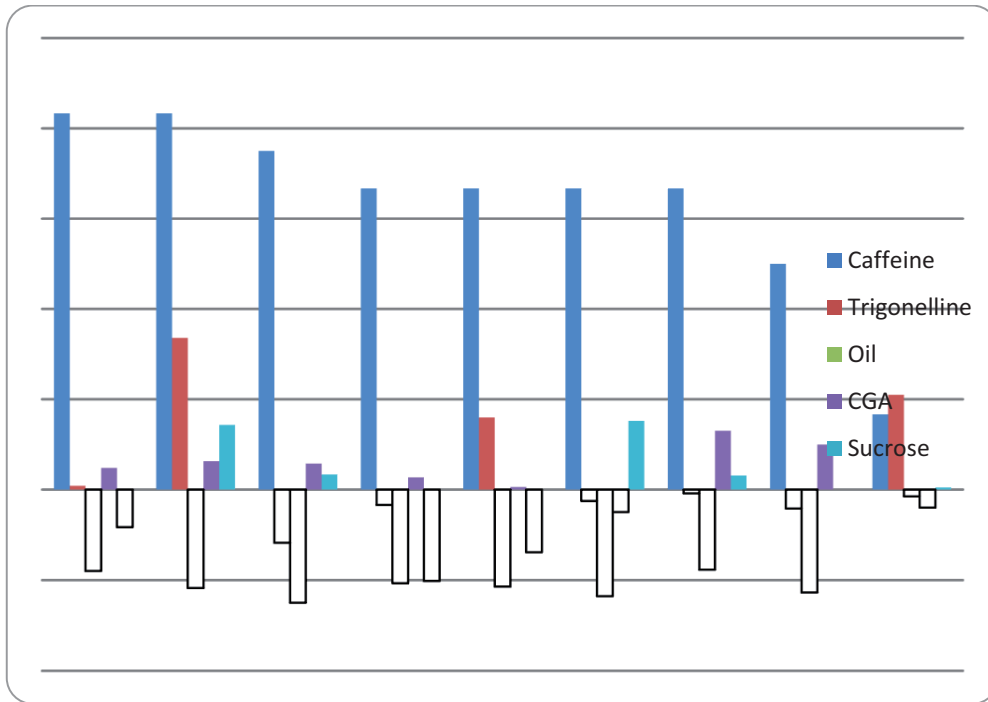
Figure1. % SH of 9 interspecific F_1 hybrids due to biochemical attributes.

Conclusion

The hybrids revealed significant heterosis for the five biochemical attributes. Eight hybrids recorded <50% SH for caffeine, an indication of high caffeine content. 5 hybrids recorded negative SH% and 4 positive SH% for trigonelline. All the hybrids recorded negative heterosis for coffee oil. Two hybrids recorded negative SH% for CGA while only five hybrids revealed positive SH% for sucrose. SL28 x UT8 was superior among all the other hybrids in this study as it exhibited the lowest caffeine content, high trigonelline, the highest oil content and the lowest CGA content with moderate amount of sucrose and therefore recommended for further studies for other attributes in different agronomic conditions for possible release as a variety.

Acknowledgement

References

Arnaud MJ (1988).The metabolism of coffee constituents. In: Clarke, R.J. and Macrae, R., eds. Coffee: physiology. London, Elsevier Applied Science, cap.2, p.33-55.

AOAC-Association of Official Analytical Chemists (1995). Official methods of analysis of AOAC International (16th Ed.) Gaithersburg, MD, USA: AOAC International.

Belay A (2011). Some biochemical compounds in coffee beans and methods developed for their analysis (Review). International Journal of the Physical Sciences, 6(28): 6373-6378.

Buffo RA, Freire CC (2004). Coffee flavour: An overview. Flavour and Fragrance Journal 19: 99–104.

Clifford MN (1985). Chlorogenic acids. In : R.J. Clarke and R. Macrae (eds), Coffee, Elsevier Appl. Sci. London 1: 153-202.

Garcia AAF, Wang S,. Melchinger AE and Zhao-Bang Zeng (2008). Quantitative Trait Loci Mapping and the Genetic Basis of Heterosis in Maize and Rice. Genetics, 180:1707–1724

Gichimu BM, Gichuru EK, Mamati GE, Nyende AB (2012). Selection within *Coffea arabica* cv. Ruiru 11 for high cup quality. African Journal of Food Science, 6(18):456-464.

Gichimu BM, Gichuru EK, Mamati GE, Nyende AB (2014). Occurrence of *Ck-1* gene conferring resistance to Coffee Berry Disease in *Coffea arabica* cv. Ruiru 11 and its parental genotypes. Journal of Agricultural and Crop Research, 2(3) :51-61

Gichuru EK, Agwanda CO, Combes MC, Mutitu EW, Ngugi ECK, Bertrand B, Lashermes P (2008). Identification of molecular markers linked to a gene conferring resistance to Coffee berry disease (*Colletotrichum kahawae*) in *Coffea arabica*. Plant Pathology, 57: 1117–1124.

Gimase JM, Thagana WM, Kirubi DT, Gichuru EK and Gichimu BM (2014). Genetic diversity of Arabusta coffee hybrids and their parental genotypes using molecular markers. Plant cell Biotechnology and molecular Biology, 15(1&2): 31-43.

Guerrero G, Suárez M and Moreno G (2001). Chlorogenic acid studies as a potential criterion in coffee genotype selections. *Journal of Agriculture and Food Chemistry,* **49**: 2454-2458.

Jaetzold R, Schimidt H (1983). Farm Management Handbook of Kenya, Vol. II/B: Natural Conditions and Farm Management Information, Central Kenya. Ministry of Agriculture, Nairobi; Kenya. p.731

Kathurima CW, Kenji GM, Muhoho SN, Boulanger R, Davrieux F (2010). Discrimination of Coffea arabica Hybrids of the Composite Cultivar Ruiru 11 by Sensorial Evaluation and Biochemical Characterization. Advanced Journal of Food Science and Technology, 2(3): 148-154.

Kathurima CW (2013). Characterization of coffee genotypes in Kenya by genetic, biochemical and beverage quality profiles (PhD thesis). Jomo Kenyatta University of Agriculture and Technology, Kenya.

Kumar A and Mishra MK (2014). A new spontaneous tetraploid inter-specific hybrid in coffee (*Coffea* sp.). Scholars Academic Journal of Biosciences, 2(2):168-171

Ky CL, Louarn J, Dussert S, Guyot B, Hamon S, Noirot M (2001b). Caffeine, trigonelline, chlorogenic acids and sucrose diversity in wild *Coffea arabica L*. and *C. canephora* P. accessions. *Food Chemistry,* 75: 223-230.

Lashermes P, Combes MC, Ansaldi C, Gichuru E, Noir S (2011). Analysis of alien introgression in coffee tree (*Coffea arabica* L.) Mol Breeding, 27: 223–232.

Macrae R (1985). Nitrogenous compounds. In : Clarke RJ, Macrae R(eds), Coffee, Elsevier Appl. Sci. London 1: 115-152.

Maria CABD, Trugo LC, Moreira RFA, and Werneck CC (1994). Composition of green coffee fractions and their contribution to the volatile profile formed during roasting. Food Chemistry, 50:141–145.

Mburu, JK (2004). The current recommendations for the processing of high quality and safe coffee in Kenya. In the Proceedings of 20th International Scientific Colloquiumon Coffee, pp 509-512. Bangalore India.

Maria CABD, Trugo LC, Moreira RFA, Werneck CC (1994). Composition of green coffee fractions and their contribution to the volatile profile formed during roasting. Food Chemistry, 50:141–145

Mohammed W (2011). Heterosis and Combining Ability Analysis for Coffee Quality in Diallel Crosses of Diverse Coffee (Coffea arabica L.) Parents in Origin East African Journal of Sciences 5(1) 12-21

Owuor JBO, Van Der Vossen HAM (1981). Interspecific Hybridization between *Coffea arabica* L. and tetraploid *C. canephora* P. Ex Fr. I. Fertility in F1 Hybrids and Backcrosses to *C. arabica*. Euphytica, 30:861-866.

Parvez S (2006). Recent advances in understanding genetic basis of heterosis in rice (*Oriza sativa L*.)

Prakash, NS, Marques, DV, Varzea, VMP, Silva MC, Combes, MC and Lashermes, P. (2004). Introgression molecular analysis of a leaf rust resistance gene from *Coffea liberica* into *C. arabica* L. *Theor Appl Genet, 109*, 1311–1317.

Rabiei B, Rahimi, M, Samizadeh H, Kafi Ghasemi A (2010). Combining Ability and Heterosis in Rice (*Oryza sativa* L.) Cultivars. *J. Agr. Sci. Tech. Vol. 12: 223-231*.

Tessema A, Sentayehu A, Taye K, Weyessa G (2011). Variability and association of quality and biochemical attributes in some promising *Coffea arabica* germplasm collection in Southwestern Ethiopia. International Journal of Plant Breeding and Genetics: 1-15.

Van der Vossen, HAM., & Walyaro, DJ (2009). Additional evidence for oligogenic inheritance of durable host resistance to coffee berry disease (*Colletotrichum kahawae*) in Arabica coffee (*Coffea arabica* L.) *Euphytica 165*, 105–111.

Viani, R (1985) Physiologically active substances in coffee. In R.J. Clarke and R. Macrae eds. *Coffee Physiology ,* cap.1, p1-30 Elsevier Applied Science

3.1.1 ECONOMIC VALUATION OF WAKITUNDU WETLAND RESOURCE IN, BUSIMBI SUB-COUNTY, UGANDA

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Abstract

The hydrology of Wakitundu wetland is not very well documented. The wetland has water throughout the year and is dominated by "kalandalugo", papyrus, miscanthus, typha domingensis, cyperus articulata, "kasalamamba", reeds, afromomum, mimosa pigra, bijumbwa, claundium and aichornia. There is need to conserve these plant species The Total Economic Value frame work was used to estimate the value of the wetland. The monetary value for the

different wetland benefits enjoyed by people who use this wetland was estimated using the Contingent Valuation Method followed by tabular analysis and linear regression for data analysis. The value of Wakitundu wetland in its current state is estimated to be US$ 126,124 per annum. It therefore implies that this wetland could be of greater value if used appropriately. Most individuals use the wetland for agriculture among other activities. The earnings from these activities per month increase the more one gets involved in the activity. This puts the future existence of the wetland at stake. The wetland is a catchment for Lake Wamala that pours its waters in R.Katonga and finally Lake Victoria whose water levels are dwindling. This calls for interventions to check on the proper use and management of the wetland including investments in policy options that aim at conservation of the wetland.

Key words: Economic valuation, Payment of Ecosystem Services, Wetland services, Wetland goods, Contingent Valuation Method.

Introduction

What is a wetland?
Human use of wetlands and exploitation of their resources has been documented for many years. Trying to draw experiences from different authors together so as to provide a precise definition of a wetland is fraught with controversy and difficulty because of the enormous variety of wetland types and the problems of defining their boundaries. The problem is compounded by the fact that many wetlands evolve over time starting as open water, but infilling with sediment and vegetation eventually to become dry land (Davidson et al 1999). Never the less, wetlands certainly occupy the transitional zones between permanently wet and generally dry environments. They share characteristics of both environments yet cannot be classified unambiguously as either aquatic or terrestrial. Wetlands differ widely in character due to regional and local differences in climate, soils, topography, hydrology, water chemistry, vegetation, and other factors (Gosselink et al, 1993). Depth and duration of inundation, a key defining force, can differ greatly between types of wetlands and also can vary from year to year within a single wetland type. According to Ramsar Convention (1971), wetlands are areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing; fresh, brackish, or salty, including areas of marine water the depth of which at low tide does not exceed six meters. Further, Ramsar, convention (1971) Article 2.1 provides that wetlands may incorporate riparian and coastal zones adjacent to the wetlands and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands.

Major categories
Wetlands are categorized as inland (also known as non-tidal, freshwater wetlands) and coastal (also known as tidal, salt water or estuarine wetlands) (Barbier et al, 1997). Man-made wetlands have also been included under wetland classes. Inland wetlands receive water from precipitation, snowmelt, ground water, and runoff while coastal while estuarine wetlands receive water from precipitation, surface water, tides and ground water discharge (Barbier et al, 1997).

Distribution and major functions of wetlands.

Wetlands are one of the world's most important assets containing a disproportionately high number of plant and animal species compared to other areas of the world. Throughout history they have been integral to human survival and development. Wetlands exist in every country and in every climatic zone, from polar regions to the tropics. Finlayson and Moser (1999) noted that wetlands are distributed around the world and cover an area that is 33% larger than the USA. They further observed that regions with humid climates tend to support more wetlands than do hot arid climates due to the high precipitation rates in the former and higher evapotranspiration in the latter. Wetlands are extensive in arctic and boreal regions and along major river valleys (Finlayson and Moser, 1999). Even regions with drier climates possess considerable wetlands (salty wetlands).Nearly half of the world's wetlands may occur between 50º-70º N latitude in the peat rich boreal and arctic regions where bogs and fens are abundant while more than one-third of the earth's wetlands exist between 20º N and 30º S latitude, where forested wetlands and marshes prevail (Finlayson and Moser, 1999). The remaining may be found in temperate zones.According to NEMA (1996) wetlands occupy 13% of Uganda's total area and are mostly located in the central region of the country, some are found in the West, Eastern and Southern areas. The most common vegetation in Uganda's wetlands is papyrus but other wetlands include bogs, flood plains and swamp forests.Wetlands perform an incredible array of ecological functions that we have only begun to appreciate. Environmental benefits of wetlands include water purification, flood protection, shoreline stabilization, ground water recharge, and stream flow maintenance (Dixon and Pagiola 1998). Wetlands also provide habitat for fish and wild life, including endangered species. These functions benefit both man and the environment directly and indirectly.Wetlands faces four major threats including; unplanned agriculture conversion, drainage activities, industrial pollution and excessive harvesting of the wetland products (National Environmental information Center, 1990).

The integrity and sustainability of these vital resources is faced by sand and clay mining, over harvesting of biomass, dumping of solid waste and pollution through release of industrial effluent and domestic wastes. The current and potential consequences include increased floods, shortage of building and crafts materials, and reduction in fish productivity, disappearance of endangered species such as mud fish, decline in water quantity and quality, reduced ground water recharge and decline in the water table as exemplified by the disappearance of springs (Barbier et al, 1997).

General objective

The general objective of this study was to estimate the total economic value of Wakitundu wetland in its current state. This was to help in guiding the authorities of Mityana district to make informed decisions based on proper economic analysis to guide use of this resource in order to ensure its conservation.

Problem Statement

The hydrology of Wakitundu wetland is not very well documented, but what is certain is that it has various biological, ecological, social, cultural and economic values which are still evident in some parts of it. It provides habitat for wild life like the wild pigs, monitor lizards, sitatunga, frogs, snakes, marsh mongoose and the warthogs. It also harbored birds such as the black cranes, little egrets, grebes, yellow billed storks and many others but both the wild animals and birds have reduced in number and some like the warthogs and grebes have completely disappeared (National Wetlands Program, 2000). Important ecological processes include water and carbon cycling. According to tales heard from old people in the area, this wetland provided them with water for domestic use, water for growing vegetables sold in Mityana market and also for their livestock to drink.

In the last 38 years, despite the National Policy for the Conservation and Management of Wetland Resources which calls for sustainable use to ensure that benefits of wetlands are maintained for the foreseeable future being in place, Wakitundu wetland has been exposed to increased encroachment through dumping of town council solid waste largely consisting of plastics, polythene bags, broken glass and organic waste from market food stuffs, increased agricultural activities involving growing of maize, yams and sugar cane, establishment of large brick kilns, sand mining and grazing of domestic animals. There is increased invasion of the open water by water hyacinth (*Eichornia crassippes*). The water in the swamp quickly dries up and people have resorted to clearing the wetland in order to sustain their agricultural practices in the dry season. Unsubstantiated claims by the community that they have lost incomes because of the loss of the services of this wetland call for an investigation. There are also complaints that catch for the traditional fish have plummeted down to even none in weeks unlike twenty years ago. These are signs of loss of the wetland's ecological integrity and also its cultural and economic attributes for which it is revered by the community. It is not clear as to what will happen to the wetland's ecological and socioeconomic attributes if the current practices (responsible for its destruction) are left unchecked. It is necessary, therefore, to generate information that will be useful to curtail this trend of Wakitundu wetland destruction.

Methods

Sampling sites and study design

Wakitundu wetland is found in Busimbi sub-county currently Mityana town council. The sub-county comprises of ten parishes and one hundred and six villages. Out of the 10 parishes, Wakitundu wetland covers only two parishes that is Kireku parish and Nakaseeta parish. Research was conducted in both parishes in specifically five villages namely: Kikuumambogo, Minana galabi, Danya, Ziribanda, and Businzigo villages. The research design used was cross sectional. This is because data was collected from the respondents at a point in time. A descriptive research design was employed where research questions were used to collect qualitative and quantitative data needed. Primary data was generated from the questionnaires which were administered to the members utilizing the wetland.

Study population

The study population encompassed all the people in Busimbi sub-county, but focus was more on the communities utilizing the wetland. This was because they had considerable amount of information and substantial exposure and knowledge of the research topic that would allow meaningful analysis and observation of the study.

Sampling procedure and sample size

The sampling procedure was based on probability sampling techniques. Simple random sampling technique was used where respondents were selected at random to fill the questionnaires. This was basically to eliminate biasness in selecting people to answer the questionnaires. The sample comprised of a total of 60 respondents, approximately 10% of the population that uses the Wakitundu wetland. They provided good scale information concerning the wetland. These included those individuals of who utilize the wetland most especially those who were found carrying out activities in the wetland.

Validity and reliability of data collection instruments

The validity of an instrument refers to the ability of the instrument to collect justifiable and truthful data (Odiya 2009). The researcher constructed a draft copy of the questionnaire which was pretested that is, was given to respondents who were not included in the final sample chosen for the study in order to determine if it would generate the required information. The necessary corrections and modifications were made there after. Reliability is the measure of the degree to which the research instrument yields the same results after repeated trials (Amin 2005). The researcher ensured reliability by interpreting the questions in the questionnaire and writing the answers for those respondents who could not read English and write. For this the researcher was able to obtain the right information needed for this research from the right respondents hence ensuring data accuracy.

Ethical consideration

Ethical principles mostly the principle of avoiding harm and invasion of privacy to participants were put into consideration. An introductory letter and identity card were presented to the respondents as a way of introduction enabling the respondents to understand that the research was purely for academic purposes. Assurance was provided to respondents that there was to be no information revealing the identity of any respondents' name in the final report unless with their permission.

Data types and collection

Both primary and secondary data was used in this research study. Primary data was collected directly from the field of study by use of questionnaires, observation and face to face interviews. Secondary data was obtained from text books, journals and documentaries mostly sourced from the internet.

Contingent valuation method was also employed in order to obtain the estimated TEV of the wetland. The two approaches of this method that is to say willingness to pay and willingness to accept were used. Open ended questions were provided to the respondents concerning how much they were willing to pay for the conservation of the wetland depending on the amount they get from the activities they practice from the wetland (direct use value) and also depending on the services that the wetland provides them (indirect use value). The same type of questions were asked to the respondents concerning how much they were willing to accept in compensation for doing a way with the wetland (non use value of the wetland). CVM is the most accepted method for estimating total economic value, including all types of non use or passive use values. CVM can estimate use values as well as existence value, option values and bequest values.

TEV of the wetland=Direct use value + Indirect use value + Non use value.

Interviews were conducted to generate more qualitative data about the study. This method involved face to face interaction with respondent to find out their view on wetland conservation plus their relationship with wetland.

The observation method involved the act of moving around the wetland so as to find out the economic activities being carried out from the wetland. It was also applied in order to take note of the facts not considered in the study before.

Methods of data processing and analysis

Data processing
Data was imported from excel to SPSS computer package for easy analysis. The analysis involved generating of frequency tables, bar graphs, pie charts and cross tables for univariate analysis.
Methods of analysis

Tabular analysis
This involves the computation of the means, percentages and frequencies. This information was used to model variables on pie-charts and bar charts. Also this was employed in generating relationships between variables by carrying out a cross tabulation. This was specifically done in order to come up with valid reasons as to why on analysis certain results were obtained.

Linear regression analysis
It is a statistical method that enables us to establish the causal relationship between variables. It was used to study the causal relationship between two variables that is an independent a dependent variable. This was used in testing the level of significance of the factors that affect individuals WTP and WTA in estimating the value of the wetland.

Result

Economic value of the wetland

An important objective was to measure the economic value of the identified use and non use values/ options of the Wakitundu wetland in its current state. In addressing this objective, respondents were requested to answer some questions which provided a basis for reaching the economic value of the wetland. Analysis was done on people's willingness to pay for conservation depending on how much they get from the activities they carry out from the wetland per month and also depending on the services the wetland provides them. Analysis was also done on the amount people were willing to accept in compensation for doing away with the wetland.

Individual's earnings from the activities they carry out from the wetland per month

The respondents were asked how much they earned from the activities they practiced from the wetland. It was discovered that most of them earn above 15,000 shillings per month.(figure 3.6)
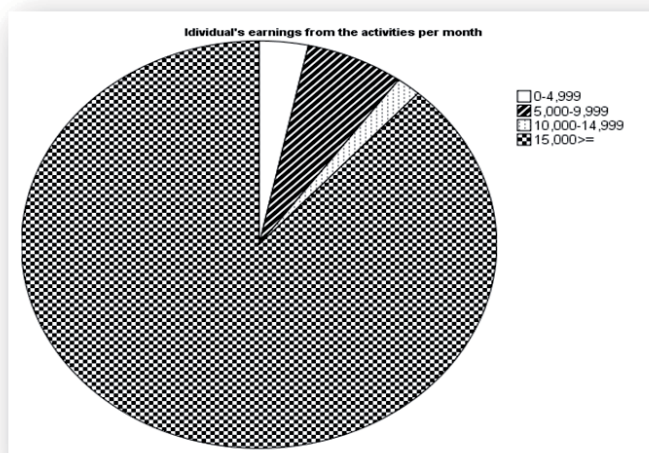
Figure 1: Individual's earnings from the activities they carry out from the wetland per month

Almost all of the individuals cultivating in the wetland do not pay rent, those who paid pay in kind. This may be the reason as to why they are able to earn above 15,000 shillings at the end of the month.

Relationship between the amount individuals earn per month and the activities they take part in

A linear regression was estimated to obtain the relationship between the amount individuals earn per month and the activities they take part in (Appendix 3). p-value was less than 0.05 that is (0.033< 0.05) which justifies that the activities that respondents take part in are statistically

significant in explaining the amount they get from these activities per month. Therefore a unit increase in the activity one carries out from the wetland brings about a 0.033 change in the amount he or she will be willing to pay for conservation of the wetland. This explains why individuals who get above 15,000 shs are mostly those who carry out cultivation in the wetland since it is the most practiced activity in the wetland. (Figure 3.7)
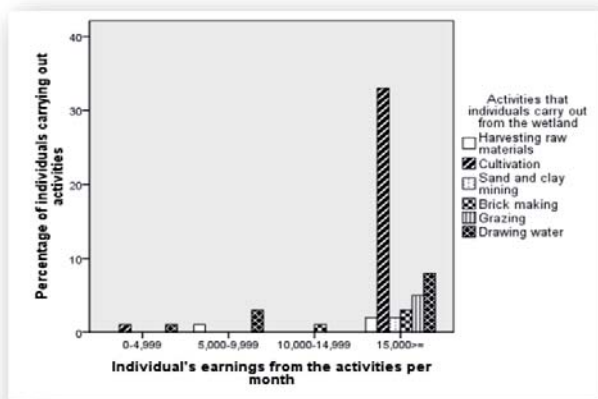
Figure 2: Relationship between individual's earnings from the activities per month and the different activities that they carry out from the wetland.

Willingness to pay for conservation of the wetland

The total amount of money that individuals were willing to pay for the conservation of Wakitundu wetland was obtained by summing the individual WTP for conservation basing on the amount individuals earn from the activities they carry out from the wetland and also basing on the services that the wetland provides them.

WTP for conservation of the wetland based on the amount individuals earn from the activities they carry out from the wetland per month

Individual's earnings from the activities they carry out from the wetland per month reflect the direct use value of the wetland.

Respondents were asked if they were willing to pay any amount of money in support of a program associated with the conservation of the wetland basing on their earnings from the activities they carry out from the wetland. Most of them were willing to pay in support of the program (Figure 3.8).
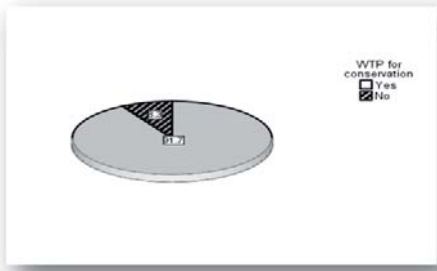
Figure 3: Individual's WTP for conservation basing on their earnings from the activities carried out from the wetland per month.

However, a few were not willing to pay any amount in support of the program. Most people think that if they state the amount they are willing to pay, they will be made to pay that amount. This probably was the reason some were not willing to pay any amount of money in support of the program.

Willingness to pay for conservation of the wetland basing on the amount earned from the activities carried out from the wetland in relation to gender**.**
Females have more positive WTP for conservation of the wetland than males (Figure 3.9).
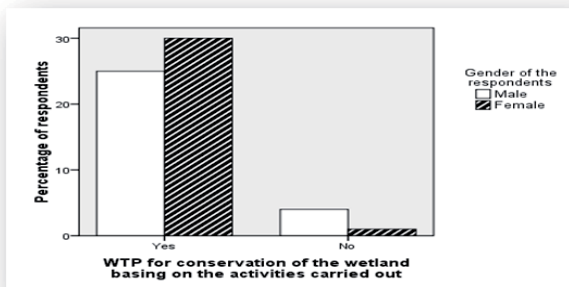
Figure 4: Representation of individuals' WTP for conservation of the wetland basing on the earnings from the activities carried out from the wetland in relation to gender.

More females depend on the wetland than males this could probably be the reason as to why they are more willing to pay for conservation of the wetland than males.

Estimated value of Wakitundu wetland basing on the amount individuals earn from the activities they carry out from the wetland per month

Individuals were required to state their WTP in support of the program associated with the conservation of the wetland their contributions (Appendix 4). Most of them were willing to pay an amount in the range of (5,001-10,000) shillings (Figure 3.10).
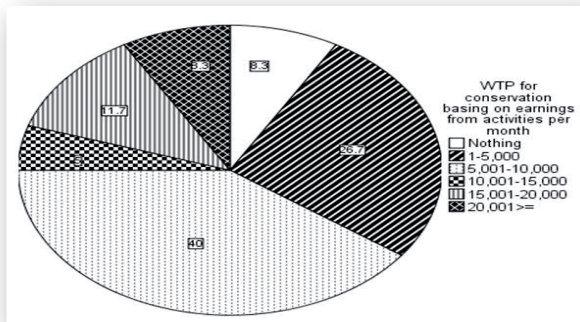
Figure 5: Amount individuals are willing to pay basing on their earnings from the activities per month.

This is probably because when most people are required to state the amount they would be willing to pay in order to conserve the wetlands, they think that some one is going to actually make them pay that amount so they would rather state a low amount.

Surprisingly some individuals were not willing to pay anything in support of the program for conservation. Perhaps most of the people who carry out activities from wetland are poor. This is probably why some where not willing to pay anything.

The value of Wakitundu wetland basing on how much individuals earn from the activities they carry out from the wetland was obtained by aggregating the WTP of difference individuals (Appendix 5). The value (direct use value) of the wetland in this case is estimated to be US$ 2,220 per annum.

Analysis of the effect of individuals' earnings from the activities they carry out from the wetland per month on the amount they were willing to pay for conservation of the wetland.
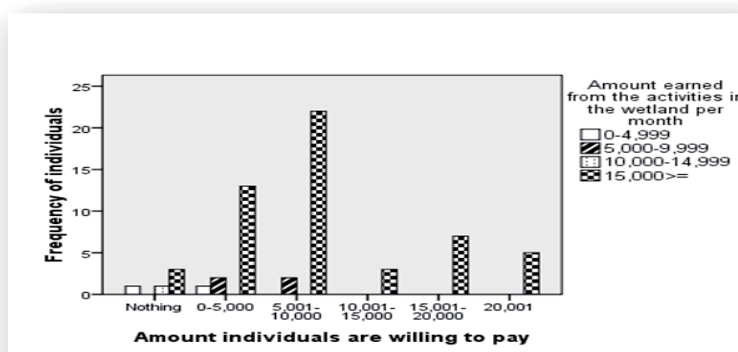
Figure 6: Representation of the relationship between amount individuals are willing to pay and the amount they earn from the activities they carry out from the wetland per month.

A linear regression model was estimated to test for hypothesis, that individuals' earnings from the activities practiced in the wetland per month affect the amount one is likely to pay for

conservation of the wetland. Results (Appendix.6). p< 0.05 that is (0.030 < 0.05) implied that the amount individuals earn from the activities they carry out from the wetland is statistically significant in explaining the amount that one is likely to pay for conservation of the wetland. Therefore a unit increase in the amount that one earns from the activities carried out in the wetland will bring about a 0.030 change in the amount that he or she will be willing to pay for conservation of the wetland.

Analysis of the effect of the size of land utilized by different individuals on the amount individuals were willing to pay for conservation of the wetland

Individuals who were using averagely larger size of land were willing to pay low amount or even nothing for the conservation of the wetland. (Figure 3.12).
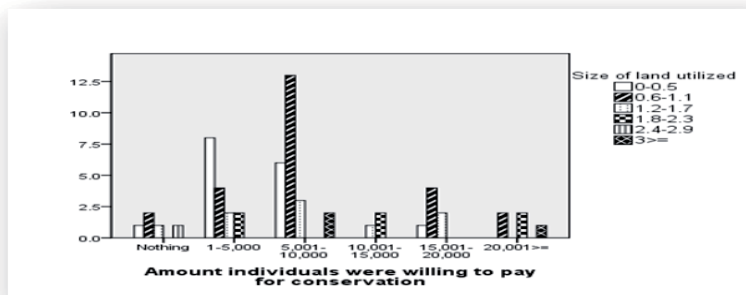
Figure 7: Relationship between the size of land utilized by different individuals and the amount they were willing to pay for conservation of the wetland.

A linear regression model was estimated to help in obtaining the relationship between the size of land that the individuals were utilizing and the amount they were willing to pay for conservation of the wetland (Appendix 7). Un expectedly, results were such that, the p> 0.05 that is (0.067>0.05). Therefore the size of land utilized by different individuals is not statistically significant in determining the amount that one would pay for conservation of the wetland. Hence a negative relationship. This suggests that individuals in stating the amount they are willing to pay they do not take into account how much land of the wetland they put to productive use.

WTP for conservation of the wetland basing on the services that the wetland provides to different individuals

Services that the wetland provided to the community were also ascertained and the results were such that conservation of water is the service that Wakitundu wetland provides to most individuals (Figure 3.13).
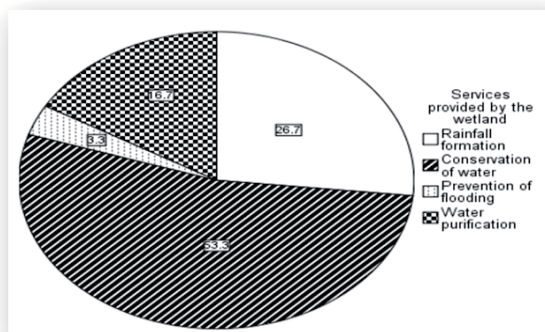
Figure 8: Services that Wakitundu wetland provides to different individuals.

Water is a basic requirement by almost all wetland resource users that is one may require it for domestic use, another may require it for brick making and someone else may require it for cultivation. This could probably be the reason as to why most individuals gave it as the major service that the wetland provides to them.

The amount that individuals were willing to pay for conservation of the wetland basing on the services that the wetland provided to them captured the indirect use value of the wetland.

Individuals' willingness to t contribute an amount of money in support of a program associated with the conservation of the wetland basing on the services that it provided them was sought and most were willing to support the program (Figure 3.14).
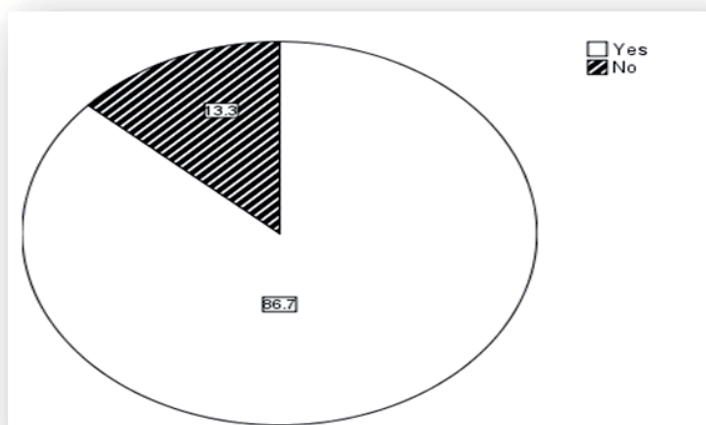
Figure 9: Individual's WTP for conservation basing on the services that the wetland provides to them

Estimated value of the wetland basing on the services that it provides to different individuals

Individuals' WTP in support of the program associated with the conservation of Wakitundu wetland basing on the services that it provided them with was ascertained and their contributions were investigated (Appendix 8). Most of them were willing to pay an amount within the range (1-5,000) shillings (Figure 3.15).
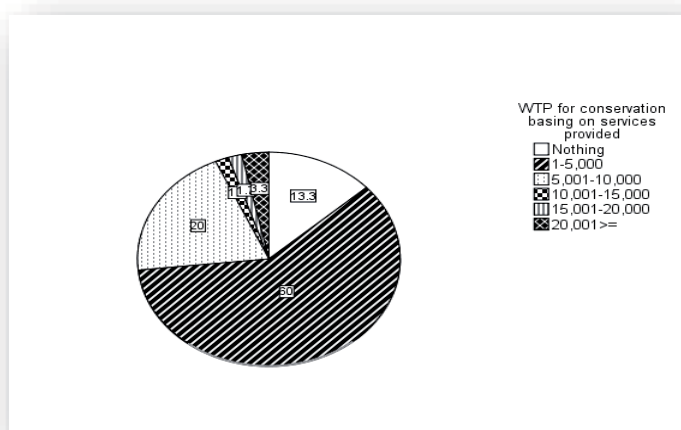
Figure 10 : Amount individuals were willing to pay for conservation of the wetland basing on the services that it provides to them

Perhaps most people cannot value wetland services. This may be the reason why most individuals were willing to pay such a low amount (1-5,000) shillings in support of a program associated with the conservation of the wetland.

The value of Wakitundu wetland basing on the services that it provides to the different individuals was obtained by aggregating the WTP of difference individuals (Appendix 9). It was estimated to be US\$ 1,152 per annum.

Analysis of the effect of individuals' level of education on the amount they were willing to pay for conservation of the wetland basing on the services that the wetland provides**.**

Individuals willing to pay higher amount for conservation of the wetland basing on the services it provides are those whose level of education is high and those willing to pay a lower amount being those with low education levels (Figure 3.16.).
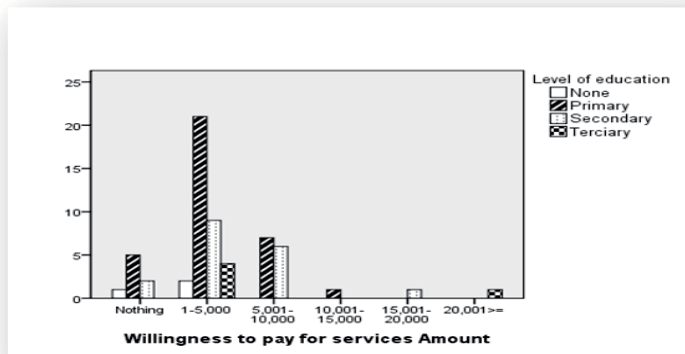
Figure 11: Relationship between individuals' level of education and the amount they were willing to pay for the conservation of the wetland basing on the services it provides to them

A linear regression was estimated to obtain a relationship between individual's education levels and the amount they were willing to pay for conservation of the wetland basing on the services that it provides to them (Appendix 10).The results were such that, the $p< 0.05$ that is, $(0.038<0.05)$.

This implied that individuals' level of education is statistically significant in determining the amount that individuals were willing to pay for conservation of the wetland basing on the services that the wetland provides them. Therefore a unit increase in one's level of education brings about a 0.038 change in the amount one is likely to pay for conservation of the wetland.

Willingness to accept compensation for doing away with the wetland

Individuals' willingness to accept compensation was used to capture most of the non use values of the wetland.When the community was asked if they would be willing to support any developmental program associated with doing away with the wetland. Most were willing to accept compensation so as to do away with the wetland (Figure 3.17).
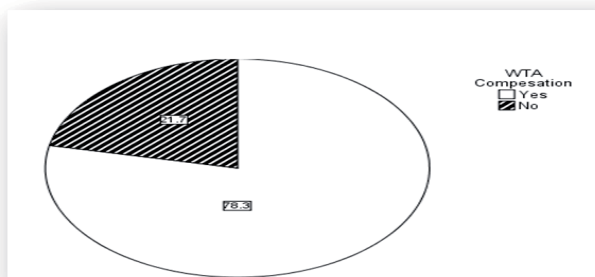
Figure 12: Individuals' WTA compensation for doing a way with the wetland.

Almost all people living adjacent to wetlands and more so those who carry out activities from these wetlands do not own the wetlands. This could probably be the reason as to why many respondents were willing to accept compensation for doing away with the wetland.

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Estimated value of the wetland basing on the amount individuals were willing to accept as compensation for doing away with the wetland

The community's willingness to accept compensation for doing away with the wetland was investigated (Appendix 11). The results were such that most of them were willing to accept an amount in the range 2,000,001>= (Figure 3.18). Whenever individuals are asked to state the amount they would be willing to accept, they imagine that they are going to be paid this money so they tend to overestimate the amount they are willing to accept. This may be the reason as to why many respondents are willing to accept such a high amount that is above 2,000,001 shillings.
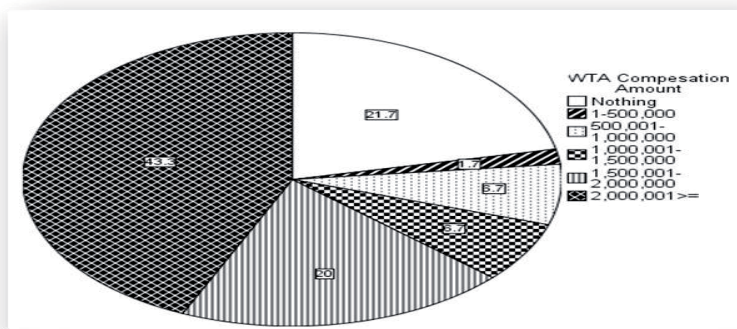
Figure 13: Amount that different individuals were willing to accept as compensation for doing away with Wakitundu wetland.

Unexpectedly, some individuals were not willing to accept any amount in order to do a way with the wetland. This is probably because they know that they can never get some services and resources that the wetland provides to them from somewhere else, also because of the cultural values that they attach to the wetland as well as the historical perspectives about the wetland.

Analysis of the relationship between individuals WTA compensation for doing away with the wetland and gender

Most individuals who are not willing to accept compensation for doing away with the wetland are females (Figure 3.19). This may be because they are the ones who; attach more cultural value to the wetland, believe that if the wetland is done away with there are services and resources (like medicinal herbs) that they can never obtain from somewhere else.
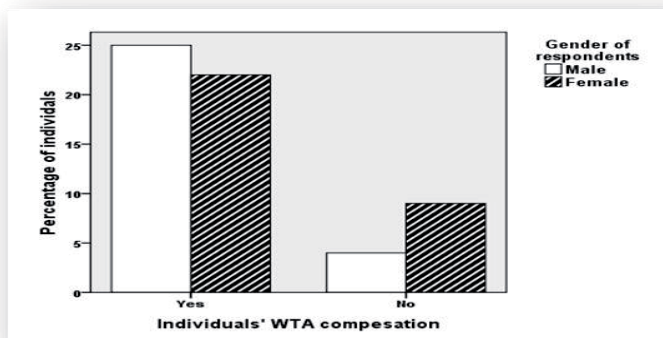
Figure 14: Representation of the relationship between individuals' WTA compensation and gender.

The value of Wakitundu wetland basing on individuals' WTA compensation for doing away with the wetland was determined (Appendix 12). It was estimated to be US$ 375,000 per annum

Estimated total economic value of Wakitundu wetland

This was obtained by summing; the direct use value of the wetland (WTP for conservation basing on individuals' earnings from activities carried out from the wetland) with the indirect use value of the wetland (WTP for conservation basing on the services that the wetland provides to different individuals) and the non use value of the wetland (WTA compensation for doing away with the wetland). The mean value of the wetland was obtained which for this research was taken as the value of the wetland as perceived by the community utilizing the wetland (Table 3 1).

Table 1: Estimated Value of Wakitundu wetland

Values/Benefits	Aggregate Amount (US$)
Direct use value	**2,220**
Indirect use value	**1,152**
Non use value	**375,000**
Total average value of the wetland	**126,124**

The TEV of Wakitundu wetland is estimated to be US$ 126,124. The economic benefit of conserving Wakitundu wetland is therefore estimated at US$ 126,124.

DISCUSSION

Economic valuation of the wetland

The more the activities are carried out from the wetland, the higher the earnings from the activities per month. Some individuals were not willing to pay any amount of money in support of the program. This is because people who depend on the wetland are usually the poor, therefore cannot afford paying any amount of money for conservation of the wetland. This is in support of

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Angelsen (1997) who argued that over half of the world's poor live in rural areas and depend on natural resources for survival.

Individuals were willing to pay such a low amount of money as compared to what they were willing to accept as compensation for doing away with the wetland. This is because most people think that if they are asked to state the amount they are willing to pay, they will be made to pay that amount. This is in support of Costanza et al. (1989) who observed that the problem with the WTP technique is that respondents may engage in strategic responses for example; if they think they may have to actually pay what they say they are willing to pay, they may state a value lower than their true value.

Also individuals were willing to pay a low amount of money for conservation of the wetland basing on the services that the wetland provides to them because they cannot value wetland services. This is in support with Lambert (2003) who noted that the reason as to why human beings destroy the essential elements of their ecosystems is because they do not value wetland services in economic and monetary term. He further argued that the reason for not valuing wetland services is linked to the fact that most of us are not aware of wetland characteristics (biological, chemical and physical) which enable the development and maintenance of their structure, which in turn is key to the provision of wetland services.

Gender was discovered to be one of the factors that affect individuals' WTP for conservation of the wetland. Females were discovered to have a more positive WTP for conservation of the wetland than males and this is because they depend on the wetland more than males. This is in support of Rio Declaration (1992) where it is pointed out that it has long been recognized that women are the primary users of many natural resources.

Other factors that affected individuals' WTP for conservation of the wetland were the amount that individuals earn from the activities they carry out from the wetland and their level of education. These were such that individuals' WTP increased with the increase in their earnings from the activities that they carry out from the wetland. This contradicts Kipkoech et al, (2010) who observed that individuals' income inversely influences the WTP amount in that those individuals with high levels of income are willing to pay less compared to those with less income, who are willing to pay more. Findings showed a similar observation with the education levels; the higher one's education level was, the higher the amount that he or she was willing to pay for especially wetland services and the lower one's education level was, the lower the amount he or she was willing to pay. However, Kipkoech et al, (2010) agued that, factors including individuals' gender and level of education do not influence their willingness to pay for conservation of wetland goods and services.

Also, just like for WTP, gender was a factor that influenced individuals' WTA compensation for doing away with the wetland. Most females were not willing to accept compensation for doing away with the wetland as compared to males and this is because females believe that once they do away with the wetland, there are some services and goods that the wetland provides that they can never get from somewhere else and besides they depend so much on the wetland for subsistence.

Indirect use, optional and Non-use values reflected the total economic value of Wakitundu wetland

The contingent valuation is one of the only ways to assign dollar values to non-use values of the environment values that do not involve market purchases and may not involve direct participation (Dennis, *et al*, 2001). These values are sometimes referred to as ''passive use'' value. They include everything from the basic life support functions associated with ecosystem health or biodiversity, to the enjoyment, to the enjoyment of a scenic view or wilderness, to appreciating the option to fish or bird watch in future, or the right to bequest those options to your grandchildren. It also includes value people place on simply knowing that say a shoe-bill exists. Non-use, or passive use, environment benefits are likely to people implicitly treated as zero unless their dollar value is somehow estimated (Dennis, *et al*, 2001). The annual aggregate value of Wakitundu wetland is estimated to be US$ 126,124. This is the economic benefit of conserving Wakitundu wetland as per the 60 respondents. Probably the value would have beeen bigger than this if more than 60 respondents were considered in the study.

Conclusion

Specific gaps in awareness were identified Wakitundu wetland users do not understand the trade offs relating to competing land uses and ecosystem services. That is they value more the wetland basing on the amount they earn from the activities they carry out from the wetland than they value it basing on the services that it provides to them. This was identified as a significant issue which needed to be addressed in the planning exercise in order to bring about proper use and managemen of the wetland. From a gender perspective, on observation women are the major users of the wetland. They are mostly involved in drawing of water from the wetland and cultivation (growing of food crops) since it is their sole responsibility to provide food for their families. Since the community living adjacent to this wetland has enormous benefits from it, efforts to conserve the wetland are urgently needed before it is completely reclaimed.

Despite its potential in supporting people's livelihood, Wakitundu wetland is being converted for other land uses and this if not put to a stop or limited, will lead to a decline of this wetland benefits to the community living adjacent to it. The increased conversion of Wakitundu wetland to other land uses especially agriculture has resulted into loss of this wetland. This continuing loss requires an appropriate approach to its management. Since it plays a significant role of maintaining the water levels in Lake Wamala that pours its water into R. Katonga and finally L Victoria whose decreasing water levels have continued to generate concerns over sustainability of its use for electricity generation. It is important and with urgent need to protect this wetland so as to save Lake Victoria.

There is a positive relationship between the amount that individuals earn from the activities they practice from the wetland and the activities that they carry out there. This creates a big threat to the future existence of Wakitundu wetland. in a way that, the more you carry out the activities the more you earn. For this reason, people tend to over exploit the wetland in the struggle to raise their incomes which may result into degradation of the wetland which brings about the question of its existence for future generation. Although conversions to other land uses yields more income to the individuals who take part in these activities, the great amount of earnings are only

in the short run and are restricted to only a few who carry out these activities from the wetland while reducing or eliminating the various type of production which previously went to many individuals in the community.

Wakitundu wetland system contributes significantly to the livelihood of local communities in adjacent villages through provision of ecosystem services and goods vital for human well-being. It is also a source of income and employment for the local residents especially those carrying out brick making and sand and clay mining. In its present form the wetland contributes goods and services worth US$ 126,124 per annum.

From the TEV of US$ 126,124 it can inferred that Wakitundu wetland contributes to each neighboring household US$ 2,220 per annum in form of DUV, US$ 1,152 per annum inform of indirect use vale and US$ 375,000 per annum in form of non use value. From this, it means that economic valuation can give an indication of the society's preferences that is easily understandable and communicable. It can help make explicit preferences that are normally hidden and not reflected in market prices. Additionary, economic valuation can translate part of the information obtained through qualitative and quantitative indicators into monetary figures. For example, the wastewater purification service provided by healthy wetlands can be valued in monetary terms through the equivalent cost of a wastewater treatment plant that would provide a similar service.

Important to note is that individuals WTA was far higher than their WTP for conservation of the wetland. However, this does not mean that they prefer doing away with the wetland to conserving. It is just that individuals need to be sensitized so as to increase their awareness about wetland goods and services. Also these individuals need to be sensitized about valuation of natural resources so as to eliminate cases of individuals stating an amount that they are willing to pay lower than their true value.

Recommendations

Wakitundu wetland is of great importance to its users, but unless emphasis is put on the awareness raising campaign on the role and wise use of Wakitundu wetland, it will continue to be degraded and its impact will affect people who depend entirely on it especially those in the vicious cycle. Good land use practices such as mulching should be promoted so as to reduce the impact that has been caused on the wetland due to poor land use practices.

I also recommend that this approach of economic valuation of resources by their users be done for all natural resources since it broadens the grounds for policy action in form of advocating for their proper management.

Given the reported decline in the water levels in Lake Victoria, Mityana district local government with the support of the central government should structure an appropriate approach to the management of Wakitundu wetland since it is a catchment for Lake Wamala that pours its waters in R.Katonga and finally Lake Victoria. The best management practice would be to fence

the wetland and prevent stock from walking into the water and grazing on riparian vegetation. It is also recommended that a buffer zone be fenced around the wetland. Interventions may require implementing the objectives of the LVEMP program in Mityana district.

Local communities and their local leaders should be sensitized on policies and laws governing environment management in Uganda, conservation values of Wakitundu wetland as well as discouraging them from setting illegal fires and wetland edge farming and employing poor land use activities in the wetland. This will help ensure that Wakitundu wetland is conserved through community by law hence increased efficiency in its management.

Environmental committees for Mityana local government should be strengthened so that local leaders directly get involved in Wakitundu wetland management. The current level of reliance on Wakitundu wetland for survival is too overwhelming. The foot prints to and from the wetland especially for the parts of Kikuumambogo can be seen which indicates daily use of the wetland. The demand for this wetland resources for other land uses since they raise great earnings to the individuals is very high. Therefore a need for Mityana district local government with support of the central government to assess needs of the community living adjacent to this wetland and advise accordingly on how such needs can be addressed without necessarily degrading the wetland.

Mityana LG through the NR department with the support of the central government should advice farmers on activities that can be sustainably carried out in Wakitundu wetland in an environmentally sound manner but yet making considerable contributions to user income. Proposed activities include; bee keeping, craft making among others.

Due to time and financial limitations, the extent of encroachment on Wakitundu wetland was not obtained. This was to enable estimate how much in dollar terms has been lost so due to encroachment on this wetland basing on the estimated value of the wetland in its current state. This could be an interesting research topic / issue that can be investigated to come up with solutions needed for decision and policy making. However communities should be trained on the wise use and role this wetland so as to limit encroachment.

I recommend that a larger group of respondents with knowledge about wetland goods and services and the general valuation process be used in the study next time. The small numbers of respondents limited the attainment of enough data that could enable modeling of the factors that affected indiviiduals' willingness to pay for wetland conservation.

Since CVM is associated with problems of individuals over stating their WTA and under stating their WTP, I recommend that another person conducts this research using a different valuation method like the replacement cost method. Measures of replacement cost are generally much easier to estimate than people's willingness to pay for ecosystem goods and services.

Acknowledgement

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References

Amin. M.E, 2005. Social science research: conception, methodology and analysis. Kampala: Makerere University Printery.

Barbier, E.B., Acreman M.C. & Knowler, D. 1997. Economic valuation of wetlands: a guide for policy makers and planners. Ramsar Convention Bureau, Gland, Switz erland.

Bateman I. J. and K.R. Turner (1999). Valuation of the environment, methods and techniques. London:Belhaven Press, p. 120-191.

Carson, R. T., Flores, N. E., Martin, K. M., and Wright, J. L. (1996), Contingent valuation and Revealed preference methodologies - comparing the estimates for quasi-public goods', Land Economics, 72: 80-99.

Costanza, R., Farber, S.C. and Maxwell, J., 1989. Valuation and management of wetland Ecosystems.

David.W.Pearce and Jeremy. Warford (1994); Economics, Environment and sustainable development.

Dennis, M.K. and Mazotta, M. (2001). Ecosytem valuation. http://www.ecosystemvaluation.org.(26/05/2013).

Dixon, J. & Pagiola, S. 1998. Economic analysis and environmental assessment. Environmental Assessment Sourcebook Update, April 1998, Number 23. Environment Dept., the World Bank. 14 pp.

Finlayson, C.M. & Davidson, N.C. (eds.) 1999. Global review of wetlands resources and priorities for wetland inventory. Wetlands International, human well-being.

Finlayson, M and Moser, M. (1991); Wetlands National waterfowl and wetlands Research Bureau. Facts on file, London and New York.

Forum for Economica and Environment (Module 9). Economic Valuation of Natual Resources and the E nvironment.

Freeman, A.Myrick (1993). The measurement of Environment and Resource Values. Theory and Methods, Resources for the Future Washington

Fretwell. D Judy Richard P, and R. Daniel Smith. National Water Summary on Wetland Resources. United States Geological Survey Water Supply Paper 2425 http://pubs.usgs.gov/wsp 2425/functions.html.(29/12/2012)

Green, P. E and Srinivasan, V (1978). Conjoint Analysis in Consumers Research Issues and Outlook, Journal of Consumer Research 5, 103-123.

Haneman, M. W. (1984). Welfare evaluation in contingent valuation experiments with discrete response data reply. American Journal of Agricultural Economics, Vol. 66, pp.322-341.

Hensher, D. A (1994). Stated preference analysis of Travel Choices.

Hussen, A. M (2000). Principles of environmental Economics: economics, ecology and public policy. Roatledge London.

IUCN (1990). The World Conservation Strategy, IUCN, Gland, Switzerland.

Mazzatto, King M Dennis (2000). Ecosystem valuation.
http://www.ecosystemvaluation.org/index.htm (8/06/2013).

Millennium Ecosystem Assessment, (2005) Ecosystem Assessment, 2005. Ecosystems and human well-being: Wetlands and water synthesis. World Resources Institute, Washington, D.C.

Mitsch, W. J and Gosselink, J.G (1993) Wetlands. Van Nestrand Reignhold, New York. Second Edition.

Mityana District Environment Action Plan, (2007/2008.) Department of Natural Resources.

Mityana district local government Annual Report (2006/2007).

Mityana District State of Environment Report (2007/2008). Department of Natural Resources.

Munasinghe, M and McNealy, j (1994). Protected area economics and policy. Linking conservation and sustainable development.

Munichi PKT, Mvena ZSK, Kajembe GC, Semu E. Maliondo SM 2003. Conflicts and Conflict Management in the Use of Water Resources.

Nakiyemba Were Alice (2013). Stakeholders' Perceptions on the Governance of Natural Resources in Ugandan Lake Victoria Catchment.

National environment information center (1994); state of environment report for Uganda. Ministry of national resources Kampala.

National Wetlands Policy Uganda (1995). National policy for conservation and management of wetland resources. The Republic of Uganda, Ministry of natural resources.

NEMA (1996). National State of the Environment Report 1996, National Environment Management Authority, Kampala Uganda

NEMA (2010). National State of the Environment Report, 2010, National Environment Management Authority, Kampala Uganda

Norbert Henninger. Ecosystem Assessment. Ecosystems and human well being
http://www.ncbi.nlm.niih.gov/pubmed/19700447(22/05/2013)

Odiya. J. N, 2009. Scholarly writing research proposals and repots in APA or MLA publication style, Kampala: Makerere University Printery

Pearce, D. and Moran, D. (1994) The economic value of biodiversity. The World Conservation Union, Gland, Switzerland.

Pearce, D.W and Warford, J.J (1993). World Without End.Oxford University Press, Oxford.

Ramsar Convetion on Wetland[1] in 1991 in Iran. http://www.ramsar.org (20/05/2013)

Ramsar, Iran (1971). A Report of the Millennium Ecosystem Assessment

Randall, A. and Stoll, J., 1980. Consumer's surplus in commodity space. Am. Econ. Rev., 70: 449-555.

Royal commission on wetlands pollution (1998). Setting environmental standards.

Russi D , Ten Brink P, Farmer A, Badura T, Coates D, Forster J, Kumar R, Davidson N (2013). The Economics of Ecosystems and Biodiversity for Water and Wetlands IEEP, London and Brussels; Ramsar Secretariat, Gland.

Scott. D.A. (1989). Design of Wetland Data Sheet for Database on Ramsar Sites. Mimeographed report to Ramsar Convention. Bureau, Gland, Switzerland.

Thang.Nam Do and Bennett (2005). An Economic Valuation of Wetlands in Vietnam's Mekong Delta.

The21stCentury Schoolhouse (1997). Depletion of Uganda's Wetlands.

Turner, K and Jones, T (1990); wetlands market and intervention failures. Earth scan

publication ltd London.

Wattage, P. Mardle, S and Pascoe, S (2002). Evaluation of the importance of fisheries management objectives.

Whitmarsh, D. and Wattage, P.(2002). Economic Valuation of Natural Environment.

Willis, K.G (1991). The recreational value of the forestry commission estate in Great Britain.

3.1.2 EFFECT OF CATTLE MANURE, MINERAL FERTILIZER AND RHIZOBIUM INOCULATION ON PRODUCTION OF CLIMBING BEANS AND SOIL PROPERTIES IN BURERA DISTRICT, RWANDA

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Abstract

Known as "meat for the poor", beans constitute a predominant source of proteins in Rwandese diet; supplying 65% of national dietary protein compared to 4% from animal sources. However, on-farm bean productivity is about 0.8 – 1.0 tons/ hectare which is quite low compared to 5 tons/hectare that is achieved under optimal conditions. The objective of the study was to assess the effect of mineral and organic fertilizers as well as rhizobium inoculation on climbing bean production in Burera district. The experimental design was a split plot in completely randomized design (CRD) with two main plots (with and without Rhizobium inoculum); four sub-plots (Cattle Manure, DAP, Cattle manure + DAP, untreated control). Data were recorded on yield, nodulation, soil properties and cost-benefit. Average yields were significantly different (P< 0.0001), at 3900 kg/ha from inoculated plots and 2946 kg/ha from non-inoculated plots. Statistically significant differences were also observed among treatments (P<0.0001) with the highest mean yield of 4782 kg/ha obtained from treatment with Inoculum + DAP + Cattle Manure against 2640 kg/ha from untreated (control) plots. The mean number of nodules was significantly different (P< 0.0001) between inoculated (60 nodules) and non-inoculated (15 nodules) plots. Regression analysis between yield and nodule number showed a coefficient of determination R^2 of 0.8 and a p value of < 0.0001, which confirmed the dependence of the yield on nodulation. Cost-benefit analysis indicated profit averaging 1,330 USD per season per hectare in the highest yielding treatment and loss of 388 USD in the lowest yielding scenario.

Introduction

Known as "meat for the poor", beans are regarded as a "near complete food" based on their nutritional values. Beside the proteins, beans provide also resistant starch, soluble and insoluble fiber,vitamin B and minerals such as Iron, Zinc, Magnesium, Copper and Potassium (Hutchins, 2011), and account for 65% of national dietary proteins compared to 4% from animal sources. Research has shown that bean consumption in Rwanda is among the highest in the world, where annual average is evaluated at 60 kg per capita compared to 17 kg per capita for Africa (WFP,

2009). Climbing beans are more profitable given that they save land by assuring higher productivity on the same area compared to bush beans (Kelly et al., 2012). Climbing bean productivity in farmers' fields is about 0.8 – 1.0 t ha^{-1}, which is very low for climbing beans compared to 5 t ha^{-1} that have been achieved under optimal management conditions (ISAR, 2009). Diseases, lack of improved seeds, small size plots, low use of fertilizers, and lack of cheaper innovations of staking are the main causes for low productivity experienced by farmers. However, the Government of Rwanda and partners in development are putting more efforts towards the development of climbing beans' program. In that context, climbing bean is being among the selected crops in Crop Intensification Program, which is more profitable in terms of accessing inputs and value addition to small land holdings.

Intensive exploitation of shrinking land brought about mainly by high population density, where 56% of the farm households exploit less than 0.5 hectare per household, repeated land cultivation with no rest and with no corresponding nutrients replenishment to maintain the soil health (MINAGRI, 2004). Though expensive to small scale farmers, mineral fertilizers are still not efficiently used in terms of rates, time of application as well as choice of the right fertilizer. Cattle manure, as one of farm available organic resources is not well managed in order to transfer its benefits to soils (Uphoff et al., 2006; Azeez and Van Averbeke, 2010). Moreover, the combination of mineral and organic fertilizers is not well understood by smallholder farmers and yet such combinations have led to increased crop yields, and sustainably improved soil conditions (Sanchez, 2002). This study sought to evaluate the effect of inoculation, organic and inorganic fertilizers on climbing beans yield as well as soil properties.

Methods

A split plot experiment in a completely randomized design (CRD) with two main plots (With and Without Inoculum) and four sub-plots (Cattle manure, DAP, Cattle manure + DAP, Control) at two levels for each; i.e 0 and 20 t/ha (Cattle manure) and 0 and 50 kg/ha (DAP) was carried out. For the inoculum (main plot), 100g of the inoculants was used, thoroughly mixed with 15 kg of beans before planting. The experiment had eight treatments which were replicated three times giving a total of 24 plots.

Before planting and setting up the experimental, land was fine tilled by hoe and raked. Because the field was sloppy, ridges were put in place so as to limit water moving from one plot to another. Plots sizes were 4×5 m, with 20 cm spacing between plants and 50 cm between rows, which gave 200 plants per plot corresponding to 100,000 plants per hectare. At each planting hole, cattle manure and DAP were applied evenly to cover all the holes in each plot at planting and were thoroughly mixed with the soil in order to avoid adverse effects on the seeds by the inputs. Climbing bean, (Gasilida variety) was planted as a test crop. Weeding was done twice; the first one, two months after planting and the second after three months and half during the growth period. The pests and diseases observed in the crop growth period such as the bean

foliage beetle in early stages of germination, some aphids at flowering and Ascoschyta leaf spot during pod filling phase, were all controlled by applying the appropriate chemicals.

Soil sampling and analysis
Soil sampling at the site was done at the beginning and at the end of experiment. The soil samples were obtained across the field by transects method from 0-15 cm and 15-30 cm depths using an auger. The soil samples of each depth from six different spots in each plot were taken and mixed from which a representative sample was obtained for analysis. The soil samples were analyzed for pH, organic carbon, total nitrogen, available nitrogen (NH_4^+ and NO_3^-), available P, cation exchange capacity, exchangeable acidity (aluminum and hydrogen), texture, and aggregate stability.

Data from farmers' fields
Data from farmers' fields were obtained from an AGRA climbing beans' project in Burera District and their raw yield data from previous season (2011A).The raw yield data were availed for analysis and, in this case, a number of 24 farmers were considered. The experiment on farmers' fields had the same treatments and same plot sizes as this research.

Plant tissue sampling and analysis
At flowering stage, plant tissues (around 10 leaves per plot), were sampled from each treatment, prepared (oven-dried at 70^{0}C and ground) before being analyzed for total nitrogen.

Growth and yield parameter measurements of climbing beans
Agronomic data were recorded along different growth stages of climbing beans. The number of nodules was recorded by uprooting and counting nodules per plant three months after planting. Yield was determined when beans were completely dried by weighing the total grain weight using a weighing scale. Bean grains, shoots and roots were harvested at maturity from each plot but leaving out one row on each side of the plot to minimize the edge effect. Raw yield data from the farmers fields were also provided by the project technician for comparison purposes.

Statistical Analysis
The analysis of variance (ANOVA) and t-test were done by SAS 9 software to determine whether significance exists, while means' separation was performed using LSD test. Correlation and regression were also performed to assess relationship and dependence among some variables. All the analyses were carried out at the level of significance (α=5%). Data processing, management and graphs were done using Microsoft Excel.

Results and discussion
The soil was fairly fertile in terms of soil physical properties and in some chemical properties except for available nitrogen and phosphorus which were somewhat low. This therefore, calls for some additional inputs (Nitrogen and Phosphate fertilizers) to increase climbing bean yields. The

soil is moderately acid and good for beans production (Ebesu, 2004). The soil structure is sandy loam, which indicates a high infiltration rate due to the fact that it has coarse texture and large porous spaces which promote fast infiltration (Makungo and Odiyo, 2009; Hamson and Orloff, 1998). Such well drained soils have a great leaching potential, which usually affect mobile nutrients such as nitrogen in form of nitrates (Czymmek *et al*., 2005). The soil's aggregate stability is fairly high, an indication of high ability to resist erosion and therefore, not susceptible to dispersal during rainstorms (Herrick *et al*., 2001). The soil CEC of the trial site is very high, almost comparable to organic matter which is also very high (8%), mainly due to the influence of the coldness and wetness of the area (Franzluebbers, 2001). Organic matter has been reported to have a four to 50 times higher CEC per given weight than clay (Shoji *et al*., 1993; Ketterings *et al*., 2007). Table 1 Shows the Physical and chemical soil properties of the experimental field at the start of trial.

Table 1: The initial physical and chemical soil properties of experimental field

Soil Properties	0-15 cm	15-30 cm
pH $_{water}$	6.01	5.94
pH $_{KCl}$	5.27	5.29
OM %	8	8
N-NO$_3^-$ (mg/kg)	8.29	8.30
N-NH$_4^+$ (mg/kg)	10.63	10.64
Total Nitrogen N (mg/kg)	21.4	21.4
Available P (mg/kg)	18.82	18.89
Potassium K (mg/kg)	74	74
CEC (meq/100g)	48.93	53.73
Exchangeable Al $^{3+}$ (meq/100g)	_	_
Exchangeable H$^+$ (meq/100g)	0.47	0.47
Aggregate stability %	41	41
% clay	14	14
% Silt	32	32
% Sand	54	54
Textural class	Sandy loam	

Effect of treatments on yield

The yields obtained from the experimental site were significantly higher in all the treatments than those from the farmers' fields (Figure 1). The yield differences ranged between 105 and 144% with respect to maximum and minimum yields from the treatments. Highest grain yields from the experimental site was 4782 kg/ha by treatment I+FYM+DAP and was followed closely by treatment I+DAP with 4194kg/ha. The control treatment had the lowest (2640kg/ha) yield, a significant difference of nearly 45% from the highest yields. When comparing yields from farmers' fields with those from experimental site, the yields from farmers' fields were significantly low ranging between 2322 and 1083 kg/ha with the highest realized by treatment I+FYM+DAP (2322kg/ha) and lowest (1083kg/ha) by sole "Inoculant" treatment. While the treatments were similar, the great differences in yields between farmers' fields and the experimental side could largely be explained by the crop husbandry management applied right from land preparation to inputs application and crop handling at large. For example the yields obtained in the inoculation treatment on the farmers' fields were very low (1083 Kg/ha) compared to those in the experimental site (3060Kg/ha).This explains the superiority of good management in controlled experiments as compared to farmers' management. Poor handling of inputs at large, and especially, inoculation during seed –inoculant mixing, could have led to low bean yield at the farmers fields. Similar observations have been reported by other researchers (RAB, 2010 and Mugwe, 2007). Mugwe (2007) reported that there can be high variability in management among farmers, which is known to mask treatment performance while RAB (2010) concluded that good crop husbandry that includes proper nutrient management, pest control and timely weeding affect crop performance.
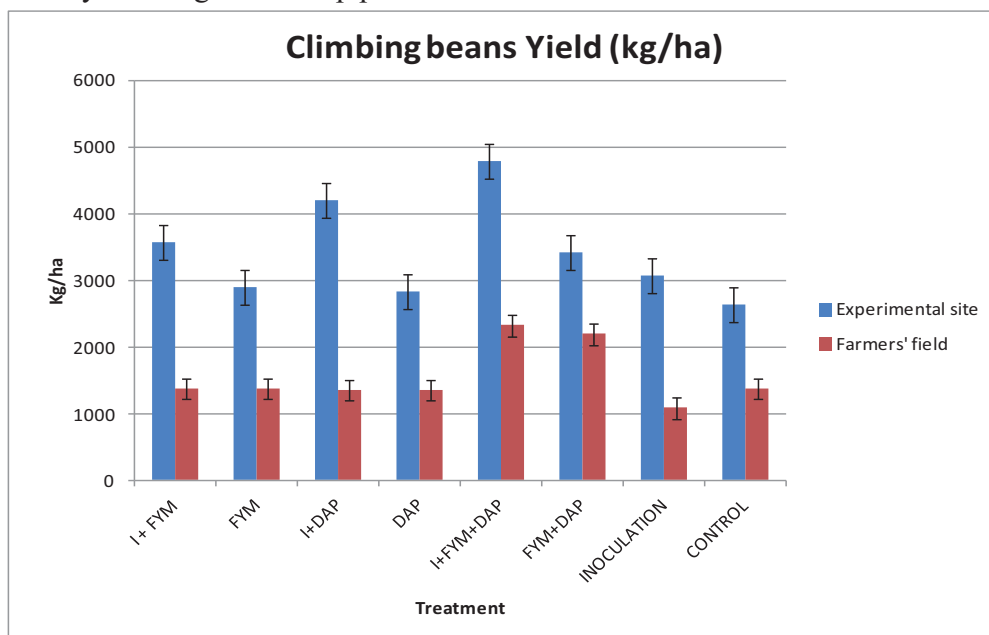
Figure 1: Comparison of bean grain yields between experimental field and farmers' fields

Effect of treatments on nodulation

There were high significant differences (p<0.0001) between the treatments in nodule numbers (Table 2). The highest number of nodules (96) was found where inoculation, cattle manure and DAP were combined followed by treatment I+DAP with 86 nodules. The lowest number of nodules was obtained in treatments FYM+DAP (10) and the control (14). This indicates that wherever inoculation, cattle manure and DAP were combined, nodulation was enhanced. This suggestion is confirmed by the work of Sessitsch et al., (2002) who stated that inoculation becomes more effective in a better environment. In this study, a range of nodules in terms of size, and distribution on the root hairs were observed. Effective nodules are generally large and are clustered on the primary and upper lateral roots, whereas ineffective ones are small, numerous, and usually distributed throughout the root system. A well-nodulated legume plant uses its own nitrogen supply that is not immediately available to weeds or companion crops which might compete for moisture, mineral nutrients or space. The nodulated legume thus has a big advantage, particularly in a nitrogen-poor soil (FAO, 1984; Graham, 2008, Karasu et al., 2011).

Table 2: Effect of treatments on nodules number.

Treatments	Nodule number
I + FYM	33^d
FYM	24^a
I+DAP	86^e
DAP	14^b
I+FYM+DAP	96^f
FYM+DAP	10^b
I	28^a
CONTROL	14^{bc}
P Value	<0.0001
LSD	4.2
CV	3%

LSD= Least significant difference of means (5% level)
Means with the same letter are not significantly different.

In terms of nodule numbers, inoculated seeds contributed four times more nodules than the non-treated seeds (60 and 15 nodules, respectively), which was highly significant (p<0.0001) in terms of main plot treatments (Table 3). Although the difference in nodulation was highly significant between the main plots, some indigenous rhizobia strains were present in this soil and that climbing beans were able to fix some nitrogen even without receiving inoculum. Correlation analysis between nodulation and yield as shown on Fig.2 indicates a coefficient of determination (r^2) of 0.8357 with a p value of <0.0001.This regression analysis suggests a good fit and indicates that the bean grain yields depended on nodule numbers. Other researchers have reported similar trends, that if beans are not nodulated, yields often remain low, regardless of the amount of nitrogen applied (Lindemann and Glover, 2003; Rai, 2006; Mbugua et al., 2007). Nodules apparently help the plant use fertilizer nitrogen efficiently (Rai, 2006). The significant nodule numbers after inoculation observed in this study has also been reported by Kala et al (2011) who indicated an increase in nodules number due to inoculum application.
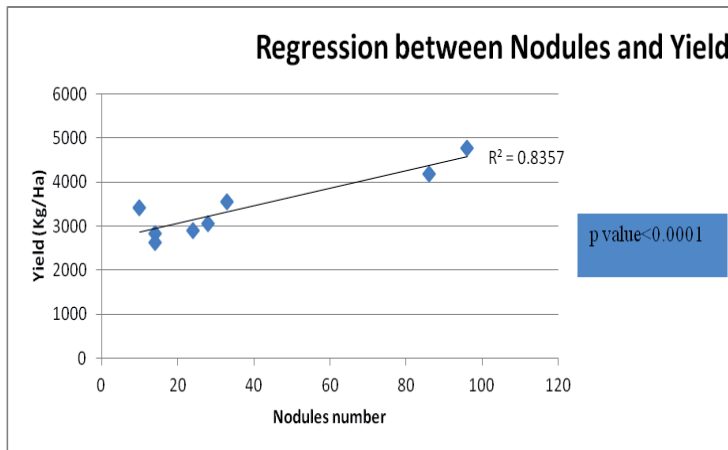
Figure 2: Correlation analysis between nodule numbers and bean grain yields

Table 3: Effect of Inoculation on nodulation

Main plot	Nodule number
Inoculation	60[a]
No Inoculation	15[b]
P Value	<0.0001
LSD	19.2
CV	3.7%

LSD= Least significant difference of means (5% level). Means with the same letter are not significantly different.

Effect of treatments and Inoculation on Nitrogen content in bean leaves

There were highly significant differences (p<0.001) between treatments in terms of nitrogen content in tissues (Table 4). The highest nitrogen content was 5.23% and was obtained in the treatment where inoculation, cattle manure and DAP were combined whereas the lowest N contents were recorded in treatments where manure and DAP were applied separately (2.6 and 3.1%, respectively). The superiority of treatment "I+FYM +DAP" is quite evident in this study for example on bean grain yields (Figs. 1), and on the nodule numbers (Table 3).This finding concurs with the findings of other researchers (Tittonel, 2008; Chivenge *et al*., 2009) who reported the importance of combining mineral fertilizers, FYM and bio-fertilizers on legume production. There was a highly significant difference between the main plots (P<0.0001), an indication that inoculation enhances nitrogen fixation and its subsequent accumulation in the plant tissues. This is also the conclusion of other researchers (Silva and Uchida, 2000; Sanginga and Woomer, 2009; Bambara, 2009; Kala *et al*., 2011) who concluded that inoculation significantly influences the plant total N content in the different plant tissues of bean crop.

Table 4: Effect of treatments on nitrogen content in beans' leaves

Treatments	% Nitrogen in tissues
I + FYM	4.7[a]
FYM	2.6[b]
I+DAP	4.2[c]
DAP	3.1[d]
I+FYM+DAP	5.23[e]
FYM+DAP	4.06[f]
I	4.7[a]
CONTROL	4.4[g]
P Value	< 0.0001
LSD	0.05
CV	0.6%

LSD= Least significant difference of means (5% level). Means with the same letter are not significantly different.

Conclusion

Bean grain yield was differently affected by the treatments used in this study. Best yields were obtained where a combination of I+FYM+DAP was applied. There was high correlation between inoculation and grain yields ($r^2= 0.835$}, and that the treatments with inoculants exhibited higher nodule formation and had higher nitrogen contents in the plant tissues than non-inoculated ones. Overall, grain yields realized from farmers' fields were very low, nearly 50% lower than those realized from the experimental site, and this could be due to poor crop husbandry by farmers.

References

Azeez, J. O. and Van Averbeke W. 2010. Nitrogen mineralization potential of three animal manures applied on a sandy clay loam soil. Tshwane University of

Technology. *Elsevier,* Bioresource Technology 101:5645–5651.

Bambara, K. S. 2009. Effect of Rhizobium inoculation, molybdenum and lime on the growth and Nitrogen fixation in *P. vulgaris*. L. Cape Peninsula University of Technology. *Theses and Dissertations*. 106 pages.

Bot, A. and Benites, J. 2005. Importance of soil organic matter. Key to drought resistant soil and sustained food and production. *FAO Soils Bulletin*, Rome. 95 pages.

Chivenge, P., Vanlauwe, B., Gentile, R., Wangechi, H., Mugendi, D., van Kessel, C. and J. Six, J. 2009. Organic and Mineral Input Management to Enhance Crop Productivity in Central Kenya. *Agronomy journal,* Vol 101, issue 5, 101:1266–1275

Czymmek, K., Ketterings, Q., Van H. E., DeGloria, S. and Albrecht, G. 2005. The New York Nitrate leaching Index. *Agronomy Fact Sheet Series,* Fact Sheet 11. Cornell University Cooperative Extension

Ebesu, R. 2004. Home garden beans. College of Tropical Agriculture and Human Resource. Department of Plant and Environmental Protection Sciences. Home Garden Vegetable-8. University of Hawaii.

Food and Agriculture Organization (FAO). 1984. Legumes inoculants and their use. FAO Pocket Manual. 75 pages.

Franzluebbers A.J. 2001. Soil organic matter stratification ratio as an indicator of soil quality. *Elsevier*, Soil and Tillage Research 66:95–106.

Fujishige, N. A., Michelle, R. L., De Hoff Peter L., Whitelegge, J. P., Faull Kym F. and Hirsch, A. M. 2008. Rhizobium common nod genes are required for biofilm formation.

Department of molecular, cell and developmental biology, Molecular biology Institute, Pasarow Mass Spectrometry Laboratory and Semel Institute, University of California.

Graham, P.H. (2008). Ecology of the root-nodule bacteria of legumes. Chapter (2), p. 23-43. In Dilworth, M. J, James, E. K, Sprent, J. I and Newton, W.E. (eds.) (2008). Nitrogen-fixing Leguminous Symbioses. Nitrogen Fixation: Orgins, Application. Volume 7, *Springer.* 402 pages.

Hanson, B. and Orloff, S. 1998. Measuring soil moisture. Irrigation program. University of California. Engeneer Handbook. 34 pages.

Hirsch, A. M. 2009. Brief history of the discovery of Nitrogen-fixing Organisms. *Nature,* Vol. 411 21.

Institut des Sciences Agronomiques du Rwanda (ISAR). 2009. Bean Program. Rwanda.

Kala, T. C., Christi, M. R. and Bai, R. N. 2011. Effect of Rhizobium inoculation on the growth and yield of Horsegram (*Dolichos Biflorus*). *Plant Archives* Vol. 11 No. 1, 97-99.

Karasu, A., Oz, M. and Dogan, R. 2011. The effect of bacterial inoculation and different nitrogen doses on yield and yield components of some dwarf dry bean cultivars (*Phaseolus vulgaris*). *Bulgarian Journal of Agricultural Science.* 17: 296-305.

Kelly, J. D., Peralta, E. and Butare, L. 2012. Combining conventional, molecular and farmer participatory breeding approaches to improve Andean Beans for resistance to biotic and abiotic stresses in Ecuador and Rwanda. Pulse CRSP.

Lindemann, W.C. and Glover, C.R. 2003. Nitrogen fixation by legumes. Cooperative Extension Service, Guide A-130. New Mexico State University.

Makungo, R. and Odiyo, J.O. 2011. Determination of steady state infiltration rates for different soil types in selected areas of Thulamela Municipality, South Africa. 15th SANCIAHS National Hydrology Symposium proceedings, Rhodes University, Grahamstown.

Ministry of Agriculture and Animal Resources (MINAGRI). 2004. National Agriculture Policy. Kigali. Rwanda.

Mugwe, J. N. 2007. An evaluation of integrated soil fertility management practices in Meru South District, Kenya. PhD Thesis, *Kenyatta University*. 191 pages

Rai, M. K. 2006. Handbook of microbial biofertilizers. *Haworth Press, Inc.,* Binghamton, New York. 42 pages.

Rwanda Agriculture Board (RAB). 2010. Integrated Bean crop management for increased productivity in Rwanda. *Extension guide*. Rwanda.

Saikia, S. P. and Jain V. 2007. Biological nitrogen fixation with non-legumes: An achievable target or a dogma? Current science, vol. 92, no. 3.

Sanchez, P. A. 2002. Soil fertility and hunger in Africa. Policy forum. *Science,* Vol. 295.

Sanginga, N. and Woomer, P. L. 2009. Integrated Soil Fertility Management in   Africa: Principles, Practices and Developmental Process. Tropical Soil Biology and Fertility. International Center for Tropical Agriculture. Nairobi. 263 pages.

Sessitsch, A., Howieson, J.G., Perret, X., Antoun, H. and Martinez-Romero, E. 2002. Advances in Rhizobium Research. Critical reviews in plant science. 21:323–378.

Silva, J. A. and Uchida, R. 2000. Biological Nitrogen Fixation. Nature's Partnership for Sustainable Agricultural Production. Chapter 13. Technical bulletin. College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa.

Shoji, S., Nanzyo, M., and Dahlgren, R. A. 1993. Volcanic ash soils- Genesis, Properties and Utilization. 1st Edition, *Elsevier,* vol 21.

Tittonell, P., Corbeels, M., van Wijk, B. M. T., Vanlauwe, B. and Giller, K. E. 2008. Combining Organic and Mineral Fertilizers for Integrated Soil Fertility Management in Smallholder Farming Systems of Kenya: Explorations Using the   Crop-Soil Model FIELD. Agronomy journal. Vol 100, issue 5.

Tropical Soil Biology and Fertility Institute of the International Center for Tropical Agriculture (TSBF-CIAT). 2006. Integrated soil fertility management in the tropics.TSBF-CIAT's Achievements and Reflexions 2002-2005. Colombia. 101 pages.

Uphoff, N., Ball, A., Fernandes, E., Herren, H., Husson, O., Laing, M., Palm, C., Pretty,J., Sanchez, P., Sanginga and N., Thies, J. 2006. Biological Approaches to Sustainable Soil Systems. CRS Press. Chapter 5. Pp 60-76. 784 pages.

Verchot, L.V., Place F., Shepherd K.D and Jama B. 2007. Science and Technological Innovations for Improving Soil Fertility and Management in Africa. A Working Paper number 30. A report for the NEPAD Science and Technology Forum. World Agroforestry Center. Working paper nº 31. Nairobi, Kenya. Pp. 102.

Wallace, M. B., and Knausenberger, W. I. 1997. Inorganic fertilizer use in Africa: Environmental and economic dimensions. Applied Research, Technical Assistance and Training. Winrock International Environmental Alliance Arlington, Virginia. USA. 63 pages.

World Food Programme (WFP). 2009. Comprehensive food security and vulnerability & Nutrition Survey. 108 pages.

World Food Programme (WFP). 2009. Comprehensive food security and vulnerability & Nutrition Survey. 108 pages.

SUB THEME 4: CROP- LIVESTOCK INTERACTIONS

4.1.0 EFFECTS OF CATTLE MANURE AND MINERAL FERTILIZERS ON SOIL NUTRIENTS AND YIELD OF CABBAGE (*Brassica orelacea var. capitata*) IN SUB SAHARA AFRICA

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Abstract
Cabbage (*Brassica orelacea* var. *capitata*) is the most widely grown vegetable in most parts of Sub-Sahara Africa. However, its production is threatened by population pressure associated with land scarcity and soil degradation. The aim of this study was to determine the effects of cattle manure and mineral fertilizers on selected soil nutrients and production of cabbage. The analysis of soil nutrients (nitrogen, phosphorous, potassium and organic carbon) were done before and after experiment while cattle manure analysis was conducted before its application. Field experiment was laid out as a randomized complete block design with 4 treatments (T1: manure at 15 t ha^{-1}, T2: manure (7.5t ha^{-1}) + NPK$_{20-10-10}$(150k g ha^{-1}), T3: NPK$_{20-10-10}$ at 300 kg ha^{-1} and T0: control) with the treatments replicated three times. The findings showed that T1 and T2 increased soil fertility significantly by improving the soil nutrients. Total nitrogen was significantly ($p<0.001$) increased by 25% by T2, and 22% by T1. T2 and T1 significantly ($p<0.001$) increased available P by 4.3 and 3.6 mg kg^{1}, respectively. T3 and Control negatively affected soil organic carbon content. The plant height was significantly ($p<0.001$) affected by T1 and T2 which were also the best treatments with large cabbage size. Therefore, this study recommends the use of manure mixed with NPK at rate of 7.5 t ha^{-1} manure and 150 kg ha^{-1} NPK (20-10-10) for soil fertility improvement to achieve sustainable production of cabbage.
Key words: Inorganic fertilizer; Nitrogen, Organic fertilizer; Phosphorous, Organic carbon

Introduction

In Sub-Sahara Africa (SSA), the majority of farmers practice subsistence agriculture (Sayre, 2011) with limited use of fertilizers and other agricultural inputs. In Rwanda, agriculture in total occupies 82% of the population (NISR., 2009) which is mainly subsistence rain-fed agriculture and contributes 36% of GDP (Bank, 2011) of the country's economy. Among the vegetables grown in SSA, cabbage *(Brassica oleracea)* is the most popular and contributes to the nutritional improvement and welfare of poor farmers. However, the high population with small size land holding in combination with soil erosion, soil nutrients depletion and poor agricultural practices leads to poor agricultural productivity, less food security and low cash income (Rutunga et al., 2007). In most parts of SSA, the high population leads to the scarcity of arable land which consequently causes overexploitation. In addition, the organic manure and inorganic fertilizers

are unaffordable by poor resources farmers, thus there is inadequate soil fertility restoration. The aforementioned factors constrained the production of cabbage and other vegetables crops in Rwanda.

The cabbage is a high value crop in the dietary of poor farmers, it is generally consumed as cooked vegetable (with water or oil), mixed with other vegetables (such as carrot) and it can also be eaten as salad. Its external leaves and stems are difficult to digest and are useful for the animal feeds. Furthermore, cabbages are highly nutritive, contains many vitamins, salt and has low amounts of fat and proteins (Grubben and Denton, 2004). The glucosinolate contained in cabbage undergo enzymatic (myrosinase enzyme) degradation to thiocynate and isothiocynate which have antimicrobial and anticancer properties, thus cabbage is of particular medicinal interest (Grubben and Denton, 2004; Schippers, 2004). However, excessive consumption can be harmful to human health, due to the glucosinolate content in all species of the Brassica. According to Holland et al. (1991), the composition of 100 g of edible cabbage is 90.1 g water, 109 kj (26 kcal) energy, 1.7 g proteins, 0.4 g lipids, 4.1g glucide, 2.9g food fibers, 52 mg Ca, 8 mg Mg, 41 mg P, 0.7 mg Fe, 0.3 mg Zn, 385 µg carotene, 0.15 mg thiamin, 0.02 mg riboflavin, 0.5 mg niacin 75 µg folate, and 49 mg ascorbic acid.

Despite its numerous production constraints, there is a strong need to improve its production by improving soil fertility using fertilizers and soil amendments (Rutunga et al., 2007). The kitchen garden initiative is one of proposed strategies for promoting the production of vegetables for Rwandese families. The soil health is generally governed by organic matter quality and quantity in soil and in turn governs crop production (Rutunga et al., 2007). Indeed, the use of manure and fertilizers can bring positive effects in soil fertility improvement and increase agricultural production (Mutwewingabo, 1987). Sadly, the level of manure and fertilizer application is very low in Rwanda, the fertilization practice is not yet sufficiently adopted by all the farmers and its importance is not well elucidated (Kanakuze, 2004). This is due to limited studies as well as the lack of fertilizer formulation adapted to the various soil types in Rwanda. The use of cattle or farm yard manure mixed with mineral fertilizers is very important to poor resource farmers in Rwanda. The mineral fertilizer such as NPK, Urea and DAP (Diammonium phosphate) are the common types found on market in Rwanda. The use of fertilizers and soil amendment need a clear understating on their handling techniques, effects on improvement of soil fertility and crops yield to encourage farmers for their adoption of the fertilizers technology. This study therefore aimed at determining the role of organic (cattle manure) and mineral fertilizer (NPK 20-10-10) in increasing soil fertility and production of headed cabbage.

Material and methods

Materials descriptions
A randomized complete block design experiment was established at Secondary School of Nemba located in Nemba sector, Gakenke District, Northern Province. It is located at 1° 38' and 29° 47' with an altitude of 1750 m. The rainfall of the area is 1500 mm with an annual precipitation varying from 1400 to 1600 mm. The large part of Gakenke District lies in the central plateau and a small part of Buberuka highland agro ecological zones. Fertilizers used were composed of organic (cattle manure) and inorganic fertilizers NPK (20-10-10) applied either solely or in combination. The treatments were T0 (control), T1 (sole manure at 15 t ha^{-1}), T2 [manure (7.5 t ha^{-1}) + NPK (150 kg ha^{-1})] and T3 (NPK at 300 kg ha^{-1}). This last treatment represented the

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recommended application rate. The compositions of organic and inorganic fertilizers were measured before application.

The incorporation of manure in soil was done two weeks before the planting as recommended by Waaijienberg (2001). The soil fertility baseline was also analyzed (Table 1) before incorporation of manure. The spot application of inorganic fertilizer was used. The experiment unit was 4.5m^2 and the plants were planted at spacing of 50x50cm. The test crop was headed cabbage, variety Capitata alba (Golden Acre). Its leaves are generally agglomerated with an apple or head compact, round or ellipsoid form reaching 30 cm in diameter (Grubben and Denton, 2004).

Analysis of cattle manure composition

The analysis of cattle manure was done first by drying followed by analysis of the total Kjeldahl nitrogen, elemental P, K, Ca and Mg. These were expressed in fertilizer credits (ie: P_2O_5 for P, K_2O for K, CaO for Ca and MgO for Mg) in percentage. The nutrient quantity for each treatment was estimated using the following formula:

$$* Formula = \frac{\text{composition of manure x applied quantity per area}}{100}$$ Equation [1]

Analysis of initial soil fertility

Composite soil samples were collected from the depth 0 – 20 cm in zigzag (Carter and Gregorich, 2008). The samples were air-dried and ground before analysis in the laboratory. Soil pH was measured in 1: 2.5 soil/water suspension using a pH meter. Soil Organic C was analyzed following the Walkley and Black modified method (Piper, 1942). Total N was determined by Kjeldahl method (Page et al., 1982). Available P was analyzed using Olsen method, while K was analyzed using Gourley method (1999).

Data collection and analysis

The data collection for cattle manure was done once during its incorporation while the data for soil (pH, total N, available P, exchangeable K, Ca and Mg) were collected at beginning and end of experiment. The growth data were collected at 3 and 6 weeks after planting while the yield data collected at harvest. All collected data were subjected to Analysis of Variance (ANOVA) using GenStat 14th edition. The mean comparisons were done using Least Significant Difference (LSD). The data arrangement and graph plotting were performed using Microsoft Excel.

Results and discussion

Soil nutrients and quality of cattle manure

The results of initial soil analysis presented in Table 1, showed the level of nutrients of experimental field.

Table1: Soil baseline characteristic

Soil properties	Values
pH	5.4
Organic C	2.8
Total N (%)	0.16
Available P(mg kg^{-1})	3.9
K (meq/100g)	0.39
NO_3-N (ppm)	9.2
P_2O_5 (ppm)	9.6
K_2O (ppm)	183.2

The experimental soil was slightly acidic, poor in organic matter and total nitrogen, phosphorus and potatssium also were in medium levels. These were in agreement with the findings of many scientists (Soil Survey Division Staff, 1993; Marx *et al*., 1996; Horneck *et al*., 2011;) who reported the levels of soil acidity and nutrients. The result of cattle manure analysis and quantity of nutrients applied for each treatments are shown in Table 2.

Table2: Composition of cattle manure and nutrients quantity per treatment

Nutrients	Nutrients composition (%) in manure	Nutrients quantity (kg ha^{-1})* per treatment			
		T0	T1	T2	T3
N	0,51	0	76.5	68.25	60
P_2O_5	0,23	0	34.5	32.25	30
K_2O	0,61	0	91.5	60.75	30
CaO	0,31	0	46.5	23.25	0
MgO	0,12	0	18	9	0

The cattle manure composition was good and enough to produce 20-30 t ha^{-1} fresh weight of cabbage as reported by Delahaut and Newenhouse (1997). The quality of manure depends on the management of cattle, type and quality of feeds, and exposure to the sunlight. The richer the feed in proteins, the richer manure is in nitrogen. Similarly, the more phosphorus and potassium in the feed the more of these constituents in manure (Lampkin et al., 2000). The losses of N are noticed in the cattle manure if delayed to be incorporated in the soil. These losses are carried out in the

form of ammonia (NH_3). The manure loses its potash by the flow of the juices if they are not collected. These are accelerated when manure is exposed to the scrubbing of rainfall (Chotte et al., 1995). Thus, the farmers should play attention to management and application of manure.

Effects of fertilizers on soil fertility
Cattle manure treatment (T1) and manure + mineral fertilizer (T2) significantly ($p<0.001$) improved the amounts of soil nutrients. They increased soil pH from 5.4 to 5.8 and 6.1, respectively. Total N was improved considerably 25% (T2) and 23% (T1) while the increase of available P was 4.3 mg kg^{-1} (T2) and 3.6 mg kg^{-1} (T1). These two treatments were similar in improving K_2O level in the soil (Table 5 and 4).

Table 4: Changes (increase or reduction) of selected soil nutrients per treatment

Treatments	pH	Total N (%)	Available P (mg kg^{-1})	P_2O_5 (ppm)	K_2O (ppm)
T0	-0.1	-0.07	-0.3	-0.1	-0.3
T1	0.4	0.23	3.6	7.6	18.1
T2	0.7	0.25	4.3	9.3	12.2
T4	-0.2	-0.01	0.6	0.7	4.4

Table 5: Effect of treatments on soil fertility parameters at the end of experiment

Treatments	pH	Total N (%)	Available P (mg kg^{-1})	P_2O_5 (ppm)	K_2O (ppm)
T0	5.3 c	0.09 b	3.6 b	9.5 b	182.9 b
T1	5.8 b	0.39 a	7.5 a	17.2 a	201.3 a
T2	6.1 a	0.41 a	8.2 a	18.9 a	195.4 ab
T3	5.2 d	0.15 b	4.5 b	10.3 b	187.6 b
P value	0.03	0.001	0.001	0.001	0.023
LSD	0.04	0.07	1.6	2.23	8.41

LSD= Least significant differences of means (5% level). Treatments with the same letter in the same column are not significantly different

Cattle manure and other animal have buffering capacity triggered from bicarbonates and organic acids which immediately affect the soil acidity (pH) few weeks after its incorporation. This corroborate to the findings of Whalen et al. (2000) who found that the application of fresh cattle manure affects soil pH immediately and persistly during 8 weeks of incubation. Total N, available P and K improved significantly due to the release of nutrients from manure and fertilizers. The effect of pH changes in soil could favor the activities of microorganisms responsible of organic matter degradation in the soil and releasing of some soil nutrients. These

findings agreed with the results of many authors (Alexander, 1977; Bürgmann et al., 2004; Fageria, 1989b; Nurlaeny et al., 1996; Ruganzu, 2009; Whalen et al., 2000) who reported soil pH changes to affect most of soil minerals important for crop growth and yield in general.

Effects of fertilizers on cabbage growth
Fertilizers significantly ($p<0.002$) affected the stand rate of cabbage. Height and leave number were also significantly ($p< 0.001$) affected by cattle manure and fertilizers application. The high performance in terms of height and leave numbers was observed in the plots that received the mixture of fertilizers (T2) followed by solely applied cattle manure (T1). The lowest records of cabbage growth were taken from the control and solely inorganic or mineral fertilizer treatments (Table 10).

Table 6: Effects of fertilizers on cabbage growth

Treatments	Stand rate	Height (cm)		Leaves number	
		3rd week	6th week	3rd week	6th week
T0 (control)	89.87 b	15.93 d	21.80 d	9.00 c	13.33 c
T1 (manure)	91.00 b	19.57 b	27.87 b	11.33 ab	15.66 ab
T2 (manure + NPK)	92.87 a	24.40 a	34.03 a	12.0 a	16.33 a
T3 (NPK)	92.97 a	18.70 c	25.97 c	10.0 bc	14.66 b
P value	*0.002*	*<0.001*	*<0.001*	*0.011*	*<0.001*
LSD	*1.593*	*0.7451*	*1.011*	*1.985*	*0.8661*

LSD= Least significant differences of means (5% level). Treatments with the same letter in the same column are not significantly different

The significant variation observed in germination rate among treatments was attributed to the high solubility of mineral fertilizer more than organic fertilizer. Low germination rate recorded in solely cattle manure plots was associated to the fact that organic manure mineralize slowly. This is in agreement with the findings of Tom (1992) who reported the nutrients content in mineral fertilizer to be water soluble and directly available to the plant. Hasan and Solaiman (2012) also confirmed that inorganic fertilizer rapidly release nutrients in the soil while organic fertilizers slowly release the nutrients. The combination of both mineral fertilizer and organic manure is of benefit in vegetables fields. The cattle manure sustain soil health by bringing humus containing macro and micro nutrients in the soil (Waaijenberg, 2001) important for the plant production; the humus makes the soil to be better arable, increases its permeability, water holding capacity and its nutritive elements. The mineral fertilizers bring timely necessary nutrients for the startup of plant growth and boost its growth.

Effects of fertilizers on cabbage yield

The treatments did not have significant effect on cabbage yield (Table 5). However, the biggest cabbage head of 22.53 cm diameter was obtained in the plots treated with mixed fertilizer of 150 kg NPK ha^{-1} and 7.5 t ha^{-1}cattle manure. The same treatment produced the highest yield. However, control plots were the poorest in terms of diameter size and yield of fresh weight.

Table 7: Effects of fertilizers on cabbage yield

Treatments	Diameter of heads (cm)	Fresh mass weight (t ha^{-1})	Dry weight (t ha^{-1})
T0 (control)	12.9 d	11.37 c	1.81 d
T1 (manure)	17.77 b	23.93 b	1.91 c
T2 (manure + NPK)	22.53 a	25.83 a	2.21 a
T3 (NPK)	16.8 c	23.93 b	2.12 b
P value	*<0.001*	*<0.001*	*0.028*
LSD	*0.3327*	*0.7103*	*0.23*

LSD= Least significant differences of means (5% level). Treatments with the same letter in the same column are not significantly different

High yield obtained in the plots with combined fertilizers was attributed to the synergy of inorganic and organic fertilizers to improve general soil fertility status from supplying nutrients to the soil fertility sustainability. Organic manure increase soil permeability and water holding capacity which consequently improves cabbage yield. Gruben and Denton (2004) reported that to insure good yield of cabbage, the water and nutrients requirement must be satisfied primarily throughout the growing season. Raemekers (2001) also recommended, for the satisfactory yield of cabbage, the incorporation of organic manure and split application mineral fertilizers. However, the fertilization of cabbage must be done by cautions because of its sensibility to the excessive nitrogen and potash deficiency. Excessive nitrogen causes the formation of loosen cabbage head and increase considerably the risks of internal rot while potash deficiency cause marginal necrose of leaves and cracking of cabbage head.

Conclusion

The organic manure provides the options for soil fertility restoration and boosting agricultural production. The use of manure mixed with NPK at rate of 7.5t ha^{-1} manure and 150kg ha^{-1} NPK $_{20-10-10}$ for soil fertility improvement was found to be appropriate for sustainable production of cabbage. The use of cattle or farm yard manure mixed with mineral fertilizers has a very great importance in soils lacking specific fertilizer formulation and recommendation; it is also helpful to the poor resources farmers with difficulties in measuring fertilizer. Therefore, this study recommends the use of manure mixed with NPK at rate of 7.5t ha^{-1} manure and 150kg ha^{-1} NPK$_{20-10-10}$ for soil fertility improvement to achieve sustainable production of cabbage in SSA.

References

ALEXANDER, M. (1977), *In"Introduction to soil microbiology",* New york, Wiley.

BANK, W. (2011), Rwanda economy update, Seeds for higher growth. Kigali,Rwanda: World Bank.

BÜRGMANN, H., WIDMER, F., VONSIGLER, W. & ZEYER, J. (2004), New molecular screening tools for analysis of free-living diazotrophs in soil. *Applied and environmental microbiology,* 70**,** 240-247.

CARTER, M. R. & GREGORICH, E. G. (2008), *Soil sampling and methods of analysis*, Taylor and Francis group.

CHOTTE, J., BRANCHART, E. & LAVELLE, P. (1995), Sustainable management of soils in the tropics. Biologocal regulation of organic matter decomposition. Dakar, Sénégal.

DELAHAUT, K. A. & NEWENHOUSE, A. C. (1997), *Growing Broccoli, Cauliflower, Cabbage, and Other Cole Crops in Wisconsin: A Guide for Fresh-market Growers*, University of Wisconsin--Extension, Cooperative Extension.

FAGERIA, N. K. (1989b), Effect of phosphorus on growth, yield and nutrient accumulation in the common bean. *Trop. Agric***,** 249-255.

GOURLEY, C., PEVERILL, K., SPARROW, L. & REUTER, D. (1999), Potassium. *Soil Analysis-an interpretation manual*.

GRUBBEN, G. & DENTON, O. (2004), PROTA 2. *Plant Resources of Tropical Africa,* 2**,** 484-487.

HASAN, M. R. & SOLAIMAN, A. (2012), Efficacy of organic and organic fertilizer on the growth of Brassica oleracea L.(Cabbage). *International Journal of Agriculture and Crop Sciences***,** 128-138.

HOLLAND, B., UNWIN, I. & BUSS, D. (1991), Vegetables, herbs and spices. *The composition of Food***,** 133.

HORNECK, D. A., SULLIVAN, D. M., OWEN, J. S. & HART, J. M. (2011), *Soil test interpretation guide*, Oregon State University, Extension Service.

KANAKUZE, V. (2004), Study contributing to the identification of constraints usage of organic and mineral fertilizers: a case study of Mutobo District. Musanze, Rwanda: Higher Institute of Agriculture and Animal Husbandry.

LAMPKIN, N., PADEL, S., FOSTER, C., BROUWER, F. & LOWE, P. (2000), *Organic farming*, CABI Publishing.

MARX, E., HART, J. M. & STEVENS, R. G. (1996), *Soil test interpretation guide*, Oregon State University Extension Service Oregon.

MUTWEWINGABO, B. (1987), Study of soils of research stations for identification of agriculture in Gikongoro Province located at Kaduha and Akanyaru valley. Kigali, Rwanda: MINAGRI - PIA.

NISR. (2009), National census. Kigali, Rwanda: National Statistical office of Rwanda.

NURLAENY, N., MARSCHNER, H. & GEORGE, E. (1996), Effects of liming and mycorrhizal colonization on soil phosphate depletion and phosphate uptake by maize(Zea Mays L.) and soybean (Glycine max L.) grown in two tropical acid soils. *Plant Soil***,** 275-285.

PAGE, J. R., MILLER, R. H., KEENEY, D. R., BAKER, D. E., ELLIS, J. R. & RHOADES, J. D. (1982), *Methods of soil analysis. II Chemical and microbiology properties,* Wisconsin, USA, Madison.

PIPER, C. S. (1942), *Soil and plant analysis,* New York, USA, Int. Sci. Publ, Inc.

RAEMAEKERS, R. H. (2001), *Agriculture in tropical Africa,* Bruxelles, Belgium, DGCI, Direction Générale de la Coopération Internationale.

RUGANZU, V. (2009), Potential of improvement of acid soils fertility by incorporation of natural fresh plant biomass combined with travertine in Rwanda. Gembloux, Belgique: Agricultural University.

RUTUNGA, V., BERT, H. J., STEPHAN, M. & MARC, J. (2007), Soil use and management strategy for raising food and cash output in Rwanda. *Journal of Food, Agriculture & Environment* 5**,** 434-441.

SAYRE, R. T. (2011), Biofortification of cassava for Africa: the BioCassava Plus program. *Chapter,* 11**,** 113-120.

SCHIPPERS, R. R. (2004), *African Indigene vegetables : presentation of grown species,* Wageningen, pays-bas, Margraf publisher GmbH.

SOIL SURVEY DIVISION STAFF. (1993), Soil survey manual. US Dept. of agriculture handbook. Washington, DC: US Govert. printing office.

TOM, V. (1992), *Soil fertility,* Wageningen, Pays-Bas, C.T.A, Agromosa.

WAAIJENBERG, H. (2001), *Vegetable garden in the tropic,* Wageningen, Pays-Bas, Agronus foundation.

WHALEN, J. K., CHANG, C., CLAYTON, G. W. & CAREFOOT, J. P. (2000), Cattle manure amendments can increase the pH of acid soils. *Soil Science Society of America Journal,* 64**,** 962-966.

4.1.1 MAIZE VARIETAL RESPONSE TO INTEGRATED NUTRIENT MANAGEMENT OF NPK AND CHICKEN MANURE

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Abstract

Maize (*Zea mays*) yields in farmers' fields are often lower than the potential of the varieties planted due to low soil fertility. The study was conducted to determine the effects of chicken manure, NPK (15-15-15) and their combinations on the growth and yield of two varieties of maize in Ghana. The experimental design was a 2 x 5 factorial arranged in a randomized complete block design with three replications. The factors studied were (A) two maize varieties [(i) 'Obaatanpa' and (ii) 'Akposoe'] and (B) five fertilizer rates [(i) Recommended Chicken Manure (3 t/ha); (ii) Recommended NPK 15-15-15 (65:38:38); (iii) ½ CM + ½ NPK; (iv) ¾ CM + ¼ NPK; (v) control (no fertilizer)]. The parameters studied included plant height, number of leaves, dry matter accumulation, 100 seed weight and grain yield. The results showed that 'Obaatanpa' was superior to 'Akposoe' for all the vegetative as well as yield and yield components measured. 'Obaatanpa' recorded a higher grain yield of (3878 kg/ha), about 65% more than the yield of 'Akposoe'. There was significant difference between the fertilizer rates for all the parameters measured. The ½ CM + ½ NPK recorded the highest grain yield of 4527.2 kg/ha and also significantly improved other traits such as plant height, dry matter accumulation and cob length. It was concluded that ½ CM + ½ NPK application in combination with Obaatanpa cultivar resulted in higher yield and yield components of maize and hence recommend for higher productivity.

Key words: chicken manure, integrated nutrient management, NPK, soil fertility

Introduction

Maize is a major staple food crop in Ghana and grown extensively in the forest and transition ecological zones (Dapaah et al, 2008). It is one of the most important food crops in Ghana and occupies 44% of the total area sown to cereals and account for an estimated 52% of the total cereal production (GGDP Annual Report, 1991).

It is the goal of many farmers in Ghana to produce sustainable high yields of crops however, maize yields in farmers fields are often less than 1 t ha $^{-1}$, while the maize cultivars grown have a potential of over 4 t ha $^{-1}$(GGDP, 1996). This low yield is as a result of rapid decline in soil fertility after few years of planting, inability of farmers to apply the needed fertilizer inputs and implementation of poor agronomic practices.

Over the years farmers have been focusing their attention on the use of chemical fertilizers to address soil fertility problems to ensure increased crop yields. The case of significant increase in fertilizer consumption and increase in crop production in Ghana is obvious from all the researches carried out so far. The main problem is that, though demonstrated yield increase from chemical fertilizer is not deniable, the escalating price of inorganic fertilizers coupled with their inability to condition the soil has directed attention to organic manure in recent times.

Apart from the soils being acidic as a result of their parent materials, weathering, and leaching (Obi and Ekperigin, 2001), continuous use of acid-forming fertilizers like sulphate of ammonia and ammonium nitrate also contributes significantly to soil acidity. Thus the

need to focus on alternative sources of nutrients that will be less damaging to the soil becomes imperative.

The importance of organic fertilizers especially poultry manure in improving the growth and yield of maize has been well established by researchers [Nanjappa et al. (2001), Dapaah et al. (2008) and Obi and Ekperigin, (2001)], however neither mineral fertilizer nor organic fertilizer is a panacea to soil fertility management (Agboola and Unamena, 1998). To increase crop production in West Africa, inorganic and organic inputs are needed (Buresh et al, 1997; FAO, 1999). Both mineral fertilizers and organic manures have their own role to play in soil fertility management, but none can solely supply all the nutrients and other conditions of growth for producing crops that can feed the teaming population.

With the release of new maize varieties from time to time, there is the need to assess the integrated management of inorganic and organic fertilizer in order for the varieties to express their full potential under decreasing soil fertility regimes. The objective of the study was to evaluate the effects of different levels of chicken manure combined with NPK on the growth and yield of two varieties of maize.

Materials and methods
The experiment was carried out at the multipurpose crop nursery site of the University of Education Winneba, College of Agriculture, Mampong, in Ashanti Region of Ghana in 2011. Mampong Ashanti ($07^0 1^{'}N$ $01^0 24^{'}$ W) with an altitude of 457.5m above sea level lies within the transition ecological zone, which is between the Guinea Savanna zone to the north and the forest zone to the South (Mampong Meteorological Service Department, 2010). The mean monthly temperature is $25^0C – 32^0C$. Annual rainfall ranges from 1270mm to 1524mm with a mean monthly distribution of 91.2mm. The soil at the site is of the Bediese series of the savannah Ochrosol.

Experimental design and Treatments
The experimental design was a 2 x 5 factorial arranged in a randomized complete block design with three replications. The factors studied include: (A) Variety [(i) Akposoe and (ii) Obaatanpa] and (B) Rates of fertilizer [(i) Recommended chicken manure (3t CM/ha); (ii) Recommended inorganic fertilizer (NPK) (65:38:38 kg/ha kg NPK/ha) (iii) ½ CM + ½ NPK (1.5 t/ha + 33:19:19 kg NPK/ha); (iv) ¾ CM + ¼ NPK (2.25t/ha + 16: 9.5:9.5 kg NPK/ha) and (v) No fertilizer (Control)].
Each experimental plot size was 4 rows (3.2m wide) and 4.8m long. The plant spacing adopted was 80cm x 40cm and the seeds were sown at 3 seeds per hill and later thinned to 2 plants per hill at a depth of 3-5 cm. The seeds of the two maize varieties Akposoe (an extra-early (80-85 days) maturing variety) and Obaatanpa (a medium (105-110 days) maturing variety) were obtained from the CSIR- Crops Research Institute, Fumesua-Kumasi.

Management and Cultural Practices
The land was cleared of all weeds and the field laid out into the various plots. A basal application of the inorganic fertilizer rates were applied as NPK 15: 15: 15 at 10 days after planting (DAP) and sulphate of Ammonia as top-dress at thirty (30) days after planting (DAP).
 The chicken manure was obtained from the broiler house of the Animal Science Department and allowed to decompose for three weeks before it was spot-applied and buried at ten days after planting (10 DAP). Optimum plant population was maintained by gap filling and thinning operations keeping two healthy plants per hill. Weeding was carried out regularly to eliminate competition between weeds and maize.

Parameters measured

Plant height (cm) was measured from the base of the plant (first nodal mark) to the tip of tassel on four plants per plot with a measuring ruler every 14 days. Number of leaves were counted and recorded for four plants per plot.

Dry Matter Production

Four randomly selected plants were cut to the ground level and oven dried at 70^0C to a constant weight and the oven dry weight recorded. Average of these data was used to estimate the dry matter per plant every 14 days.

100 seeds were taken from four randomly selected cobs per plot and the weight measured with an electronic scale.

Analysis of variance (ANOVA) for the data collected was carried out using the SAS Statistical package (SAS,1999) and where significant difference were observed, least significant difference (LSD) was used to separate means at the 5% probability ($p<0.05$).

Results

Soil and Chicken Manure Characteristics

Results of the soil samples taken from the depth of 0-40cm during the cropping season are presented in Table 1 below. The soil analysis showed that the pH of the soil was slightly alkaline with moderate Organic matter content. The total nitrogen level was moderate with high exchangeable calcium, magnesium and potassium. Available P and Bray extractable K were also high.

Table 1: Soil chemical properties

pH (1:1 H$_2$O)	Organic Matter (%)	Exchangeable (me/100g)				Cations	Total Nitrogen (%)	Bray No. 2 Extractable (pCM)	
		Ca	Mg	K	Na			P	K
7.35	1.32	10.55	3.85	0.80	0.12	0.10		220.5	101.70

Table 2 shows the results obtained from the analysis of the chicken manure (CM) used for the experiment. The pH level of the poultry manure was alkaline. The organic carbon and organic matter contents were relatively high. Total nitrogen and the Exchangeable cations especially calcium, magnesium, potassium and available P were high.

Table 2: Chemical properties of poultry manure

pH (1:1 H$_2$O)	Organic Carbon (%)	Organic Matter (%)	Total Nitrogen (%)	Available P (pCM)	Exchangeable (me/100g)			Cations
					Ca	Mg	K	Na
7.9	24.4	48.7	3.0	300.45	42.7	21.4	157.9	20.1

Plant height, dry matter accumulation and number of leaves

Generally, the Obaatanpa variety proved to be superior to the Akposoe variety for all the parameters measured (plant height fig.1; number of leaves fig.3;and dry matter accumulation fig.5), Significant differences ($p<0.05$) were not observed in the performance of the two varieties for plant height, number of leaves and dry matter accumulation in the early stages of growth (30 and 44 days after planting), however; significant differences ($p<0.05$) were observed at the mid to latter stages of growth (58 – 86 days after planting).

Results of plant height (fig.2), number of leaves (fig. 4) and dry matter accumulation (fig.6) for the fertilizer rates were similar to that of the varieties in that significant differences ($p<0.05$) were only observed at the mid to latter growth stages (58-86 DAP). The ½ CM + ½ NPK gave the highest plant height, number of leaves and dry matter accumulation at 72, 72 and 58 days after planting (DAP) respectively while the 3 t/ha Chicken manure consistently recorded lower values for plant height and dry matter accumulation for all the sampling periods with the control (no fertilizer) recording the lowest for all the above parameters.
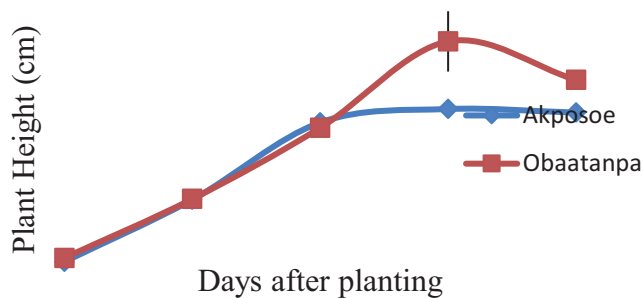
Figure 1: Effect of variety on plant height of maize, 2011.
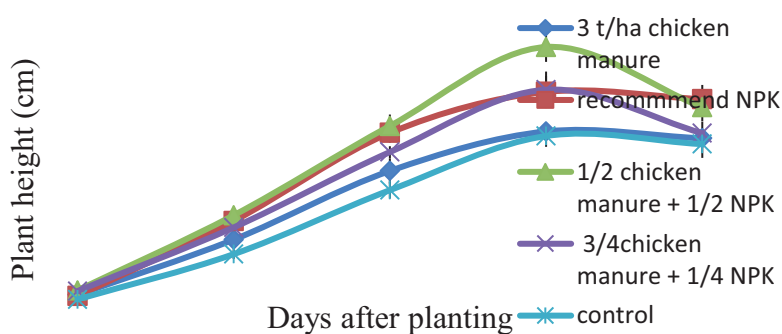
Figure 2: Effect of fertilizer rates on plant height of maize, 2011
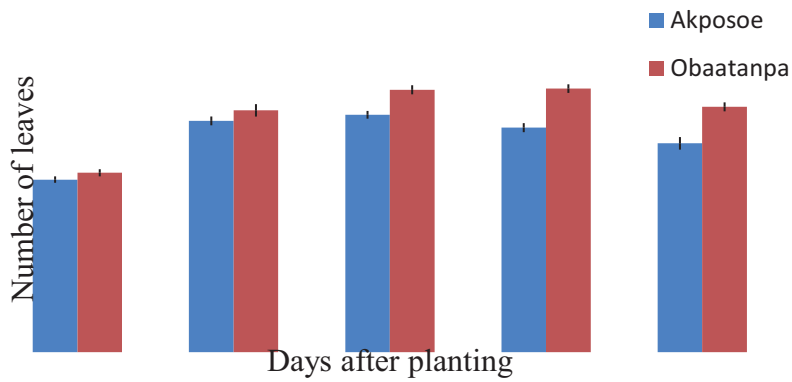
Figure 3: Effect of variety on number of leaves of maize, 2011
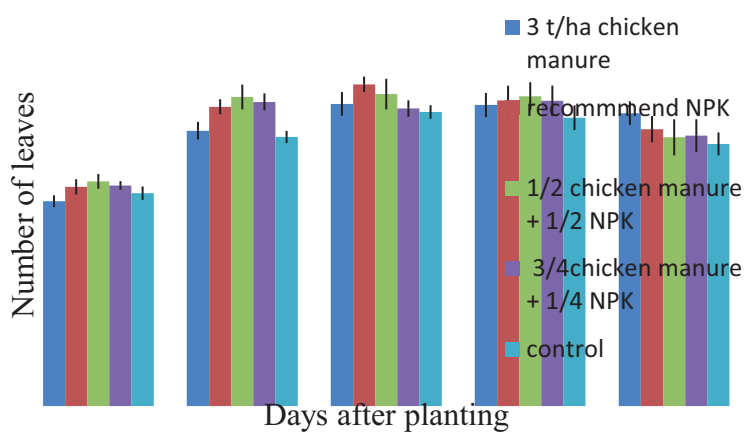
Figure 4: effect of fertilizer rates on number of leaves of maize, 2011
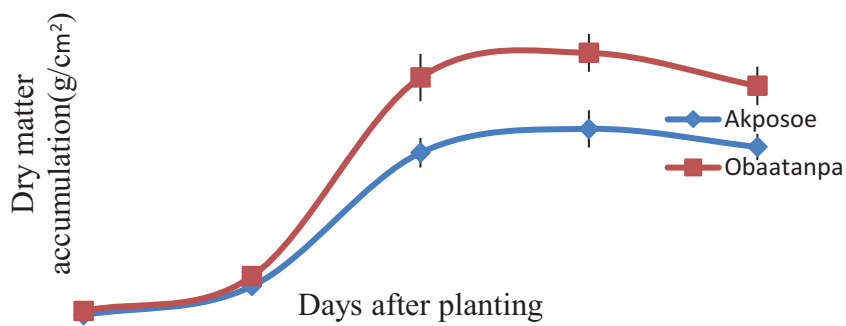
Figure 5: Effect of variety dry matter accumulation of maize, 2011

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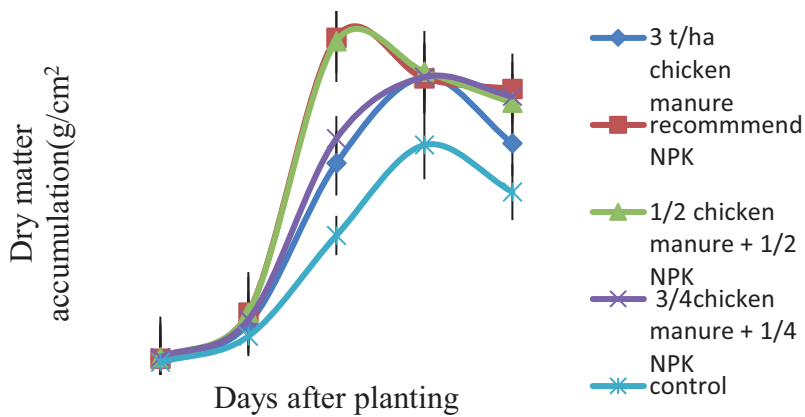
Figure 6: Effect of fertilizer rates on dry matter accumulation of maize, 2011

Yield and yield components

Results of the yield and yield components (table 3) for the varieties followed the same trend as the vegetative or growth parameters in that Obaatanpa recorded significantly high 100 seed weight, cob length, cob diameter and grain yield compared to the Akposoe variety, however; for harvest index, Akposoe was superior to Obaatanpa. The grain yield recorded by Obaatanpa (3878 kg/ha) was about 65% more than that of Akposoe (2343.4 kg/ha).

Significant differences were also observed for the fertilizer rates for cob length and grain yield; however no significant differences were recorded for 100 seed weight, cob diameter and harvest index. The ½ CM + ½ NPK treatment recorded highest values for 100 seed weight, cob length and grain yield (4527.2 kg/ha), ¾ CM + ¼ NPK and 3 t/ha treatments recorded intermediate cob length, cob diameter and grain yield while the least was recorded by the control treatment.

Table 3. Effects of Variety and fertilizer rates on 100 seed weight, cob length, cob diameter, grain yield and harvest index of maize, 2011.

Treatment	100 seed wt (g)	Cob length (cm)	Cob diameter (cm)	Grain yield (kg/ha)	Harvest index
Variety					
Akposoe	29.98	13.80	4.65	2343.3	0.63
Obaatanpa	35.05	14.95	5.10	3878.6	0.60
Mean	32.52	14.38	4.88	3111.0	0.62
Lsd (0.05)	3.57 *	0.76 *	0.18 *	840.0 *	0.05 *
Fertilizer rates					
CM (3 t/ha)	32.95	13.97	4.79	2176.8	0.60
NPK (65: 38: 38)	32.08	15.39	4.99	3731.4	0.58
½ CM+ ½ NPK	33.07	15.78	4.95	4527.2	0.58
¾ CM + ¼ NPK	32.65	14.80	4.97	3102.4	0.66
Control	31.85	11.96	4.69	2016.9	0.68
Mean	32.51	14.38	4.88	3111.0	0.62
Lsd (0.05)	5.64 ns	1.2 *	0.28 ns	1328.7 *	0.078 ns
Cv	14.29	6.90	4.80	35.21	10.45
Variety X Fertilizer interaction	ns	ns	ns	*	ns

(*) = significant at 5 % probability level, (cv) = coefficient of variation

Discussions

The results indicate that growth rate progressively increased with time during the vegetative growth up 58 DAP with a peak at 58 and 72 DAP after which growth declined. The superiority of Obaatanpa variety for plant height, number of leaves and dry matter accumulation could be partly because it is a medium maturing maize variety (105-110 days) while Akposoe is an extra early (80-85 days) maize variety. So given the same conditions of growth and the high rainfall during the experimental period, Obaatanpa had more growing days to utilize the available growth resources and partly due to its high responsiveness to fertilizer.

The higher results of plant height, number of leaves and dry matter accumulation recorded by the ½ CM + ½ NPK treatment could be attributed to the synergy of the chicken manure improving the physical conditions of the soil and the NPK also improving the nutrient status of the soil by making available more N both from NPK as well as Chicken manure throughout the growing season. This is in agreement with the findings of Kawsar et al.(2011), Ashok et al. (2005), Karki et al. (2005) and Namakka et al. (2008) who recorded higher plant height and dry matter accumulation of maize with the combined application of organic and inorganic fertilizers.

Regarding the varieties, the longer ears obtained from Obaatanpa and shorter ears from Akposoe could partly be due to the reason that Obaatanpa was more responsive to fertilizer than to Akposoe and partly due to more efficient utilization of water received from rain fall. Similarly Obaatanpa variety resulted in maximum grain yield as compare to Akposoe variety. These results are in accordance with Dapaah et al, (2008) who suggested that timely availability of N could be insured and corn productivity can be positively increased by combined use of inorganic fertilizer and Organic manures.

The highest grain yield obtained by ½ CM + ½ NPK treatment could be attributed to improved uptake of N by maize through enhancing the organic matter decomposition-mineralization process and the synergy of chicken manure and NPK. This confirm the finding of Kawsar et al.(2011) and Sharma et al. (1998) who reported that soil physio-chemical properties can be improved and corn yield can be increased by the application of organic and inorganic fertilizer.

The long cob length recorded by ½ CM + ½ NPK treatment could be due to least N loses and availability of nutrients from both the chicken manure and NPK throughout the growing season of the crop. These results are in line with Zhang et al. (1998) and Kawsar et al. (2011) who indicated that combined allocation of manure and mineral fertilizer to maize crop can increase for yield response.

Conclusion and recommendations

From the results of the present study it is concluded that the integrated use of chicken manure with NPK gave more yield response than sole application of each. The ½ CM + ½ NPK combination is recommended for high grain yield of maize. Similarly Obaatanpa variety may be used for better yield as compared to Akposoe variety.

References

Agboola, A.A. and Unamena, R.P.A. (1998). Maintenance of soil fertility under traditional farming systems. Paper Presented at the National Seminar on Organic Fertilizer.Lagos, Nigeria.

Ashok, K. R. C., Guatam, R., Singh, J. and Rana, K. S., (2005). Growth, yield and economics of maize (Zea mays) – wheat (Triticum aestivum) cropping sequence as influenced by integrated nutrient management. Indian Journal of. Agricultural. Science., 75(11): 709-711.

Buresh, R.J., Sanchez, P.A. and Calhoun, F.(ed). (1997) Replenishing Soil Fertility in Africa. SSSA Special Publication 51, SSSA and ASA. Madison, WI

Dapaah, H.K., Ennin, S. A., and Asafu-Agyei, J.N. (2008). Combining inorganic fertilizer with poultry manure for sustainable production of quality protein maize in Ghana. Ghana journal of Agriculture Science 41, 49-57

FAO (1999). Soil Fertility Initiative for Sub-Saharan Africa. Proceeding. SFI/FAO Consultation, Rome, 19-20. Nov. 1999. FAO, Rome

Ghana Grains Development Project (GGDP) (1991). Maize and Cowpea Production Guide. CIDA, Crop Research Institute. 49 pp.

Ghana Grains Development Project –GGDP (1996). Annual Report 1996 Crop Research Institute.

Karki, T. B., Ashok, K. and Gautam, R. C., (2005). Influence of integrated nutrient management on growth, yield, content and uptake of nutrients and soil fertility status in maize (Zea mays). Indian Journal of Agricultural Science. 75(10): 682-685.

Kawsar, A., Munsif, F., Muhammad, Z., Habib, A., Zahid, H., Muhammad ,S., IftikhaR, U.and Naushad, K. (2011) management of organic and inorganic nitrogen for different maize varieties. Sarhad Journal of Agric. Vol.27, No.4, 2011.

Meteorological Service Department of Mampong-Ashanti (2010). Geological Location of Mampong-Ashanti.

Nanjappa, H. V., Ramachandrappa, B. K. and Mallikarjun, B. O., (2001). Effect of integrated nutrient management on yield and nutrient balance in maize (Zea mays).Indian Jornal . Agronomy., 46(4): 698-701.

Namakka A., Abubakar, I. U., Sadik I. A., Sharifai A. I.and Hassas A. H. (2008). Effect of sowing date and nitrogen level on yield and yield components of two extra early maize varieties. ARPN Journal of Agricultural and Biological Science.

Obi, O and Ekperign, J. (2001). Effects of wastes and soil pH on growth and grain yield of crops. African Soils, 32: 3- 15

SAS, (1999). Statistical Analysis System Institute, SAS/STATS User's Guide, 1999 edn. SAS Institute Inc. Cary N.C. USA.

Sharma, M.P. and J.P. Gupta. 1998. Effect of organic material on soil properties and growth and yield of maize wheat cropping system. Indian Journal Agricultural Science. 68:715-723.

Sharma, M.P. and J.P. Gupta. 1998. Effect of organic material on soil properties and growth and yield of maize wheat cropping system. Indian Journal of Agricultural Science. 68:715-723.

Zhang, H., D. Smell and J. Tomko. 1998. Nitrogen fertilizer value of feed lot manure for irrigated corn production. Journal of Plant Nutrition. 21: 287-296.

SUB THEME 5: GENDER, POLICY AND GOVERNANCE

5.1.0 DEGREE OF COMMERCIALIZATION BY MALE AND FEMALE RICE FARMERS': A CASE FOR AHERO IRRIGATION SCHEME, KENYA

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Abstract
Agricultural commercialization has a potential to increase farming households income, improve food security and reduction in poverty levels. Agricultural commercialization entails the extent of output and input markets participation, hence it can be either input oriented or output oriented. The current study focused on rice commercialization, a commodity whose consumption has steadily been increasing at a higher rate relative to maize and wheat. The study assessed the degree of rice commercialization and the determinants of commercialization of male and female rice farmers in Ahero Irrigation Scheme, Kenya. Data on farm household and farming characteristics were collected through a pretested household questionnaire. Stratified sampling and probability proportionate to size sampling were used to select a sample of 221 rice farmers. A Household Commercialization Index (HCI) was computed to estimate the degree of output commercialization. The Household Commercialization Index was then modeled as a function of explanatory variables. Informed by the Chow test, three linear regressions were estimated; for male farmers, female farmers and the whole sample. The commercialization indices for male, female and whole sample were 0.77, 0.79 and 0.78 respectively. Household size, participation in off-farm income generating activities, household income, output price and use of insecticides/fungicides were found to be important determinants of rice commercialization. The recommended policy options are to advice and train farmers on insecticides/fungicides use and the government to have a planned exit from agriculture by introducing attractive off-farm income generating activities.

Keywords: Smallholder farmers, commercialization, rice, Kenya, gender

Introduction
Agriculture is the cornerstone of Kenya's economy, to which it contributes 26% of the Gross Domestic Product (GDP) directly and 25% indirectly (Republic of Kenya, 2010). Kenya's population growth of 2.5% per annum requires a shift from low productivity to intensive agricultural production that is commercially oriented (Republic of Kenya, 2012). Rising urban food demand and diversification of diets calls for increased agricultural commercialization (Pingali et al., 2006).

Kenya's Agriculture Sector Development Strategy (ASDS) 2010-2020 recognizes that development and growth of the agricultural sector are hinged on increasing productivity, commercialization and competitiveness of agricultural commodities and enterprises (Republic of Kenya, 2010). Furthermore, the Kenya Vision 2030 has identified agriculture as an important sector to increase economic growth, through transformation to an innovative and commercially oriented sector (Republic of Kenya, 2007). To achieve significant contributions to economic growth, the agriculture sector needs to be commercialized to enable smallholder farmers participate in markets (Jagwe et al. 2010).

Agricultural commercialization is the transition from subsistence farming to market oriented production (KIPPRA, 2007; Omiti et al., 2009) and use of high quality inputs (Omiti et al., 2007). Pradhan et al. (2010) defines agricultural commercialization as the process of

increasing the proportion of agricultural produce that is sold by farmers. Agricultural commercialization goes beyond marketing of agricultural produce and focus on product choice and input use decisions that are based on profit maximization objectives (Pingali and Rosegrant, 1995; Pingali, 1997). Agricultural commercialization can be input or output oriented, characterized by increase in marketable surplus or increase in use of purchased inputs in the output and input dimensions respectively, or both (Jaleta, 2009; Martey et al., 2012). The main drivers of commercialization are population growth which creates high demand for food, high opportunity cost for family labour, urbanization, technological progress (KIPPRA, 2007; Okezie et al. 2012), globalization and rising per capita incomes (Omiti et al., 2007).

Output market participation by smallholder farmers is expected to increase their incomes and improve their welfare (Jagwe et al., 2010; KIPPRA, 2007). Otieno et al., (2009) argues that promotion of market orientation among smallholder farmers in developing countries is important for development of value chains that are effective in food supply. One of the policies in the Strategy for Revitalization of Agriculture (SRA) for economic growth is enhancement of market orientation of smallholder farmers (Republic of Kenya, 2005). Marketing has been identified as the main activity in the agricultural commodity value chain (Otieno et al., 2009) which is critical in improving productivity and commercialization (Republic of Kenya, 2010). At the farm level, which is the beginning of the market chain, production must be high enough to attract enough market participants to ensure efficient distribution (Enete and Igbokwe, 2009).

Pingali and Rosegrant (1995) classified food production systems into subsistence, semi-commercial and commercial systems. The authors classify rice production as semi-commercial system. This is particularly true for rice production in Ahero Irrigation Scheme in Kenya where some of the rice produced is consumed by the farm households while inputs are purchased. Rice is among the most important cereals in Kenya, ranked third after maize and wheat (Export Processing Zones Authority, 2005; Republic of Kenya, 2008; Kamau, 2013). Although rice is ranked third in terms of consumption and production, its consumption has been steadily increasing at a rate of 12% compared to 4% and 1% for wheat and maize respectively (Republic of Kenya 2008). Kenya's rice per capita consumption has increased by about 32%, from 5.8kg/capita/year in 2004 to 7.6kg/capita/year in 2009 (Omondi and Shikuku, 2013).

Some authors attribute this to the changing eating habits among Kenyans (Emongór et al., 2009). About 80% of rice production in Kenya is under government established irrigation schemes while 20% is grown under rain fed conditions (Republic of Kenya 2008). However, domestic rice production has not kept pace with the rising demand and the deficit is met through imports (Chemonics International Inc., 2010). Despite the huge deficit ranging between 75%-85% (Chemonics International Inc., 2010), demand for rice is expected to increase in future. Promotion of rice production and consumption is expected to reduce over-reliance on maize as the main food staple hence increasing farmers' income and ensuring food security (European Cooperative for Rural Development, 2012).

In an effort to bridge the demand-supply gap, the Kenyan government initiated the National Rice Development Strategy (NRDS) 2008-2018 which will ensure increased production from 75,000 MT/year to 178,580 MT/year by 2018 (Republic of Kenya, 2008). About 300,000 smallholder farmers in Kenya depend on rice farming for their livelihood (European Cooperative for Rural Development, 2012), hence underscoring its importance. Although the efforts appear attractive, farmers' participation in rice market is an important area to consider for the strategy to succeed.

There is ample evidence indicating that there are gender differences in agriculture, in terms of access to production inputs such as land, labour, fertilizer and certified seed,

extension services, education and productivity. Women play an important role in agricultural production, providing about 80% of the labour force in food production and 50% in cash crop production (African Development Bank, 2007). Women disproportionately work for longer hours compared to their male counterparts (Kabutha and Kiara, 2008; Republic of Kenya, 2010) and in addition, perform household chores and take care of the young and sick family members (African Development Bank, 2007) which may hinder their market participation. Although there is considerable literature on gender- agricultural productivity- technology adoption nexus in Sub Saharan Africa which constrain women productivity, gender gaps in agricultural commercialization has received far less rigorous empirical attention.

The study therefore assessed the degree of commercialization of male and female rice farmers and the factors conditioning the degree of commercialization. The decision to pool or separate data for site specific or groups' analysis is often subjective (Otieno et al., 2009). For example, Oladeebo and Fajuyigbe (2007) in a study of technical efficiency of men and women rice farmers in Benin estimated two production functions for male and female farmers without testing for equality of coefficients of the two regressions. Alene et al., (2008) also pooled data from eight districts in Western Kenya without conducting a test to justify the pooling.

However, this study estimated male and female regressions, justified by the Chow test, which indicated that the sample could be separated into male and female sub samples. The test indicated that the coefficients in male farmers' and female farmers' regressions were significantly different. The study analysed the degree of commercialization of smallholder male and female rice farmers in Ahero Irrigation Scheme, Kenya, through application of Chow test (Chow, 1960) for sample differences. The specific objectives of the study were:

I.   To estimate and compare the degree of rice commercialization between male and female rice farmers in Ahero Irrigation Scheme, Kenya
II. To analyse the factors that influence the degree of commercialization of male and female rice farmers in Ahero Irrigation Scheme, Kenya

The study provides insights for developing policies that target improvement of rural households' welfare through improved market participation and consequently income improvement. Such policies would ensure reduction of extreme poverty and hunger which constitute the Millennium Development Goal 1(MDG 1). Furthermore, the study conducts a gender analysis on the degree of commercialization and the different determinants of commercialization among the two genders. The study further assessed input commercialization which is mostly neglected in agricultural commercialization studies. For example, Gebreselassie and Sharp (2008), Otieno et al. (2009), Enete and Igbokwe (2009) focused only on output commercialization. To the best of the author's knowledge, no previous study has been conducted to estimate the degree of rice commercialization in Kenya.

This paper is organized as follows. Section 1 provided the introduction while the method used is presented in section 2. Section 3 presents results and discussions while section 4 presents conclusions.

Method

Study area and the data

The study was conducted in Ahero Irrigation Scheme in Nyando District, Kisumu County, Kenya in April 2012. The scheme, which is managed jointly by the National Irrigation Board

(NIB) and farmers, is located in Kisumu County, in the outskirts of Kisumu city. Rice is the main crop cultivated in the scheme under irrigation.

A pretested household questionnaire was used to collect primary data from rice farmers. A list of all the farmers in the scheme was used as the sampling frame. Using the 12 blocks as strata, 8 blocks were randomly selected. Probability proportionate to size sampling was then performed to select a sample of 221 farmers. The data collected was on input use, volume of outputs, input and output prices as well as socioeconomic variables.

Empirical model

To estimate the degree of commercialization, a Household Commercialization Index (HCI) was computed. HCI is the ratio of output sold to the total output produced. A value of zero would indicate a household that is completely subsistence while values close to one indicate households that are more market oriented. HCI was computed as follows:

$$HCI = \frac{Quantity\ of\ rice\ sold}{Total\ quantity\ of\ rice\ harvested}$$

Commercialization Index has been used by several authors in estimating the intensity of market participation (Strasberg et al., 1999; Burke et al., 2007; Gebreselassie and Sharp, 2008; Otieno et al., 2009; Jaleta et al., 2009; Omiti et al., 2009; Martey et al., 2012; Mpogole et al., 2012; Agwu et al., 2012; Nmadu et al., 2012; Asuming-Brempong et al., 2013).

The HCI was modelled as a function of explanatory variables which have been hypothesised to influence the quantity of output sold. A linear regression was estimated as follows.

$$HCI_i = \beta_0 + \sum_{K=1}^{9} \beta_i x_i + \varepsilon_i$$

Where HCI_i is the ratio of rice sold to total rice harvested; β_0 is the intercept; β_i is a vector of parameters to be estimated; x_i is a vector of explanatory variables (described in Table 1) and ε is the error term.

Table 1: Description of variables used in the regression model

Variable	Description	Expected sign
Experience	Natural logarithm of number of years of farming	+
Education	Natural logarithm of number of years of formal education of household head	+
Household size	Natural logarithm of the number of persons in a household	±
Off farm income	Binary variable (1=earns off farm income, 0=does not earn off farm income)	±
Annual household income	Natural logarithm of the annual income in Ksh. earned by a household	+
Credit	Binary variable (1=accessed credit, 0=did not access credit)	+
Price	Natural logarithm of price of dry paddy (Ksh./kg)	+
Insecticide	Binary variable (1=applied insecticide , 0=did not apply insecticide)	+

The total quantity of rice harvested was omitted from the model because it was used to generate the HCI. To control for endogeneity, cultivated land size, labour, and quantity of fertilizer and seeds used were omitted from the output commercialization model because they are the key factors in the production function where output is produced (Otieno et al., 2009). Although group membership enhances input access and search for better markets (Onumah et al., 2007; Shiferaw et al., 2006), it was omitted from the variable because all farmers in Ahero Irrigation Scheme belong to a water user group. Distance to output market which is an indicator of travel time and cost of accessing the market (Mathenge et al., 2010) was also omitted because most farmers sold their paddy to brokers who purchased paddy at the farm gate.

Chow test

Chow test was employed to determine whether it was appropriate to pool or separate the models into male and female models. Two models, for male (Equation 1) and female (Equation 2) sub samples were specified as follows:

$$Y_m = \beta_m X_m + \varepsilon_m \tag{1}$$
$$Y_f = \beta_f X_f + \varepsilon_f \tag{2}$$

Where Y_m and Y_f are vectors of the dependent variable; x_i (i=m, f for male and female subsamples respectively) is a vector of explanatory variables; β_i are the parameters to be estimated. The null hypothesis tested was that the coefficients are equal for male and female sub samples (Equation 3)

$$H_0 = \beta_m = \beta_f \tag{3}$$

Three separate models were estimated, one for the whole sample; and two for male and female sub-samples. The Chow test was computed as follows:

$$F^* = \frac{RSS_w - (RSS_m + RSS_f)}{(RSS_m + RSS_f)} * \frac{(T - 2K)}{K}$$

Where F* is the test statistic.

RSSw = Residual sum of squares for the whole sample.

RSSm = Residual sum of squares for the male sub-sample.

RSSf = Residual sum of squares for the female sub-sample.

T = Total number of observations in the whole sample.

K = Number of regressors (including the intercept term) in each unrestricted sub- sample regression.

$2K$ = Number of regressors in both unrestricted sub sample regressions (Whole sample).

Table 2: Computation of Chow test

RSS$_W$	RSS$_F$	RSS$_M$	F*	F(K,T-K) at 5% significance level	Decision
6.35	1.45	4.29	2.39	1.99	Separate male and female data

Source: computed from survey data (2012)

The results of Chow test are presented in Table 2. The test statistic (F*) is 2.39 which is greater than the respective F statistic (1.99) at 5% level of significance. The null hypothesis was therefore rejected and it was concluded that the male and female sub samples were significantly different. Consequently, separate models were estimated for the male and female farmers. For comparison purposes, a whole sample regression was also estimated.

Results

The descriptive statistics of the sampled rice farmers is presented in Table 3. The statistics include comparison of socioeconomic factors among male and female farmers, as well as the characteristics of all the sampled rice farmers.

Table 3: Descriptive statistics for testing for differences in means between male and female rice farmers

Variable	Mean Male farmers (n=154)	Mean Female farmers (n=66)	Mean Whole sample (N=220)	Mean difference
Age (years)	53.62	53.91	53.71	-0.29
Farming experience (years)	17.84	18.48	18.03	-0.66
Education (years)	8.18	5.39	7.32	2.74***
Household size (number)	5.90	5.09	5.66	0.81***
Annual income (Ksh.)	80,396.14	76,397.17	79201.88	3,999
Off farm income (1=earns off farm income,0=otherwise)	0.45	0.27	0.39	0.17**
Land size (acres)	4.40	3.91	4.26	0.49*
Credit (1=accessed credit,0=otherwise)	0.26	0.39	0.30	-0.13*
Extension (1=accessed extension services,0=otherwise)	0.79	0.70	0.76	0.10
Insecticide/fungicides(1=used insecticides/fungicides,0=otherwise)	0.83	0.88	0.85	-0.05
Rice harvested (kg/acre)	2,093.94	1,860.45	2024.21	233.49***
Rice sold (%)	76.83	79.31	77.57	-2.48
Price (Ksh.)	43.31	43.49	43.37	-0.18
Distance (km)	2.75	2.73	2.75	0.02

Source: Computed from field survey data 2012 *,**,*** means significance at 10%, 5% and 1% level

Male farmers comprised about 70% of the sample. Years of formal education of the household head, household size, participation in off farm income activities, land size cultivated, credit access and the amount of rice harvested varied significantly between male and female farmers. Specifically, male farmers had about 3 years more of formal education compared to female farmers. The male headed households on average comprised of 6 persons while female headed households comprised of 5 persons. About 45% of male farmers participated in off farm income generating activities compared to 27% of female farmers. Male farmers also owned 0.49 acres of land more compared to female farmers. Land is a significant input for agriculture and its size greatly determines the amount of output. Male farmers harvested about 79 kg per acre of rice more compared to female farmers.

There were no significant differences in age and experience of the household head, annual household income, access to extension advice, use of insecticides/fungicides, percentage of output sold and price of paddy between male and female farmers. However, the effect of these variables on the degree of commercialization (percentage of output sold) may be different because of the effect of other exogenous variables like education and off farm income, which vary between male and female farmers.

Table 4 represents the test of differences in means of input use by rice growers in Ahero Irrigation Scheme. This can be interpreted as input commercialization because all the inputs are purchased except for family labour, whose use is minimal considering that rice farming is labour intensive.

Table 4: Test for differences in means of input use intensity and input prices among male and female farmers

Variable	Mean Male farmers (n=155)	Mean Female farmers (n=66)	Mean Whole sample (N=221)	Mean difference
Quantity of seed (kg/acre)	25.22	25.30	25.25	-0.08
Quantity of fertilizer (kg/acre)	82.90	85.23	83.60	-2.32
Chemical cost (Ksh./acre)	494.77	492.42	494.07	2.35
Labour cost (Ksh./acre)	24,426.72	24,048.83	24,313.72	378.39
Seed price (Ksh./kg)	67.26	72.15	68.72	-4.89***
Fertilizer price (Ksh./kg)	45.42	46.25	45.67	-0.83

Source: Computed from field survey data 2012 *, **, *** means significance at 10%, 5% and 1% level

There were no significant differences in the quantities of seed, fertilizer, chemicals and labour costs between male and female farmers. On average, farmers planted 25kg of rice seed per acre and applied about 86kg of fertilizer per acre. The chemical cost on average was Ksh.494 per acre while labour cost, which constituted the largest proportion of total cost was Ksh. 24,313 per acre. There was no significance difference in fertilizer price which is about Ksh. 46 per kg. However, there were significant differences in the price of seed. Male farmers bought rice seed at a cost which was Ksh. 5 per kg less compared to female farmers.The distribution of percentage of rice sold by male and female farmers is presented in Table 5. As indicated in Table 5 rice farmers are generally commercially oriented.

Table 5: Distribution of the percentage of paddy sold by male and female farmers

Range of the percentage of rice sold	Male farmers (n=155) %	Female farmers (n=66) %
0-10	1.9	0.0
11-20	1.3	0.0
21-30	5.3	0.0
31-40	7.1	4.5
41-50	4.5	7.6
51-60	1.3	4.5
61-70	3.9	7.6
71-80	12.3	22.7
81-90	28.4	25.8
91-100	34.2	27.3

Source: Computed from field survey data 2012

About 21% of male farmers sold less than 60% of their producer. However, about 34% of male farmers sold more than 90% of their produce. On the other hand, about 17% of female farmers sold less than 60% of their produce with 27% selling more than 90% of the paddy harvested.

Table 6: Determinants of the degree of rice commercialization among male and female farmers

Variable	Male farmers (n=155)		Female farmers (n=66)		Whole sample (N=221)	
	Coefficient	t-ratio	Coefficient	t-ratio	Coefficient	t-ratio
Experience	-0.01	-0.06	0.02	0.47	0.01	0.37
Education	0.01	0.48	0.01	1.15	0.00	0.86
Household size	0.01	0.34	-0.07	-2.29**	-0.01	-0.51
Off farm income	-0.09	-2.80***	-0.12	-1.98*	-0.10	-3.37***
Annual income	0.04	0.83	0.13	2.05**	0.07	1.78*
Credit	0.10	2.77***	0.05	1.18	0.09	3.56***
Price	0.40	2.07**	0.09	0.40	0.37	2.58**
Insecticide	0.37	6.34***	0.08	0.95	0.29	5.81***
Constant	-1.50	-1.85*	-1.01	-0.94	-1.68	-2.68***
R^2	0.5439		0.2666		0.4435	

Source: Computed from field survey data 2012 *, **, *** means significance at 10%, 5% and 1% level

The results demonstrate that participation in off farm income generating activities negatively influences the degree of commercialization for both male and female farmers. Similar findings were obtained by Otieno et al., (2009) and Omiti et al., (2009). In addition, credit access, paddy price and use of insecticides/fungicides positively influenced the degree of rice commercialization among male farmers. The findings corroborate findings from similar studies (Alene et al., 2008; Enete and Igbokwe, 2009; Omiti et. al., 2009; Mathenge et al., 2010; Martey et. al., 2012) that price positively influence the amount of output sold. Martey et al., (2012) found a positive coefficient for credit though not significant. A positive relationship between access to credit and output commercialization was also obtained by (Mathenge et al., 2010). Use of insecticides/fungicides contributes to increased yield,

consequently contributing to increased sales. Insecticides/fungicides help in abating yield loss due to destructive insects/fungi.

On the other hand, household size and annual household income significantly influenced the degree of output commercialization among female farmers. Specifically, household size negatively influenced the amount of dry paddy sold. Households with higher number of persons demand more output for consumption and food security, hence selling relatively smaller amounts. Similar findings were obtained by Otieno et al., (2009) and Agwu et al., (2012). Household income positively influenced the amount of paddy sold. Households earning higher incomes sold more output compared to households earning less income. This finding corroborates that of Agwu et al., (2012).

Overall, participation in activities that earn off farm income, annual household income, credit access, output price and use of insecticides/fungicides determined the degree of output commercialization.

Conclusions

There is need to improve the degree of commercialization among rice farmers, in order to increase their incomes as well as reduce the rice import bill. To achieve this, productivity must be increased such that farmers have adequate quantities to sell and for household consumption. Credit access and use of insecticides/fungicides have the potential to increase farmers' commercialization. The use of insecticides/fungicides reduces yield loss to insects and fungal diseases hence increasing commercialization. Farmers should be trained and advised on insecticides/fungicides use.

Since participation in off farm income generating activities reduces the degree of commercialization, there is need for the government to have a planned exit from agriculture. This underpins the importance of developing attractive off farm income generating activities that will motivate exit from farming of the less productive and landless citizens. The direction of change should be towards a more diversified rural economy with a variety of livelihood sources and increased returns from agriculture.

Price motivates farmers to participate more in output markets. However, policies that target increase in price to increase the degree of commercialization for an important staple such as rice will only benefit farmers in the short run but have negative effects to buyers. Furthermore, since Kenya is a net importer of rice, increasing price to benefit producers will lead to Kenyan farmers being uncompetitive with other countries importing rice to Kenya. Therefore, it is recommended that other non-price incentives such as use of insecticides/fungicides, improving credit access and household incomes be used as a motivating factor for output commercialization. Reduction of input prices such as seed, chemicals and fertilizer would improve their usage (Omondi and Shikuku, 2013) and consequently productivity. The government should also improve on education of farmers, particularly female famers whose education is significantly lower compared to male farmers.

However, these findings should be interpreted with care as they may not necessarily be true in other regions of Kenya where opportunities and farming conditions are different.

End notes
US$1 = approximately 85 Kenya shillings
Competing interests
The author declares that there are no competing interests with any party

References

African Development Bank. (2007). Kenya Country Gender Profile. Human Development Department (OSHD)

Agwu, N.M., Anyanwu, C.I. and Mendie, E.I. (2012). Socio-Economic Determinants of Commercialization among Small Holder Farmers in Abia State, Nigeria. *Greener Journal of Agricultural Sciences,* 2(8):392-397

Alene, A.D., Manyong, V.M., Omanya, G., Mignouna, H.D., Bokanga, M. and Odhiambo, G. (2008). Smallholder market participation under transactions costs: Maize supply and fertilizer demand in Kenya. *Food Policy,* 33:318–328

Asuming-Brempong, S., Anarfi, J.K., Arthur, S. and Asante, S. (2013). Determinants of Commercialization of Smallholder Tomato and Pineapple Farms in Ghana. *American Journal of Experimental Agriculture, 3(3): 606-630*

Burke, W.J., Jayne, T.S., Freeman, H.A. and Kristjanson, P. (2007). Factors Associated with Farm Households' Movement Into and Out of Poverty in Kenya: The Rising Importance of Livestock. MSU International Development Working Paper No.90, 2007

Chemonics International Inc. (2010). Staple foods value chain analysis. USAID country report – Kenya

Chow, G.C. (1960). Tests of equality between sets of coefficients in two linear Regressions. *Econometrica*, 28(3):591-605

Emongór R.A., Mureithi, F.M., Ndirangu, S.N., Kitaka, D.M. and Walela, B.M. (2009). The rice value chain in Kenya with reference to rice producers. Kenya Agricultural research institute, Kenya

Enete, A.A. and Igbokwe, E.M. (2009). Cassava Market Participation Decisions of Producing Households in Africa. *Tropicultura*, 27(3):129-136

European Cooperative for Rural Development. (2012). Rice Sector Development in East Africa. A desk study prepared for the Common Fund for Commodities

Export Processing Zones Authority. (2005). Grain production in Kenya

Gebremedhin, B. and Jaleta, M. (2010). Commercialization of smallholders: Does market orientation translate into market participation? International Livestock Research Institute, Working Paper No. 22, Nairobi, Kenya, ILRI

Gebreselassie, S. and Sharp, K. (2008). Commercialisation of Smallholder Agriculture in Selected Tef-growing Areas of Ethiopia. Future Agricultures, Discussion Paper 006

Jagwe, J., Machethe, C. and Ouma, E. (2010). Transaction costs and smallholder farmers' participation in banana markets in the Great Lakes Region of Burundi, Rwanda and the Democratic Republic of Congo. *African Journal of Agricultural Research,* 6(1):302-317

Jaleta, M., Gebremedhin, B. and Hoekstra, D. (2009). Smallholder commercialization: Processes, determinants and impact. Discussion Paper No. 18. Improving Productivity and Market Success (IPMS) of Ethiopian Farmers Project, ILRI (International Livestock Research Institute), Nairobi, Kenya

Kabutha, C. and Kiara, E. (2008). Gender Study of the Smallholder Irrigation Project Mount Kenya Region (SIPMK)

Kamau, C.N. (2013). Grain and Feed Annual- 2013 Kenya Corn, Wheat, and Rice Report. Global Agricultural Information Network report

KIPPRA. (2007). Enhancing the Commercialization of Smallholder agriculture in Kenya. The Kenya Institute for Public Policy Research and Analysis, Policy brief No. 5, 2007

Martey, E., Al-Hassan, R.M. and Kuwornu, J.K.M. (2012). Commercialization of smallholder agriculture in Ghana: A Tobit regression analysis. *African Journal of Agricultural Research*, 7(14):2131-2141

Mathenge, M., Place, F., Olwande, J. and Mithoefer, D. (2010). Participation in agricultural markets among the poor and marginalized: analysis of factors influencing participation and impacts on income and poverty in Kenya. Tegemeo Institute of Agricultural Policy and Development, Study report

Mpogole, H., Mlambiti, M.E Kadigi, R.M.J. (2012). Round potato (*Solanum tuberosum*) production in southern highlands of Tanzania: Are smallholder farmers becoming commercial? *Journal of Agricultural Extension and Rural Development*, 4(14):385-391

Nmadu, J.N., Iwuajoku, R.C. and Jiya, E.Z. (2012). Commercialisation Level of Poultry Production in Minna Metropolis, Niger State, Nigeria. *Asian Journal of Agricultural Extension, Economics & Sociology,* 1(1): 1-15

Okezie, C.A., Sulaiman, J. and Nwosu, A.C. (2012). Farm – Level Determinants of Agricultural Commercialization. *International Journal of Agriculture and Forestry*, 2(2):1-5

Oladeebo, J.O. and Fajuyigbe, A. A. (2007). Technical Efficiency of Men and Women Upland Rice Farmers in Osun State, Nigeria. *Journal of Human Ecology*, 22(2): 93-100

Omiti, J., Otieno, D., McCullogh, E. and Nyanamba, T. (2007). Strategies to Promote Market-Oriented Smallholder Agriculture in Developing Countries: A Case of Kenya. AAAE Ghana Conference Proceedings (2007), 259-264

Omiti, J.M, Otieno, D.J., Nyanamba, T.O. and Mccullough, E. (2009). Factors influencing the intensity of market participation by smallholder farmers: A case study of rural and peri-urban areas of Kenya. *African Journal of Agricultural Research,* 3(1):57-82

Omondi, S.O. and Shikuku, K.M. (2013). An Analysis of Technical Efficiency of Rice Farmers in Ahero Irrigation Scheme, Kenya. *Journal of Economics and Sustainable Development*, 4(10):9-16

Onumah, G., Davis, J., Kleih, U. and Proctor, F. (2007). Empowering Smallholder Farmers in Markets: Changing agricultural marketing systems and innovative responses by producer organizations. ESFIM Working Paper 2

Otieno, D.J., Omiti, J., Nyanamba, T. and McCullough, E. (2009). Market participation by vegetable farmers in Kenya: A comparison of rural and peri-urban areas. *African Journal of Agricultural Research,* 4(5):451-460

Pingali, P.L. (1997). From Subsistence to Commercial Production Systems: The Transformation of Asian Agriculture. *American Journal of Agricultural Economics*, 79(2):628-634

Pingali, P.L. and Rosegrant, M.W. (1995). Agricultural commercialization and diversification: processes and policies. *Food policy*, 20(3):171-185

Pradhan, K., Dewina, R. and Minten, B. (2010). Agricultural commercialization and diversification in Bhutan. Ministry of Agriculture and International Food Policy Research Institute, Agricultural and Food Policy Research and Capacity Development project summary, July 2010

Republic of Kenya (2005). Strategy for Revitalizing Agriculture (2004-2014). Ministry of Agriculture, Ministry of Livestock and Fisheries Development, Ministry of Cooperative Development and Marketing, Nairobi

Republic of Kenya. (2007). Kenya Vision 2030 A Globally Competitive and Prosperous Kenya

Republic of Kenya. (2008). National Rice Development Strategy (2008-2018). Ministry of Agriculture, Kenya

Republic of Kenya. (2010). Agricultural Sector Development Strategy 2010–2020

Republic of Kenya. (2012). National Agribusiness Strategy-Making Kenya's agribusiness sector a competitive driver of growth. Agricultural Sector Coordination Unit (ASCU)

Shiferaw, B., Obare, G. and Muricho, G. (2006). Rural Institutions and Producer Organizations in Imperfect Markets: Experiences from Producer Marketing Groups in Semi-Arid Eastern Kenya. *SAT eJournal*, 2(1):1-36

Strasberg, P.J., Jayne, T.S., Yamano, T., Nyoro, J., Karanja, D. and Strauss, J. (1999). Effects of Agricultural Commercialization on Food Crop Input Use and Productivity in Kenya. MSU International Development, Working Paper No. 7

SUB THEME 6: SOIL, TILLAGE AND WATER MANAGEMENT

6.1.0 REGIONAL MSC TRAINING IN INTEGRATED SOIL FERTILITY MANAGEMENT IN FRANCOPHONE WEST AFRICA AT RURAL POLYTECHNIC INSTITUTE OF KATIBOUGOU- MALI

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Abstract

African agriculture is among the most pressing development challenges of today. In recent years, agricultural production is on the decline. One of the major causes of the declining agricultural productivity in West Africa is due to limited numbers of trained experts to deliver the required services to farmers. This is particularly critical in the area of soil science. The current cadre of soil scientists in West Africa is too small, largely reaching retirement age, and tends to be out of touch with modern soil science and with on the ground problems and village level agriculture. To address this challenge, a partnership was established between IPR/IFRA and AGRA through a training grant proposal entitled: "Regional MSc Training Program in Integrated Soil Fertility Management in Francophone West Africa at Rural Polytechnic Institute of Katibougou, IPR/IFRA, and Mali". In this respect, IPR/IFRA is offering a Regional Graduate Program in soil science by providing a 2-year MSc in Integrated Soil Fertility Management, whereas the AGRA support is seen as a "seed support" in a training program that is expected to expand over the years through a well-planned project sustainable/exit strategy. 10 MSc. students drawn from the three countries--Burkina Faso (2), Mali (6) and Niger (2) will be trained and it is expected that the initial AGRA investment will influence other resources to enable the training program to progress. The training approach combines one year course work and one year field excursions using a group of well experienced academic staff to achieve the goal of building well-equipped professionals in Integrated Soil Fertility Management (ISFM) to improve agricultural productivity. The program was launched in January 21, 2014 and this poster presents our approach; key achievements; Lessons learnt and way forward.
Key words: MSc. Training, ISFM, soil science

Background

Capacity building for sustainable agricultural development remains fundamental to the development of Africa (UNEP, 2002). Generally, agriculture is becoming more market-oriented in the Sahel. The percentage of farm products brought and sold on markets rose from 20% in 1950 to about 50% in 2000 (Cour, 2001).

It is the dominant employer and a key factor in the gross domestic product growth. The economies of the countries in the Sahel region are largely dependent on agriculture, with about 80-90% of the population actively engaged in agriculture (UNEP, 2012). Agriculture continues to be the mainstay of the economy of vast majority of African countries. According to the online Fact Book of Central Intelligence Agency (CIA, 2011), agriculture accounts for a third of gross domestic product (GDP) (FAO, 2006; African Development Bank, 2013) and represents up to 40% of exports in Africa. It employs more than 80% of the working population, and is the sole source of income for many families. In Burkina-Faso and Niger agriculture occupies approximately 90% of the working population. In Mali it employs about 80% of the working population. The per cent of GDP generated from agricultural activities in year 2000 in Niger was estimated at 38.8%. For Burkina Faso and Mali, the per cent of GDP generated from agricultural activities in 2007 was estimated at 30.1% and 45%, respectively. Public expenditure on agricultural research as percentage of agricultural GDP for Burkina Faso, Mali, and Niger were 0.5, 1.0 and 0.2, respectively. The annual growth in agriculture research spending (1990 –2000) was -1.2%, 0.8% and -6.2% for Burkina, Mali and Niger, respectively. These countries have economies that are strongly tied to the performance of the agricultural sectors.

However, African agriculture is among the most pressing development challenges of today. In recent years, agricultural production is on the decline. According to Omotayo et al (2009) a World Bank report estimated the rate of cereal yield increase in Africa over the years at a very low rate of 0.7% compared to growth rates in other developing regions of the world of 1.2 - 2.3% (AGRA, 2007). Major causes of the falling agricultural productivity in Africa have been identified as declining soil fertility, land degradation and agricultural production based on marginal lands. Lack of improved crop varieties and seeds and low levels of soil ameliorants also contribute to low yields. With agriculture being the main economic activity in the Sahel (Suttie et al., 2005), the effects of land degradation can be significant (UNEP, 2012).

Dealing with soil fertility and management issues needs a large investment in scientific research which, in turn, requires producing a critical mass of soil scientists capable of developing innovative and adaptable technologies for addressing current and emerging soil constraints to improve agricultural productivity in Africa. However, many African countries do not have the minimum threshold numbers of trained experts to deliver the required services to farmers and other to other actors in the soil health and food crops value chains. The inadequate numbers of scientists and extension personnel seem to be most critical in the drier landlocked countries in West Africa.

The statistics of Africa's position in global professional development, population and food production trends show a pronounced downward trend in sub-Saharan Africa (Diagana, 2003). The New Partnership for Africa's Development (NEPAD) estimates that only 2% of Africa's Agricultural scientists are in the soil sciences, making it extremely difficult for African countries to overcome agricultural problems related to soil fertility and sustainable land use and management. In 2011, a study by Beintema and Stads show that there were 313, 240 and 93 agricultural researchers in Mali, Burkina Faso and Niger, respectively. These figures are in agreement with data from the same countries in a 2011 Survey that focused on soil scientists/researchers. That survey showed that in Burkina Faso, Mali and Niger there were 25, 25 and 20 soil scientists (MSc and PhD level) respectively. A key problem in countries like the Mali, Niger and Burkina Faso as elsewhere in the African continent is their aging—and hence imminently retiring—pool of qualified researchers. The Survey also

showed that of the 70 soil science graduates at MSc/PhD level in the three countries, 60% are above the age of 45.

In West Africa, tertiary education institutions serving the agricultural and related sectors have made significant contributions to the development of agriculture. It is, however, widely agreed that they have been slow to respond effectively to changing socio-economic development needs (Chakeredza et al., 2008).

In order to close the gap in manpower for long term agricultural production, there is an urgent need to train more soil scientists and agronomists in the West African sub-region, who will respond to the prerequisites for attaining the objectives of the African Green Revolution.

Meanwhile, the current approaches to training more soil scientists in the countries in the region appear not to be effective in overcoming the challenges faced by the tertiary institutions in graduating students for the agriculture and related sectors. For example, in Mali, the Rural Polytechnic Institute recorded a decline in the number of students pursuing agronomy/soil science at undergraduate and BAC+2 levels. In 2008, 11 registered for the soil fertility option at undergraduate level (8 male students and 3 female students). In 2009, the number decreased to 9 (7 males and 2 female student). In 2010, the number continued decreasing to 6 (3 males and 3 female students). The lack of financial support in form of scholarships for training at MSc. and PhD levels is one of the principal constraints contributing to the weak capacity building in the country in general and at the Institute. In more recent times AGRA has been providing support to Universities providing MSc/PhD training in soil science. One such national training program is at the Polytechnic University at Bobo-Dioulasso. In addition to the AGRA supported students, there are self-supported students from Burkina Faso, Niger and Mali enrolled in the Program.

The proposed project provides a major opportunity for the 3 West African counties--Mali, Niger and Burkina Faso--targeted here to address the critical human capacity shortage in the agricultural education and training in the region.

The Rural Polytechnic Institute at Katibougou seeks to respond to this challenge by offering a Regional Graduate Program in soil science and agronomy by providing a 2-year MSc in soil science with agronomy options. The AGRA support is seen as a "seed support" in a training program that is expected to expand over the years through a well planned project sustainable/exit strategy. It is expected the initial AGRA investment will leverage other resources to enable the training program to progress.

10 MSc. students drawn from the three countries--Burkina Faso (2), Mali (6) and Niger (2) will be trained and it is expected that the initial AGRA investment will leverage other resources to enable the training program to progress.

The objectives of the program are:

a) To increase the number of soil scientists in targeted countries,

b) To strengthen the teaching and research capacity in soil sciences at Rural Polytechnic Institute of Katibougou, Mali.

Approach
The main outcomes of the project will be brought about through: improved professional skills in soil sciences in Burkina Faso, Mali and Niger; Enhanced teaching and research capacity at IPR and better trained students in ISFM; Improved infrastructure (computing and Laboratory

equipment) at the Department of Science and Agricultural Techniques; and improved learning experience and skills of MSc students in academic courses and research.

In terms of approach, the program combines theory, practical skills and field excursions using a group of well experienced academic staff to achieve the goal of building capacity of a cadre of well-equipped professionals with a broad range of theoretical and practical skills in Integrated Soil Fertility Management (ISFM) to improve agricultural productivity in Burkina Faso, Mali and Niger. In addition, the approach includes meetings, exploration of program documents from several countries, recruitment of both national lecturers and visiting professors from Burkina Faso and Niger, participation in AGRA workshops (in Nairobi, Accra, Bamako, Ouagadougou) and gender-based selection process.

Activities

The program was launched in January 21, 2014 and several activities have been carried out toward the accomplishment of the objectives:

3.1. Develop, validate and launch an upgraded curriculum
3.2. Advertise scholarships and select AGRA scholarship awardees
3.3. Recruit 5 MSc students at IPR of Katibougou
3.4. Recruit visiting professors.
3.5. Teach courses to MSc students
3.6. Purchase project vehicle
3.7. Conduct an inventory of equipment in   Soil Science laboratory.
3.8. Prioritize equipment for replacement.
3.9. Procure new field/ laboratory equipment
3.10.   Install Software (antivirus,Arc GIS, Envi, Genstat)
3.11.   Recruit and train lab technicians.

Key achievements

Expected results are:

1. Development of ISFM-based curriculum and Recruitment of first cohort of students; Launching of the Regional Training Program; Upgrade of laboratory facilities
2. Implementation of Cohort1 Research Programs: Graduation of first cohort of students; Enrolment of second cohort of students.
3. Implementation of Cohort 2 research; Graduation of second cohorts

According to these expected results, the following key achievements were done:

Curriculum development and validation

Through inclusive process within IPR/IFRA, a curriculum was developed and validated before October, 2013. This process consisted mainly of meetings, participation in workshops, literature reviews etc.

To date four meetings of department and the project team level are to be noted; Project coordinator participated in five AGRA Workshops organized in Nairobi, Accra, Bamako and Ouagadougou;

Recruitment of the first cohort of MSC students and lab technician

The selection process was done on the basis of entry requirements include all documents to be submitted: 1) completed application form; 2) Copy of birth certificate; 3) copy of certificate of nationality; 4) official latest Diploma transcript or equivalent; 5) transcript of grades for the obtainment of latest Diploma or equivalent; 6) detailed CV; 7) Engagement letter from employer guarantying future M.Sc. graduates to advance ISFM applications in their country. 8) Support letter from employer, granting study leave, in case of success; 9) Names and contact details of 2 referees, one of whom must be his/her latest teacher; 10) Letter of motivation with "AGRA MSC training in ISFM at Katibougou" as the headline. In order to be considered as fully admitted the selected candidates should provide their original documents during registration in December.

A total of 44 applications were received drawn from the three countries Burkina-Faso (12), Mali (30), Niger (2); from applicants 38 were males and 6 females. From applicants 14 were selected as probable self-supporting students. They provided an appropriate Diploma with its grade transcript and all the relevant required documents compared to the rest of candidates. All the rest (25 applications) was rejected either for improper diploma or incomplete application. Through that selection process, 10 MSC Students (5 AGRA sponsored and 5 self-supporting) drawn from Burkina Faso, Mali and Niger were recruited. It is worth noting that this total number of recruited Students encompasses 8 males and 2 females. Scholarships were advertized mainly by email toward personal of IPR/IFRA, Institute of Rural Economy, ICRISAT Mali and Niger, Operations Haute Vallee, CMDT, Toguna-sa, University of science Technique and Technology in Bamako, Université Abdou Moumouni de Niamey, Université de Maradi, Université de Ouagadougou, Université Polytechnique de Bobo, Les 2IE Ouagadougou, and published in AGRA and IPR web sites.

Five (5) Laptops for students and one (1) laptop for projector use, were procured and distributed by February 2014, the same for LCD projector and screen, photocopier and scanner, procure printer; Internet service is provided it was reinforced by Malitel internet Pack, the telephone service is paid according to the budget line.

According to the student health insurance, the coverage rate is 80% with a company called "Allianz Insurance Mali, avenue de la Porte NATION 560 BP E4447 Bamako, Tel.(223) 20246200 Fax (223)20246201"

With regards to the recruitment of the lab technician, the main requirements were as follows:

1. Candidates must be from one of the 3 program countries (Burkina Faso, Mali, Niger);
2. Candidates must have a Diploma of technician in chemistry (Diplôme d'Etudes Fondamentales DEF + 4 or) with more years experience in specialized laboratory.
3. Candidates must have full time availability from April1, 2014 for a period of three (3) years.

4. Candidate must submit the following documents: 1) Copy of birth certificate; 2) copy of certificate of nationality; 3) official latest Diploma transcript or equivalent; 4) detailed CV; 5) Names and contact details of 2 referees; 6) Motivation letter

Enrolment of second cohort of students

The call for application was launched and published in AGRA and IPR web sites. The selection process will be done on the basis of entry requirements include all documents to be submitted; it is as a same as a selection process of first cohort (see previous chapter entitled **Recruitment of the first cohort of MSC students and lab technician).**

Selection of lecturers and visiting professors

A total of twenty five (25) lecturers were selected in the first year. In the semester I and II were selected 13 and 12 respectively. Among them 4 visiting professors were from universitté 2iE, Université Polytechnique de Bobo Agrhymet; and ICRISAT-Niger. In addition, 3 lecturers came from national collaborating universities (USTTB) and research centres (lab of IER). Apart from the last course entitled "climate, agriculture and environment", which will start on November 3th, all the rest was done.

Procurement of lab equipments and project vehicle

According to the priority equipment procurement at Rural Polytechnic Institute of Katibougou invoices proforma were received from following vendors: KEIT MOBILE SARL in Bamako (Mali); SOCIETÉ DIAMA SARL (Bamako, Mali); LUSTINER BURKINA, LB (Burkina Faso); THEKAMAT (France) and NEO-TECH (Belgium).

 THEKAMAT sarl was selected because of its suitable price and equipment quality; the first tranch of equipment cost is being transferred;

Linked with the minibus (project vehicle) vendor selection following companies in Bamako la MALIENNE DE L'AUTOMOBILE), LINCO AUTOMOBILE, CFAO MOTORS and MY AUTO submitted proforma. The last one MY AUTO was selected because of its suitable price to our approved budget. Project new minibus was procured. It was necessary to process a budget revision because some budgeted amounts were lower than market price.

Partnership

Links are being established with Universities in Niger (Abdou Moumouni de Niamey, Aghrimet) and Burkina Faso (Université 2ie, Université de Ouagadougou, Université Polytechnique de Bobo), Université des Sciences, Techniques et Technologiques de Bamako (USTTB) and the « Laboratoire Sol -Eau –Plante » of Sotuba, Institut d'Economie Rurale.

Monitoring and Evaluation

In order to follow up the performance of the students, the project team has established a regular daily monitoring system for pedagogic activities and an evaluation after each course. In the view to improve the teaching activities and project management and coordination capacity, there is a suggestion notebook in the class.

Table 1: Key Outcomes, Outputs and Activities

OBJECTIVE	ACTIVITY	OUTPUT	OUTCOME
Objective 1: To increase the number of soil scientists in targeted countries	1.Develop, validate and launch an upgraded curriculum	Output 1. - One ISFM curriculum Developed and advertised Output 1..2 AGRA Scholarship	Outcomes .1: Qualified MSc graduates trained in soil science and ISFM

	2:Advertise scholarships and select AGRA scholarship awardees 3.Recruit MSc students at IPR of Katibougou 4. Recruit visiting prof. 5. Teach courses to MSc students	awarded(4 males and 1 female) Output 1.3 Self-supporting students recruited (five 5) Output 1.4: Five (5) AGRA sponsored and five (5) Self-supporting students trained in 15 courses as follow: Applied soil Physics; Applied soil Chemistry; soil Microbiology and Biochemistry; Research Methodology I ; Plant Physiology and Biochemistry ; Communication in Agriculture; Scientific English; Agribusiness Management; Integrated Soil Fertility Management; Biometry; GIS and Remote sensing applications; Research Methodology II; Soil and Water Management and Conservation; Methods of Soil, Water and plant Analysis; Soil Classification and Land Evaluation Output 1.5 Project minibus procured	
Objective 2, To strengthen the teaching and research capacity in soil sciences at Rural Polytechnic Institute of Katibougou, Mal	1. Conduct an inventory of equipment in Soil Science laboratory. 2. Prioritize equipment for repair and replacement. .3 Procure new field/	Output .1 Five students computers equipped; One computer for projector use equipped (software facilities: antivirus-Kasperski, Envi, Genstat) at the Department of science and agricultural techniques Output .2	Outcomes 2: Enhanced teaching and research capacity in soil sciences at Rural Polytechnic Institute of Katibougou

	laboratory equipment	Lab equipment inventoried, prioritized for procurement	
	4. Purchase Install antivirus software	Output .3 One lab technician recruited	
	5. Recruit lab technicians.		

Gaps and challenges/ experiences

1.1. Inadequate text books; In terms of access to the library, most books at katibougou are not related to agribusiness, Biometry and communication in agriculture

1.2. Attracting a similar number of students next year and in 3 years without AGRA support

1.3. Procurement process has been very lengthy; Hopeful that the vehicle can be successfully purchased during the second semester

1.4. Chemical and reagents cost for practical training in collaborative Lab was not budgeted e.g. soil microbiology & biochemistry;

1.5. Poor internet access depending on period

1.6. The requirement for gender balance was unattainable

1.7. Slow procurement process of lab equipment, Future purchase process to be initiated earlier

1.8. Research capacity of students

1.9. Meetings with Director and the Chairman of Department together with other staff

1.10.　　　Getting visiting professors not easy

LESSONS LEARNT

6.1. Need to plan Finance officer allowance

6.2. Establish link with Universities

6.3. Shortage of chemical and reagents both for practical training in microbiology & biochemistry or practical cost

6.4. Need to improve the visiting professors number

6.5. Need to plan a budget line for practical training in others lab

6.6. Better to have serious vendors of lab equipment in Europe and in Africa at the beginning, in the view to compare to prices and select the best vendor.

6.7. Procurement process for lab equipments has been very lengthy because of the rigorous administrative procedures in Mali.

6.8. Meeting with all departmental staff and students (Many of them think that the program is personal and belongs to the coordinator)

Conclusions & way forward

To date all the courses excepted climate Agriculture and Environment were trained consequently, year one is almost over and the development of student research proposals will start from November 15 to December 31.

In order to make the program more sustainable, three ways are to be explored:

1. elaborate and implement with financial partners a regional PhD program in ISFM
2. create and promote a bachelor level in the view to make the MSC in ISFM sustainable
3. plan a follow up strategy for the MSC graduates in terms of re-investment of their acquired knowledge and skills
4.

References

African Development Bank, 2013. African Statistical year Book. pp361

AGRA (2007). Alliance for a Green Revolution in Africa: AGRA at work. Retrieved 13th March, 2008 from www.agra-alliance.org/work/

Beintema, N. M., and G. J. Stads.2011a. African Agricultural R&D in the New Millennium: Progress for Some, Challenges for Many. IFPRI Food Policy Report. Washington, DC: International Food Policy Research Institute.

Central Intelligence Agency (CIA), 2011, The online Fact book, ISSN 1553-8133
Chakeredza, S., Temu, A., Saka, J., Munthali, D., Leresche, K., Akinnifesi, F., & Cour, J.M. 2001. The Sahel in West Africa: Countries in transition to a full market economy. Global Environmental Change 11(1): 31-47.

FAO, 2006. The state of food and Agric.U.N. FAO, Rome.

Omotayo, O. E. and K. S. Chukwuka, 2009. Soil fertility restoration techniques in sub-Saharan Africa using organic resources, African Journal of Agricultural Research Vol. 4 (3), pp. 144-150.

Sileshi, G. (2008). Tailoring tertiary agricultural education for sustainable development in Sub-Saharan Africa: Opportunities and challenges. Scientific Research and Essay, 3(8), 326-332.
Suttie, J.M., Reynolds, S.G., Batello, C. (Eds.). 2005. Grasslands of the world. Plant Production and Protection Series, No. 34. Food and Agriculture Organization of the United Nations (FAO). Rome. UNEP

UNEP 2002; Division of Environmental Policy Implementation, , Capacity building for sustainable development: AN OVERVIEW OF UNEP ENVIRONMENTAL CAPACITY DEVELOPMENT INITIATIVES, ISBN: 92-807-2266-2

UNEP 2012; Sahel Atlas of Changing Landscapes: Tracing trends and variations in vegetation cover and soil condition. United Nations-Environment Programme. Nairobi.

6.1.1 SOIL MOISTURE STORAGE AND MAIZE RESPONSE UNDER DIFFERENT SOIL AMENDMENTS WITHIN CONSERVATION TILLAGE SYSTEMS IN THE SEMI-DECIDUOUS FOREST ZONE OF GHANA

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Abstract
Soil moisture conservation is a major requisite for sustainable maize production under rainfed agriculture. The study assessed soil moisture storage and maize response to different soil amendments under two conservation tillage systems. The soil amendments consisted of control, NPK, poultry manure (PM), ½ NPK+½ PM and while tillage systems were no-till and plough-plant. A split plot experimental design with three replications was used. Soil moisture was monitored at three critical periods of moisture stress. Results show that soil moisture storage increased with depth at each dry spell under the two tillage systems. Plough-plant recorded greater moisture at 15 -30 cm depth than the no-till. Total soil moisture at the 30 cm depth ranged from 48.7 -76.6 mm, 48.2 – 84.3 mm, and 99.0 – 103.1 mm at the first, second and third period respectively. At each dry spell, plough-plant was superior in soil moisture storage. Plots with ½ NPK+½ PM out-yielded the other treatments in terms of plant height, stover yield and total biomass. Grain yield was significantly greater under PM and ½ NPK+½ PM than NPK. The tillage x amendment interactions significantly affected grain yield. The responses of grain yield to NPK, PM and ½ NPK+½ PM were 67.0%, 112.2% and 202.6% respectively over the control on the no-till. On the plough-plant, grain yield was 4.7%, 291.3% and 56.2% higher than control in the order of NPK, PM and ½ NPK+½ PM respectively. For increased maize yield on smallholder farms, farmers need to adopt integrated plant nutrition on conservation tillage systems.
Keywords: grain yield, in-situ soil moisture, integrated plant nutrition, soil amendments, tillage systems.

Introduction
Maize is the most important cereal crop and produced by 70 % of small holder farmers in Sub-Saharan Africa (FAO, 2008). It is the most widely consumed staple food in the region with increasing production since 1965 (Morris *et al*., 1999). In Ghana, though being a major food security crop, its production still lags behind annual consumption (MoFA, 2010; Wienco, 2011). It is produced predominantly by smallholder resource poor farmers under rainfed conditions (SARI, 1996). Low soil fertility and inadequate application of external inputs are the two major reasons that account for low productivity in maize (MoFA, 2010). The incidence of dry spells during critical growth stages further worsen the situation. Attempts to increase maize production on smallholder farms should therefore seek ways and means to improve soil fertility status through a combination of soil amendments coupled with practices that enhance in-situ moisture conservation under rainfed farming. This, however, has not received the needed research attention.
Water shortage in the root zone during critical crop development stages is a fundamental constraining factor to sustainable crop production (Slegers and Stroosnijder, 2008) especially under rainfed agriculture with no supplemental irrigation. Insufficient in-situ moisture conservation has been ascribed to a highly variable rainfall regime, leading to frequent dry-spells (Barron *et al*., 2003), coupled with large un-productive flows in the field water balance

(Rockström *et al*., 2004). The latter is dependent on the climatic factors, soil characteristics and land management practices. Among these factors, the focus is usually on land management practices because it could mitigate the adverse effect of climatic variables and improve soil characteristics when properly implemented.

Tillage and soil fertility amendments are of critical concerns in land and fertility management strategies for sustained increase in crop production (Negassal *et al*., 2007; Efthimiadou *et al*., 2010). The soil hydrological characteristics, soil structure and soil organic matter, seed germination, root development are affected by the choice of tillage. Consequently the latter is expected to influence crop yield but choosing the appropriate type of tillage is a major challenge and needs to be adequately investigated because the performance of a particular tillage system may differ in different agro-ecologies and on different soil types (FAO, 1993).

Conserving soil moisture through conservation tillage methods has been recommended as an adaptive measure to overcome the adverse effects of climate change on crop production (ACT, 2014). One of the major challenges in this proposition is that the relative effectiveness of these conservation tillage systems in different agro-ecologies and on different soil types was not clearly stated. Research has also shown that irrespective of the tillage practices, crop yield could be low without fertilizer and/ or manure applications particularly on poor soils (Negassal *et al*., 2007; Mesele, 2014). The comparative advantages of the conservation tillage systems in terms of the growth and yield of maize with and without soil amendments especially under integrated plant nutrition were yet to be widely investigated. It was in this context that the objective of the study was set to assess soil moisture storage and maize response to different soil amendments within two conservation tillage systems.

Materials and methods

Location: The study was conducted at the Agricultural Research Station, Anwomaso of the Faculty of Agriculture, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi located within the semi-deciduous forest zone of Ghana. Anwomaso lies between latitude 1° 31'W and longitude 6° 41'N. The soil is sandy loam in texture. It belongs to Asuansi series and classified as Ferric Acrisol (FAO-WRB, 2006).

Treatments and Experimental Design:
The treatments comprised two conservation tillage systems which are no-till and plough-plant and while the soil amendments included control, NPK, poultry manure (PM), ½ NPK + ½ PM. In the control plot no amendment was applied, the NPK plot contains 60- 60-60 kg N-P_2O_5-K_2O/ha + 30 kg N/ha (Urea), the poultry manure (PM) amended plot contains 3 t PM/ha while the ½ NPK + ½ PM plot contains 30- 30-30 kg N-P_2O_5-K_2O/ha + 15 kg N/ha (Urea) + 1.5 t PM/ha. Hundred percent surface-contact cover was maintained at the start of the experiment on the no-till plot with no soil disturbance. The plough-plant treatment was disc ploughed with two traffic passes to a depth of 20 cm after which planting was done manually. The amendments (poultry manure, poultry manure + NPK fertilizer and NPK fertilizer) were applied to their respective treatment plots two weeks after planting (WAP). At five WAP, plots amended with poultry manure + NPK fertilizer, and NPK fertilizers were top dressed with N in the form of urea. The experiment was a 2 x 4 factorial, split plot arranged in randomized complete block design (RCBD) with three replications. The main plot dimension was 12 m by 7.32 m and that of subplot was 12 m by 2.44 m.

Soil Moisture Storage Determination:
Bulk density was determined by the core method (Blake and Hartge, 1986). Soil moisture storage under the various tillage systems was assessed during critical dry spell periods that occurred in the 2013 minor cropping season. Volumetric water content was measured gravimetrically. Soil moisture storage was calculated as: $Sms = \theta v \; x \; soil \; depth \; (mm)$, where θv is volumetric soil water content.

Agronomic Practices, growth and yield assessment: Maize (variety Obatanpa) which is a 110 day variety with 95 % germination was planted in rows. Three seeds were sown per hole and firmed. The spacing was 80 cm x 40 cm. Planting was carried out the same day for all treatments. Thinning was done two weeks after emergence. Weeding was done when it became necessary using a hoe but for the no-till plots, the weeds were controlled using herbicide (Atrazine).

Plant height was taken starting from 4 weeks after planting till maturity, the dry matter yield (total biomass) was obtained by the following procedure: sampling of 6 tagged plants within the net plot (the middle rows of each treatment plot), cutting of the above ground part of the plant at harvest and the drying of plant material at 60^0C to constant weight and weighed in the laboratory. The grain weights (kg/ha) of the maize plant were also taken from net plots in each treatment.

Statistical analysis: The data were subjected to analysis of variance (ANOVA) using Genstat package Edition 9 and significant treatment means were compared using Least Significant Difference (LSD) method at 5% probability.

Results

Rainfall distribution during the experimental period
The observance of long dry spells during the experimental period led to the analysis of the rainfall records at the experimental site for weekly rainfall distribution. The results (Figure 1) showed that the incidence of dry spell during the period of the experiment (2013 minor wet season) started from the first week in November and lasted till the onset of the major dry season in December. The low seasonal rainfall of 292 mm and the prolonged dry spell adversely affected growth and yield of the maize crop.
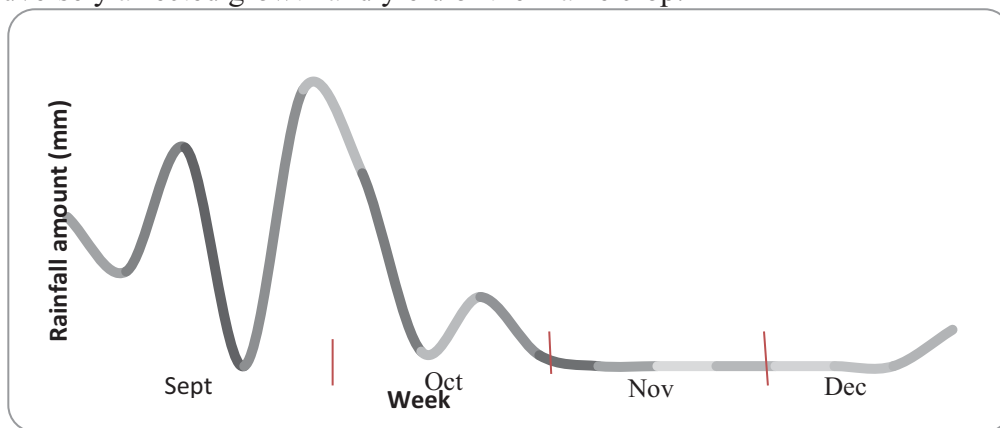
Figure 1: *Weekly distribution of rainfall amount at the experimental site*

The analysis of rainfall distribution pattern (Figure 1) showed the occurrence of dry spells during the experimental period. Consequently gravimetric soil moisture and bulk density

measurements were carried out with the view to assessing the relative moisture conserved (mm) under the tillage practices. The periods of sampling were 24th October, 7th November and 21st November, 2013 designated as sampling period 1, 2 and 3 respectively.

The means of soil water storage under the tillage practices are presented in Table 1. The results showed that there was no significant difference in the soil moisture storage under No-till and plough-plant tillage systems. Cumulative soil water storage at 30 cm depth was also not significant among tillage systems. Soil moisture storage increased with depth at each dry spell period under the various tillage treatments (Table 1). At the 1st and 2nd sampling period, water storage at the 0-15 cm depth was greater under plough-plant than the no-till. However, at the 3rd sampling period, the plough-plant tended to record greater soil moisture storage.

Total soil moisture at the 30 cm depth ranged from 48.7 -76.6 mm, 48.2 – 84.3 mm, and 55.4 – 103.1 mm at the first, second and third sampling period. At each sampling time, the plough-plant was superior in soil moisture storage.

Table 1: *Soil water storage at different depths during dry spells under different tillage practices*

	Soil water storage (mm)								
	1st Sampling			**2nd Sampling**			**3rd Sampling**		
Depth (cm)	**0-15**	**15-30**	**Total**	**0-15**	**15-30**	**Total**	**0-15**	**15-30**	**Total**
No-till	19.2	29.5	48.7	20.8	27.4	48.2	20.5	78.5	99.0
Plough-plant	25.3	51.3	76.6	27.4	56.9	84.3	10.9	92.2	103.1
Lsd (P<0.05)	12.3								
CV (%)	28.2								

1st sampling=24th October; 2nd sampling = 7th November and 3rd sampling = 21st November. All in 2013

The Impact of Soil Amendments on Grain, Stover and Total Biomass Yield
The mean growth and yield parameters under the various tillage practices are presented in Table 2. The results of the grain, stover and total biomass yields were significantly influenced by different soil amendments. Stover yield ranged from 5143 kg /ha in the control to 6667 kg/ha in the soils amended with ½ NPK + ½ PM. Total biomass ranged from 6424 kg/ha in poultry manure amended soils to 7765 kg/ha in soils amended with ½ NPK + ½ PM. In all, soils amended with poultry manure recorded the least stover and total biomass yield after the control but with greater grain yield.

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Table 2*: The means of maize grain, stover and total biomass yield under soil amendments applications*

Soil amendment	Plant height (cm)	Grain yield	Stover Yield (kg/ha)	Total Biomass
Control	139	585	5143	6586
½ PM+ ½ NPK	153	1049	6667	7765
NPK	152	741	6098	7155
PM	152	1143	5698	6424
Lsd (P<0.05)	13	529	709	718
CV (%)	9	9	13	12

The Impact of Tillage x Soil Amendments Interaction on Grain Yield

The mean grain weights under the tillage x soil amendments interactions (Fig. 3) showed increased grain yield relative to the control. Plough-plant amended with poultry manure gave the highest grain yield of 1984 kg/ha. The response of grain yield to different soil management practices was best with tillage x ½ NPK + ½ PM.

The Impact of Tillage x Soil Amendments Interaction on Stover Yield

The means of stover weights under the tillage x soil amendments interactions (Fig. 4) showed increased stover yield relative to the control where no amendment was applied. Stover yield was higher in all tillage x ½ NPK + ½ PM. These differences were not significant at $P < 0.05$.

The Impact of Tillage x Soil Amendments Interaction on Total Above-Ground Biomass Yield

The mean total biomass yield under tillage x soil amendment interactions (Fig. 5) were not significant at $P=0.05$. Total biomass yield was however higher in all tillage treatments amended with ½ rates of NPK+PM. Plough-plant with no amendment had the lowest biomass yield of 5427 kg/ha. No-till amended with ½ rates of NPK and ½ poultry manure gave the highest total biomass yield of 9147 kg/ha.

Table 3: *The means of stover weights under the tillage x soil amendments interactions*

Tillage system	½ NPK + ½PM	NPK	PM	Control
No-till	7684	5549	6464	5001
Plough-plant	5915	5854	4635	4940
Lsd (p=0.05)	1783			
CV (%)	10			

Table 4: *The means of total biomass yield under tillage x soil amendment interactions*

Tillage system	½ NPK + ½ PM	NPK	PM	Control
No-till (kg/ha)	9147	6952	7379	7196
Plough-plant (kg/ha)	7074	6708	5427	6159
Lsd (p=0.05)	1900			
CV (%)	10.4			

Table 5: *The means of grain weights under the tillage x soil amendments interactions*

Tillage system	Control	½ NPK + ½ PM	NPK	PM
No-till	378	1144	639	802
Plough-plant	507	792	531	1984
Lsd (p<0.05)	303			
CV (%)	9.2			

Discussion

Soil moisture storage

In-situ moisture conservation is pertinent to sustaining high crop growth and yield, particularly in rainfed agriculture. The results of the study demonstrates the relative effectiveness of tillage practices in conserving water, particularly during critical periods of dry spells in the growing seasons. The mean moisture storage determined during the incidence of dry spells in the cropping cycle showed plough-plant to store more moisture than the no-till treatment at both 0-15 cm and 15-30 cm depths. The higher clay content (result not presented) of the former treatments than the latter may account for the higher moisture storage.

In all cases moisture storage was greater in the 15-30 cm than the 0-15 cm depth. This has a positive effect on in-situ moisture conservation. During dry spells surface layers are subject more to the prevailing high temperatures resulting in higher rates of evaporation/evapotranspiration without a corresponding replenishment from deeper layers due to possible tillage-induced pore discontinuity (Ehlers *et al*., 1987; Dangolani and Narob, 2013). The latter effect is more pronounced on a plough-plant field which often results in a cloddier surface and discontinuous capillary pores. Thus, the plough-plant recorded greater moisture storage at the 15 -30 cm depth than the no-till. At periods of dry spells, tillage practices that store greater cumulative moisture, particularly at deeper depth, such as the plough-plant at the 15-30 cm depth are preferable, especially in rainfed agriculture. Such effect could be obtained on a no-till field with adequate cover.

Monitoring the temporal variations of cumulative moisture storage at the 0-30 cm depth during the dry spells; reveal a 4-week moisture deficit and inadequate moisture storage under all the tillage treatments for maize growth. This affected the yield of the maize crop, overshadowed the impact of the soil amendments and consequently led to low grain yield. Similar observations were reported by Munodawafa (2012). It appears, in the face of current climate variability, supplemental irrigation in rainfed agriculture is becoming a necessity for sustainable high crop yields.

The Impact of Tillage and Soil Amendment on growth and yield of Maize

Maize accounts for about 56 % of cultivated land while about 98 per cent of the 3.5 million small-scale farmers in Ghana are engaged in crop production; yet the production level is far below the annual consumption rates (MoFA, 2010; Wienco, 2011). Soil management practices that increase and sustain crop yield are therefore preferable in reducing food insecurity, poverty and hunger. The impact of tillage and soil amendments on growth parameters such as plant height and yield parameters such as grain, stover and total biomass yield of maize were assessed.

The product of the genetic make-up of a crop and its environment determine, to a large extent, the magnitude of growth and yield. For a given variety of maize in a season, the major influencing factor is the edaphic environment as impacted upon by tillage practices. A major objective of tillage is the creation of favourable soil conditions for plant growth, biomass production and grain yield (FAO, 1993). Such conditions include soil infiltrability, in-situ moisture storage and availability of moisture, reduced loss of soil and nutrients.

The relative merits of different tillage practices in attaining the above conditions inform the choice of the practice that sustains crop productivity. The tillage x soil amendments interactions significantly affected grain yield, stover and total biomass production. The responses of grain yield under no-till to NPK, PM and ½ NPK+½ PM were 67.0%, 112.2% and 202.6% respectively over the control whereas it were 4.7%, 291.3% and 56.2% in the order of NPK, PM and ½ NPK+½ PM respectively on the plough-plant. Maize grain yield was more responsive to ½ NPK+½ PM on the no-till and PM on the plough-plant compared to the other treatments. Cumulatively, maize yield was more responsive to integrated plant nutrition on the no-till than the plough-plant. This observation could be accounted for by the implicitly higher fertility erosion rate on the plough-plant than the no-till which might have resulted in greater loss of the highly soluble NPK than the poultry manure.

It has been shown generally that different soil amendments improve plant growth and yield relative to the control - where no amendment was applied but the magnitude of the increase is usually dependent on the type of soil amendments as evidenced in this study. Poultry manure and its combination with mineral fertilizers gave significantly greater grain yield and taller plants than the control and the sole application of mineral fertilizers. Stover yield and total biomass production was however higher under the latter than the sole application of poultry manure, but their interactions with tillage were not significant at $p < 0.05$. Similar observations were reported by Ezeaku *et al.* (2013). In all cases, the combination of poultry manure with mineral fertilizers was a better option in terms of grain yield, stover yield and total biomass production. This however confirms the benefits of integrated plant nutrition as the best choice in the selection of soil amendments for the purpose of increased and sustained food crop production.

Conclusion

The study demonstrated that soils amended with ½ NPK+½ PM out-yielded the other treatments in terms of plant height, stover yield and total biomass. Grain yield was significantly greater under poultry manure and its combination with mineral fertilizer than the control and the sole application of mineral fertilizers. The response of grain yield to different soil amendments was greater with ½ NPK + ½ PM and PM on the plough-plant and no-till respectively. Smallholder farmers can therefore increase their maize production through the adoption and integral use of conservation tillage systems with integrated soil fertility management options. However, due to the low in-situ moisture storage under the different tillage systems relative to the evapotranspiration demands, most importantly, in the face of current climate variability/change, supplemental irrigation in rainfed agriculture is recommended for sustainable high crop yields in the long-term. In the short-term, the focus should be on improving in-situ moisture conservation through conservation tillage and reducing the non-productive loss of water through weed control and improved cover and residue management.

References

African Conservation Tillage Network (ACT). (2014). Building entrepreneurship and griculture. Lusaka, Zambia, from 18th to 21st March 2014.

Barron, J., Rockström, J., Gichuki, F., Hatibu, N. (2003). Dry-spell analysis and maize yields for two semi-arid locations in east Africa. Agric. Forest Meteorol., Volume: 117 pp: 23– 37.

Blake, G. R. and Hartge, K. H. (1986). Bulk density. In: A. Klute (Editor), Methods of Agronomic Moisture Constants and Soil Physical Properties. Samsun 55139.

Dangolani, S.K. and Narob, M.C. (2013). The effect of four types of tillage operations on soil moisture and morphology and performance of three varieties of cotton. Pelagia Research Library. European Journal of Experimental Biology, 2013, Vol. 3 No: 1 pp: 694-698

Efthimiadou, A; Bilalis, D., Karkanis, A. and Froud-Williams, B. (2010) Combined organic/inorganic fertilization enhance soil quality and increased yield, photosynthesis and sustainability of sweet maize crop. Australian Journal of Crop Science. AJCS Vol. 4 No: 9 pp: 722-729

Ehlers, W., Goss, M.J. and Boone, F.R.C. (1987). Tillage Effects on Soil Moisture, Root Development and Crop Water extraction. Plant Research and Development. Institute for Scientific Co-operation, Tubingen, Vol. 25 pp: 92-110.

Ezeaku, C.A, Adamu S. and Onwualu, A.P. (2013). Maize Response to Tillage and Organic Manure in a Sandy Loam Soil in North East Nigeria. Online article.

FAOSTAT (2008). FAO Statistical Databases. 2008. FAOSTAT: Agriculture Data. Available online: http://faostat.fao.org.

FAO (1993). Soil tillage in Africa: needs and challenges. FAO soils bulletin 69.

Mesele, S.A. (2014). Quantifying maize yield and soil erosion influencing factors for soil loss prediction under different tillage and soil amendments. An MSc Thesis submitted to the Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

MoFA (2010). Agriculture in Ghana. Facts and Figures. Ministry of Food and Agriculture. Statistics, Research and Information Directorate (SRID) *MAY, 2011*

Morris, M.L., Tripp, R. and Dankyi, A.A. (1999). Adoption and Impacts of Improved Maize Production Technology. A Case Study of the Ghana Grains Development Project, Economics Program Paper 99-01. Mexico, D.F., CIMMYT. Available online

http://www.cimmyt.org/Research/economics/map/research_results/program_papers/pdf/EPP%2099_01.pdf.

Munodawafa, A. (2012) The Effect of Rainfall Characteristics and Tillage on Sheet Erosion and Maize Grain Yield in Semiarid Conditions and Granitic Sandy Soils of Zimbabwe Applied and Environmental Soil Science Volume 2012 , Article ID 243815, http://dx.doi.org/10.1155/2012/243815.

Negassal,W; Getaneh, F; Deressa, A. and Dinsa, B. (2007) Integrated Use of Organic and Inorganic Fertilizers for Maize Production. Utilization of diversity in land use systems: Sustainable and organic approaches to meet human needs. Tropentag 2007, October 9 - 11, 2007 Witzenhausen

Rockstrom, J., Folke, C., Gordon, L., Hatibu, N., Jewitt, G., de Vries, P.F., Rwehumbisa, F., Sally, H., Savenije, H., Schulze, R. (2004). A watershed approach to upgrade rainfed agriculture in water scarce regions through Water System Innovations: an integrated research initiative on water for food and rural livelihoods in balance with ecosystem functions. Phys. Chem. Earth 29, 1109–1118.

SARI (1996). Savanna Agricultural Research Institute. Annual Report. *1996.*

Slegers, M.F.W., Stroosnijder, L., (2008). Beyond the desertification narrative: a framework for agricultural drought in semi-arid East Africa. Ambio., Vol: 37 pp: 372–380.

Wienco (2011) Ghana consumes 40 million bags of maize annually. The launch of Masara N'Arziki Farmers Association (MAFA), Ghana. Available online.

6.1.2 NITROGEN MOVEMENT IN COARSE-TEXTURED SOILS AND ITS AVAILABILITY TO MAIZE (*ZEA MAYS L.*) PLANT

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Abstract

Nitrogen (N) is the most important determinant nutrient for plant growth and crop yield. Plants lacking N show stunted growth and yellowish leaves. Plant growth and crop yield usually increase when N is added. However, too much N leads to weak stems in grain crops (lodging) which result into low yield. The aim of the study was to delineate changes of N concentration, its direction of movement and its pattern of disposition in the soil as influenced by amount of applied water and nitrogen so as to reduce N losses and maximise its absorption by maize roots.The study was conducted during irrigatation seasons of 2011 and 2012 at Nkango Irrigation Scheme, Malawi. The trials consisted of factorial arrangement in a Randomised Complete Block Design (RCBD). The factors were water and N and both were at four levels. The Triscan Sensor was used to measure total N concentration at difference vertical and lateral points. The study inferred that changes of N concentration, its direction of movement and its pattern of disposition in the soil are influenced by water flux and absorption rate of plants roots due to gradient created by absorption. The study noted that when N is in low supply, its movement towards maize roots is greatly influenced by diffusion. The study concluded that to maximise N absorption by maize roots, the point of N

application should be at 5 cm away from the planting station to minimise N losses through drifting away from the maize rooting zone.

Key Words: N Concentration, Water flux, Absorption rate, Diffusion

Introduction

General

Nitrogen (N) is the most important determinant nutrient for plant growth and crop yield. [1] reported that N is the most limiting nutrient to crop production in most cases. Plants lacking N show stunted growth and yellowish leaves. Plant growth and crop yield usually increase when N is added. However, too much N leads to weak stems in grain crops (lodging), reduce quality in fruit such as peaches and apples, lower sugar content in sugar beets, and lead to an accumulation of nitrate in edible foliage of plants. [2,3] reported that excessive N supply in the soil stimulated excess pepper vegetative growth, which was detrimental to reproductive growth and resulted in a decrease in fruit yield. Identifying the most economic rate of N fertilizer is very important in high N demanding crops such as maize, to maximize profitability and reduce N losses to the environment [4]. However, determining how much N fertilizer is required by a maize crop is an imperfect science at its best [5]. This is because as reported by [6] economic N fertilizer rate is variable and depends on many factors such as climatic conditions and crop management. The behaviour of N in the soil system is complex, yet an understanding of the basic N processes is essential for a more efficient N management program [7]. Major N processes in the soil are: mineralization, immobilization, denitrification and nitrification, and leaching. The most efficient way is to understand processes that contribute to N losses in soil and how can mineralization and nitrification be harnessed to improve N content in the soil.

In coarse-textured soil, leaching is a dominant process that results in N losses. Nitrate-nitrogen (NO_3-N) is soluble and moves readily with soil water becoming a potential source of ground water pollution [8]. Ammonium Nitrogen is less subjected to leaching from the soil compared to nitrate because of its adsorption in the Cation Exchange Capacity. However, losses of ammonium nitrogen through leaching occur in coarse-textured soil with a low Exchange Capacity [9]. Leaching is major N loss mechanism in coarse textured soil. Therefore, proper understanding of N movement in coarse-textured soils can reduce N losses through leaching in the soil. This study aimed at delineating vertical movement and disposition pattern of nitrogen in the soil as influenced by amount of applied water and nitrogen. This understanding will ensure that applied water is maximising the disposition of nitrogen within the rooting zone of the plants to facilitate its uptake and reduce losses. This study is further necessitated with the knowledge that 75% of cereals' roots are concentrated in the upper soil layers of within 20 -35 cm [10].

Materials and Methods

Site description

The research study was done at Nkango Irrigation Scheme in Kasungu district. Data were taken in three irrigation growing seasons of 26th September to 18th December, 2011; 1st June to 8th September, 2012; and 10st September to 5th December, 2012. Nkango Irrigation Scheme is an informal scheme which is owned and managed by the local communities and is situated at Latitude $12^035'$ South and Longitudes $33^031'$ East and is at 1186 m above sea level. The study area has a unimodal type of rainfall with rains between December and April. The mean

annual rainfall is about 800 mm. The site lies within maize production zone of Malawi and has dominant soil type of coarse sandy loam. Smallholder farmers in the area practise irrigation and are conversant with water application regimes.

The soil of the plots is sandy loam with a low soil organic matter and nutrient concentration as described in (Table 1). The Cation Exchange Capacity is low (50.00 - 80.00 µeq g^{-1}), and the pH decreased from acidic (5.2) to strongly acidic (4.7). The salinity of the soil was very low (1.7 mmhos/cm).

**Table 1:** Characteristics of soil at the research site

Soil properties	Values
Clay (%)	13
Silt (%)	17
Sand (%)	70
Carbon (%)	0.599
C/N ratio	13.011
OM (%)	1.0773
Total nitrogen (%)	0.046
Total phosphorus (ppm)	33.206
Total potassium (µeq K g-1)	1.2153
Exchangeable calcium (µeq Ca g-1)	19.254
Exchangeable magnesium (µeq Mg g-1)	28.964
Moisture Content (%)	4.163
Field Capacity (%)	20
Wilting Capacity (%)	10
Bulk Density (g/cm3)	1.59
pH	5.2

Experiemental design

The plot size was 5 m by 5 m and ridges were spaced at 75 cm. The plots were separated from one another by a 2-metre boundary to avoid 'sharing' of responses, water and nitrogen (edge effects). Three maize seeds of hybrid maize (SC 407) were planted per hole at spacing of 25 cm. They were later on thinned to one seed per station 7 days after germination.

The trials consisted of factorial arrangement in a Randomised Complete Block Design (RCBD). The factors were water and nitrogen and both were at four levels. Water had four application regimes and these were as follows: farmers' practice regime; full (100%) water requirement regime (FWRR) of maize plant; 60% of FWRR; and 40% of FWRR. A full maize water requirement was determined by using the procudure described in FAO Paper 56 [11]. Nitrogen had four application regimes and these were as follows: The Typical Nitrogen Application Rate in the area (TNPRA) of 92 kg N/ha was used as a basis to determine other dosage levels in the study [25]. The nitrogen dosage levels were as follows: TNPRA, 92 kg N/ha; 125% of TNPRA, 115 kg N/ha; 75% of TNPRA, 69 kg N/ha; and 50% of TNPRA, 46 kg N/ha.
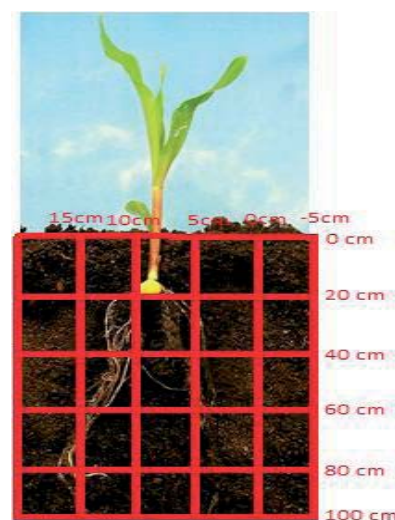
Figure 1: Showing measurement points

The fertlizer was applied two times, basal and top dressings, 21 and 51 days after planting respectively. At each application time, the following methods were used to achieve the nitrogen dosage levels [12]:

1. To acheive 50% of TNPRA, 46 kg N/ha, 2.8g fertilizer scooped using one coke bottle top with inside lining was applied per station.
2. To achieve 75% of TNPRA, 69 kg N/ha, 4.2g fertilizer scooped using one coke bottle top without inside lining was applied on each station.
3. To achieve TNPRA, 92 kg N/ha: apply 5.6g fertilizer that is 2 coke bottle tops per station without inside lining.
4. To achieve125% of TNPRA, 115 kg N/ha: apply 8.4g fertilizer using 3 coke bottle tops without inside lining.

Data collection

The Triscan Sensor (EnviroScan, Sentek Pty Ltd, Stepney, Australia), which has ability to monitor the direction and movement of nitrogen in the soil at the instant time of inserting the monitoring probe in the soil, was used to measure total nitrogen concentration at lateral distances. The measurement of the sensor is in Volumetric Ion Concentration (VIC), but using standazation equation the concentration of total nitrogen on each point was known. The lateral distances at which measurements were taken were as follows: at point of application (represented by 0cm), at 5 cm away from the plant (represented by -5 cm), at 5 cm towards the plant, 10 cm towards the plant (this point was maize planting station), and 15 cm (this point was 5 cm after planting station in the direction opposite from where N was applied) as shown in Figure 1. The lateral distances were taken based on spreading and elongation pattern of lateral roots of maize plants. The lateral reading of nitrogen were respecively taken at five soil depths of 20, 40, 60, 80, and 100 cm. The soil depths were selected based on maize roots growth habits which extend down to 100 cm [13] Confirmation of data was done through analyising soil samples collected from the respective points. The soil profile was dug to a depth of 120 cm and horizontally using soil auger, soil samples were collected from the lateral points for laborotary analysis.

Data analysis

The data presented in this paper were from treatments combination 60% of FWRR and 92 N Kg/Ha because statistically the plots gave optimum yields compared to other plots. The GENSTAT software (VSNi, Hemel Hempstead, UK) was used for statistical analysis. The data are presented in graphical form to indicate comparative change of N concentration and direction of flow which was the main purpose of this study.
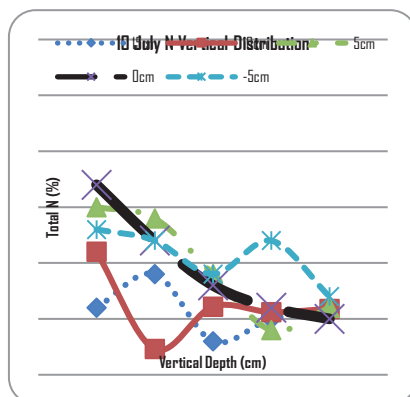
Results and Discussion

Figure 2: N distribution on 10th July, 2012

Figure 2 represents the distribution of N concentration for different lateral distances of measurements. At 20 cm deep, the N concentration is highest at the point of N application (0 cm) followed by concentration at lateral distance of 5 cm towards the maize roots. It was observed that despite having the same lateral distance of 5 cm from the point of N application, N concentration was higher towards the maize roots than away from the maize roots. The N concentration at lateral distance of 10 cm from point of N application was lower than the proceeding distances of 5 cm, 0 cm and -5 cm. The N concentration was the lowest at 15 cm. The behaviour of N at 20cm deep suggests that the pulling effect by maize roots was influencing movement direction of nitrogen. At lateral distance of 10 cm, this is where maize seeds were planted and low N concentration suggests that at this point N was absorbed by the maize roots as maize roots will absorb nitrogen next to it. On 10th July, maize plants were 6 weeks old and during this period maize root system develop very rapidly and absorption of nitrogen is thus increased.

The N concentration decreased with depth i.e. concentrations were high at 20 cm deep expect at lateral distance of 15 cm and gradually decreased down to 100 cm. Considering lateral redistribution at particular depths, the N concentration suddenly decreased from 20 cm to 40 cm for the 10 cm line. This can be due to differences in soil porosity of the layer above 40 cm and below. The soils on planting stations were prepared to ensure that plant seed germination is not restricted but this preparation increased soil pores such that movement of water and air was increased. However, beneath this 'disturbed' layer, soil pores were small and as reported by [14] small pores in compacted soil layer may slow water percolation so that the overlying soil becomes waterlogged and poorly aerated which may facilitate rapid N loss through denitrification. The rapid decrease of total nitrogen concentration on all measured points from the depth of 40 cm to 60 cm may be due to denitrification of nitrogen to gas. Excessive irrigation promotes nitrogen loss not only by promoting nitrate leaching from the plant root zone, but also by creating wet soil conditions that favour denitrification.
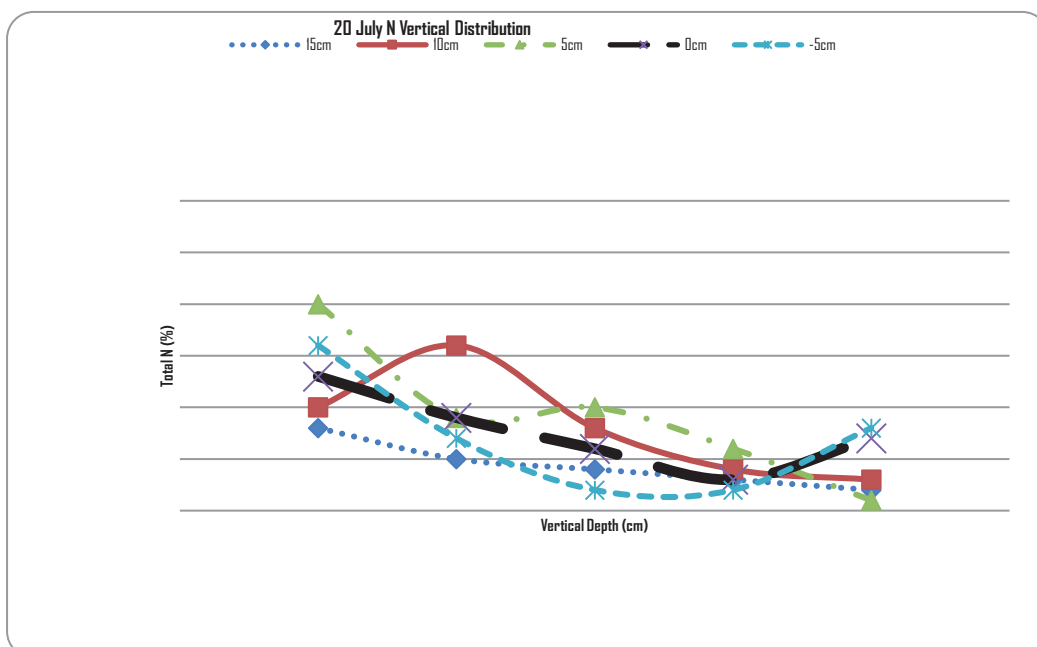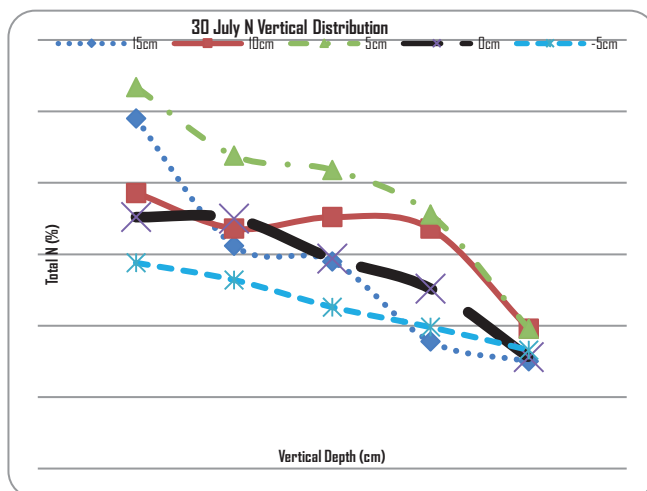

Figure 3: N distribution on 20th July, 2012

Figure 3 shows that at 20 cm deep the N concentration was highest at lateral distance of 5 cm (toward the maize roots), followed by concentration at 5 cm (away from the roots). The N

concentration at the point of N application is lower than the two neighbouring measure points of 5 cm. The N concentration at lateral distance of 10 cm is again lower than the three proceeding points while at 15 cm the concentration is the lowest. The trend of N movement direction indicates that N is moving towards the maize roots and at 10 cm, the maize roots is absorbing N hence low concentration.

 The behaviour of N at the depth of 40 cm shows that N concentration is highest at 10 cm, while N concentrations at other measured points have rapidly decreased for example at 5 cm towards the plant roots, the concentration changed from 0.2 at 20 cm deep to 0.09 at 40 cm deep. The trend of N decline suggests that plant uptake during this period was very high. The date of measurement of 20th July was Maize's 50's day after planting and [5] reported that maize enters in its rapid nutrient accumulation phase four to eight weeks. When N demand is high, the plant creates a negative gradient and nitrogen is attracted from the neighbouring areas to regions next to maize roots through diffusion process. [15] reported that if N concentration at the root surface is different from that in the bulk soil solution, nitrogen will move by diffusion from the zone of higher to lower concentration. As soil water content decreases, not only does the energy status of water change, but also hydraulic conductivity decreases logarithmically, restricting soil water flow to the root. The quantity of nutrient flowing with the water will also decline. However, when mass flow does not meet the plant's nutrient demand, i.e., the amount arriving at the root system is less than that required by the plant, the nutrient concentration in the rhizosphere is reduced relative to the soil solution outside the rhizosphere – a nutrient gradient develops. A plant experiencing a nutrient deficiency must have diffusive flow supplying a portion of that nutrient [16].

Figure 4: N distribution on 30th July, 2012

On 30 July, about 60 days after planting maize, the figure 3 shows that at 20 cm deep the N concentration was highest at 5 cm (towards the maize roots) followed by concentration at 15 cm and then followed by concentration at 10 cm but on all five points the figures shows that N concentrations were generally higher than those measured on 20th July. The top dressing of Urea was done on 21st July which increased N concentrations. The N concentration at 15 cm appears to be increasing and this might be due to native nitrogen and applied mineral nitrogen that might have moved to this point due to water flux.

The N concentrations declined at 40 cm suggesting that absorption of nitrogen is very active. The transpiration of maize plant during this period (two months after planting) was very high

because this period leaf surface area has increased and the roots have fully developed thereby increasing absorption of nitrogen. However, during the same period as indicated by figure 5, the need of nitrogen by maize plants has also increased. Nitrogen supplied by water flux alone is not meeting demand of maize plant hence diffusion movement has come in to meet the demand. [17] Reported that roots normally maintain a capability to acquire N at a faster rate than can be supplied by the physical transport delivery, through maintaining low internal concentrations and active ion pumps.
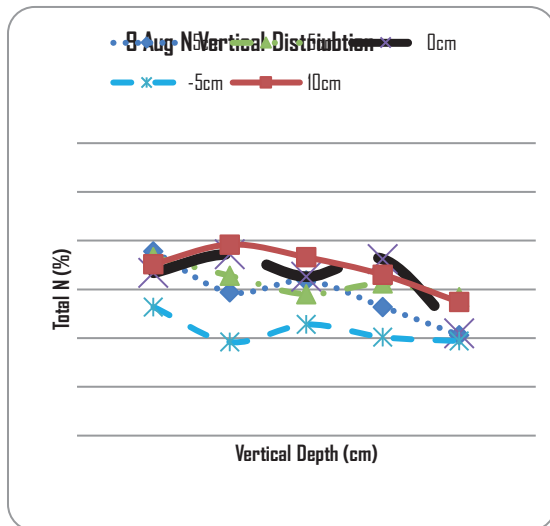
Figure 5: N distribution on 9th August, 2012

The effect of diffusion has increased nitrogen concentration at lateral distance of 10 cm at 40 cm and 60 cm deep. The N concentrations on other points are lower than at 10 cm because nitrogen has been mobilised from these regions. The general trend of N concentrations appears to be increasing downwards points suggesting that down movement of water due to gravitational force is influencing down movement of N concentrations from 20 cm deep to 40 cm, 60 cm and 80 cm deep.
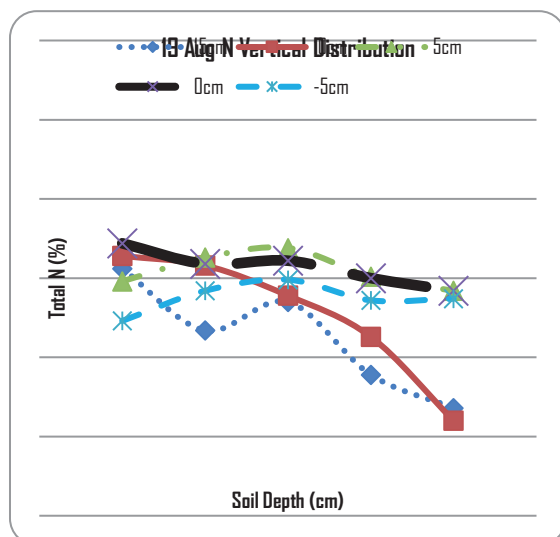
Figure 6: N distribution on 19th August, 2012

On 19th August, the Figure 6 shows that N concentration on all points appears are more less the same, for example the line at 0 cm, 5 cm and -5 cm appears to be relatively flat. However, if compared with N concentrations measured on 9th August, it shows that at 40 cm deep the N concentration at 0 cm has decreased from 0.19 to 0.16, at 60 cm deep the N concentration at 0 cm has decreased from o.16 to 0.15, at 80 cm deep the N concentration at 0 cm has decreased from 0.18 to 0.14, while at 100 cm deep the N concentration at 0 cm has increased from 0.10 to 0.14. The trend suggests that there has been leaching where nitrogen has moved from top layers to underlying layers and beyond.
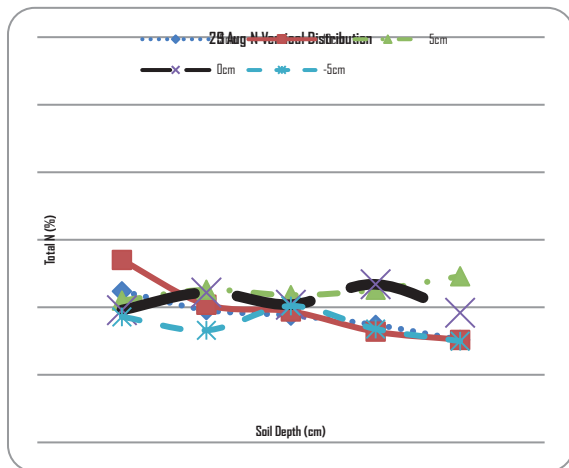
Figure 7: N distribution on 29th August, 2012
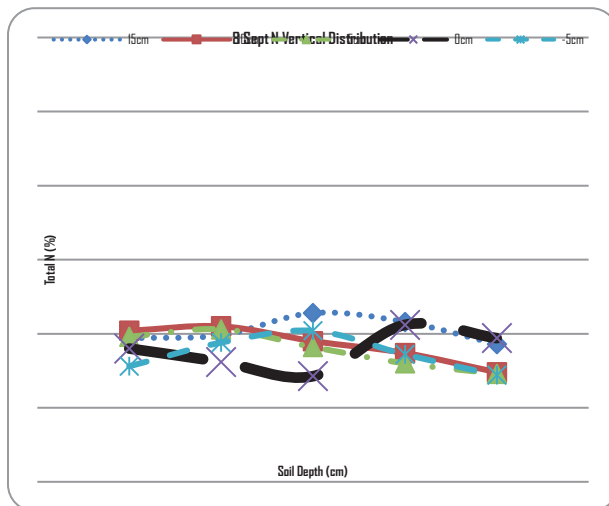
Figure 8: N distribution on 8th September, 2012

Figure 7 and Figure 8 show that N concentrations at all points are almost uniform there are minimum differences of concentration at all points. However, the N concentrations from top layers of 20 cm, 40 cm and 60 cm have further declined while at lower layers of 80 cm and 100 cm. while this may be attributed to be mining of nitrogen by maize plants in the top layers, the increase of N concentrations at lower layers may be due leaching that have moved nitrogen from top to down layers.

Conclusion

In this study, we infer that vertical movement of nitrogen is influenced by water flux and direction of flow is greatly influenced by absorption rate of plants roots due to gradient created by absorption. When supply of nitrogen is low due to high absorption of plants roots especially during the period when plants require large quantities of nitrogen, the lateral movement of nitrogen towards plant roots is greatly influenced by diffusion.

To maximise N absorption N should be applied at 5 cm away from the planting station. This will ensure that more n moves towards the maize roots due to hydraulic gradient created by the roots. But even if the N moves away from the plants roots, at 5 cm the n will still be within maize roots active zone so the chances of it being used by maize roots are very high.

Acknowledgements

References

Zhang, Q.T., Liu, K., Tan, S. C., Hong, P. J. and Warner, J. (2010) Evaluation of Agronomic and Economic Effects of Nitrogen and Phosphorus Additions to Green Pepper with Drip Fertigation. Published in Agronomy Journal 102: 1434 – 1440(2010)

Aliyu, L. (2000) Effects of organic and mineral fertilizers on growth, yield and composition of Pepper (*capsicum annuum*). Biol. Agric. Hortic. 18: 29 -36

Qawasmi, W., Mohammed, J. M., Najim, H. and Qubursi, R. (1999) Response to bell pepper grown inside plastic houses to nitrogen fertigation. Commum. Soil. Sci. Plant Anal. 30: 2499 – 2509

Nyiraneza, J., N'Dayegamiye, A., Gasser, O.M., Giroux, M., Grenier, M., Landry, C., and Guertin, S. (2010) Soil and Crop Parameters related to corn nitrogen response in Eastern Canada. Published in Agronomy Journal 102: 1478 -1490 (2010)

Holland, H. K. and Schepers, S. J. (2010) Derivation of a Variable Rate Nitrogen Application Model for In-Season Fertilization of Corn. Published in Agronomy Journal. 102: 1415 -1427 (2010)

Al-Kaisi, M., Kwaw-Mensah, D., 2007. Effect of tillage and nitrogen rate on corn yield and nitrogen and phosphorus uptake in a corn-soybean rotation. Agron. J. 99, 1548-1558.

O'Leary, M., Rehm, G. and Schmitt, M. (2002) Understanding Nitrogen in Soils. http://www.extension.umn.edu/distribution/cropsystems/dc3770.html

Iqbal, M.T. (2011) Nitrogen Leaching from Paddy Field under Different Fertilization Rates

Schepers, J. S., Moravek, M.G. and Bishop, R. (1991) Impact of nitrogen and water management on ground water quality. P. 641 – 647. In. W.F Ritter (ed) Irrigation and Drainage. Am. Soc. Civil Eng., New York

FOASTAT (2000) Maize. http://www.fao.org/nr/water/cropinfo_maize.html

Allen, G. R., Pereira, S. L., Raes, D. and Smith, M. (1998) FAO Irrigation and Drainage Paper No. 56. Crop Evapotranspiration (guidelines for computing crop water requirements). FAO - Food and Agriculture Organization of the United Nations, Rome, M-56 ISBN 92-5-104219-5

Ministry of Agriculture and Food Security. (2011). Annual reports and notes. Lilongwe, Malawi.

Gardenas, A., Hopmans, J.W., Hanson, B.R. and Simunek, J. 2005. Two-dimensional modeling of nitrate leaching for various fertigation scenarios under micro-irrigation. Agric. Water Manage. 74:219–242.

Brady, C. N. and Weil, R. R. (2008) The Nature and Properties of SOILS. Pearson Education, Inc., Upper Saddle River, New Jersey 07458. 14th ed.

Comerford, B. N. (2005) Soil Factors Affecting Nutrient Bioavailability. Ecological Studies,Vol. 181. H.BassiriRad (Ed.) Nutrient Acquisition by Plants. An Ecological Perspective. © Springer-Verlag Berlin Heidelberg 2005

Ourry, A., Gordon, A. J. and Macduff, J. H. (1997) Nitrogen uptake and assimilation in roots and root modules. A Molecular Approach to Primary Metabolism in Higher Plants, C. H. Foyer and W. P. Quick, Eds., Taylor and Francis, 237–254.

Dickinson, E. R., Berry A. J., Bonan, G. B., Collatz, G, J., Field, B. C., Fung, I. Y., Goulden, M., Hoffmann, A.W., Jackson, B. R., Myneni, R., Sellers, J. and P., Shaikh, M. (2002) Nitrogen Controls on Climate Model Evapotranspiration. American Meteorological Society (2002). Journal of Climate Volume 15

Perfect, E., Sukop, M. C. and Haszler, G. R. (2002). Prediction of dispersivity for undisturbed soil columns from water retention parameters. Soil Sci. Soc. Am. J., 66: 696-701

Simunek, J., Sejna, M. and van Genuchten, M.Th. 1999. The HYDRUS-2D software package for simulating two-dimensional movement of water, heat, and multiple solutes in variably saturated media. Version 2.0, IGWMC - TPS - 53, International Ground Water Modeling Center, Colorado School of Mines, Golden, Colorado, 251pp.

6.1.3 EFFECTS OF STREAM CHANNEL INCISION ON SOIL WATER LEVELS, AND SOIL MORPHOLOGY OF A WETLAND IN THE HOGSBACK AREA, EASTERN CAPE, SOUTH AFRICA

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Abstract
Wetland degradation in the form of channel incisioning can significantly alter the hydrological functioning of a wetland. In this study in a small headwater wetland in the Hogsback area, Eastern Cape Province, the impact of channel incisioning on soil water levels

and soil morphology was examined. A good correlation ($R^2 = 0.89$) exist between the depth of channel incisioning and average water table depths in most of the 21 installed piezometers. In localised cases the upslope supply of water was in equilibrium with drainage from the piezometers. Although all the studied soils show hydromorphic characteristics, those continuously saturated close to the surface exhibit redox accumulations in oxygen supplying macropores, whereas gleyic colour patterns occur deeper in soils where the water table has been lowered by channel incision. The nature and occurrence of different hydromorphic soil indicators observed confirm the contribution of soil morphology as valuable indicator of long-term averaged soil water conditions.

Keywords: Hydromorphic properties; water regime; wetland hydrology

Introduction

Wetlands are defined as *"… land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water… under normal circumstances"*, where the 'normal circumstances' refer to environmental conditions without anthropogenic interference (National Water Act, 1998). Although hydrology is normally seen as the force behind the creation and maintenance of wetlands, it is considered the least useful delineator in wetland characterisation due to its dynamic nature that varies daily, seasonally and yearly (Ingram, 1983). Long term hydrometrical measurements of water levels are absent for most wetlands, and indirect indicators, such as soil morphology and vegetation, are normally used to identify wetlands (Grundling, 1999).

The process of soil formation is relatively long (10^2 to 10^4 years) and properties related to soil morphology are unlikely to change over decades, even with anthropogenic modifications such as artificial drainage (MacEwan, 1997). As opposed to vegetation, soil morphology can therefore be used to delineate and identify wetlands whose hydrology has been altered by anthropogenic impacts (Mausbach and Richardson, 1994). Hydromorphic soil properties relevant to wetland classification include the following: organic carbon (OC) accumulation (>10% OC); peat layers; gray matrix colours (chroma<2); high chroma mottles in gray matrix; low chroma mottles (>10%) in high chroma matrix; and oxidized root channels (Mitsch and Gosselink, 1993; Vepraskas *et al*., 1994; Verpraskas and Faulkner, 2001; Vepraskas and Lindbo, 2012). These morphological properties should occur within 500 mm from the surface in order for the soils to classify as wetland soils.

Hydromorhic soil properties related to wetlands are formed under anaerobic conditions. Anaerobic occurs when 1) there is organic matter present, 2) microorganisms are actively oxidising organic material, 3) the soil is saturated and 4) dissolved oxygen is removed from the pores (Verpraskas et al., 2012). When one of these four conditions is not present, hydromorphic properties in soils will not form. Alhtough hydromorphic properties indicate that anaerobic conditions existed, they do not indicate the duration of saturation and reduction (Verpraskas et al., 2012). Comparision in terms of the relative duration of saturation can however be conducted in terms of the prominence of various hydromorphic properties in a given area (Lindbo et al., 2010). The distribution of hydromorphic properties depends on the distribution of oxygen in the soil and it is controlled by the depth and duration of the water table and aeration of the soil through interpedal and biopores (Veneman, Vepraskas & Bouma, 1976 and Vepraskas & Blouma, 1976).

The rapid and continuous loss and degradation of wetlands threaten human well-being through the loss of goods and services provided by these ecosystems (Millennium Ecosystem Assessment, 2005). These services include lodging of a large and diverse number of animal and plant species (Gislason and Russell, 1997), water purification by trapping sediments and

excessive nutrients and heavy metals (Mitsch and Gosselink, 1993), water storage; thereby enhancing groundwater recharge and prolonging baseflow as well as reducing peak flows (Kotze et al., 2005) and carbon sequestration (Badiou et al, 2010).

Channel incision is one of the major causes of wetland and river ecosystem degradation (Naiman et al., 2005; Steiger et al., 2005; Loheide and Booth, 2011). With the lowering and widening of the streambed, wetlands are often dewatered as groundwater will flow towards incised streams as opposed to parallel to unincised streams (Shields et al., 2009; Shields et al., 2010). Water flow through incised wetlands is concentrated to the stream channel and high turbidity flow; with high erosive energy are often recorded (Shields et al., 2009). Increased sediment loss and reduced base flows results in increase in pollution levels, degradation of the physical habitat and consequently a reduction in biodiversity (Shields et al., 2010). Channel incision can be caused by direct channelization and straightening of stream networks or by land use change that result in an enhanced peak discharge (overland flow) or reduced sediment in discharging the water (Shields et al., 2010).

In this study the influence of channel incision on water levels and soil morphology are studied on a stream with varying degrees of channel incision. This research will address two important questions 1) how do the degree of channel incision influence water levels, 2) are changes in the water regime evident in the soil morphology.

Study area and methodology

The study area is a wetland of approximately 5 ha the foot of Gaika's head (1963 m.a.m.s.l) in the Hogsback region (Figure 1). The site is the property of Amathole Forest Company (AFC). Hogsback has a cool climate with mean annual temperatures of approximately 14 °C. Cold winters with mean minimum temperatures of 1 °C and frequent snowfall are characteristic of this region. Rainfall is high with a mean annual of approximately 1 200 mm, the bulk of which falls during summer. The geology of the area is sedimentary rocks of the Balfour formation, part of the Beaufort Group (Coleman, 1999). The wetland is densely vegetated with grass and some shrubs with some of the dominant species being *Restio* spp. and sedges, *Carex* and *Pycreus*, with ground orchids commonly occurring (Coleman, 1999). A 1st order tributary to the Klipplaats River (which is a tributary to the Swart Kei River), with various degrees of incision, drains the wetland in a south-eastern direction over a rehabiltation weir where streamflow was recorded (Figure 1c and Figure 2).

Figure 1: The location of the study area (a & b) and instrumental layout in the study area (c).

Rainfall was recorded with a David rain gauge (0.2 mm tipping bucket) and temperature with a Barologger Edge (Solinst), both installed next to a rehabilitation weir in the south-eastern corner of the study site (Figure 2). Rainfall for the study period is presented as daily totals (mm) and temperatures as daily minimum and maximum in Figure 3. The study period stretched over approximately 5 months, commenced at the end of the wet rainy season (20 March 2013) throughout the relatively dry winter and ended on the 16 August 2013).

Figure 2: Experimental layout and degree of channel incision in the study area (**none** = incision < 10 cm; **moderate** = incision 10 – 60 cm; **severe** = incision > 60 cm).

Figure 3: Dates of field visits, daily rainfall and minimum and maximum temperatures recorded during the study period

During the study period a total of 344 mm rain was recorded, the average maximum temperatures was 17.5˚C and the average minimum temperature was 0˚C (Figure 3).

The depth of channel incision was directly measured for the main stream channel. The channel was then grouped into three classes based on the degree of channel incision (Figure 2). Severe; where the channel was incised deeper than 60 cm, Moderate; when the channel was incised between 10 and 60 cm and None; where no significan incision was measured (<10 cm).

The impact of expansion of the road network, to facilitate afforestation, on surface hydrology is considered to be the major cause of channel incision in the Hogsback area. Afforestation around the site commenced around 1984 and roads concetrating overland flow might have altered the natural streamflow regime resulting in channel incision. Visual comparison between satelite images of 2000 and 2009 (Figure 4) suggests however that significant incision occured in the past decade. It is hypothesised that the deforestation of plantation blocks above the study site in 2002 might have changed the streamflow regime dramatically i.e. higher peak flows and higher total flows resulting in increased channel incision.

Figure 4: Increase in channel incision over 10 years.

A total of 29 piezometers were installed on the study site, marked HP1 – HP29 in Figure 2. The piezometers are 55 mm diameter PVC pipes partially slotted at the bottom, following the methodology of Sprecher (2000). The piezometers were installed to the depth of refusal (bedrock) at different localities to capture the variation in the degree of channel incision (Figure 2). Water levels in all the piezometers were manually recorded during field visits (Figure 3). Only data from the piezometers directly next to the stream channel (21 piezometers) are reported in this study.

The soils at the 21 piezometer sites were described and classified in accordance with Soil clasification, a taxonomic system for South Africa (Soil Classification Working Group, 1991). Of special interest was micromorhological properties such as Fe accumulations and depletions and where they occur. Samples were taken at 10 cm depth intervals and analysed for organic carbon (OC) following the Walkey-Black method.

To simplify representation and interpretation of the data the 21 piezometer sites were divided into 9 groups of similar taxonomic class, channel incision, water levels and hydromorphic properties. These groups are presented in Table 1.

Results
The groups of piezometers, the depth of channel incision, minimum, maximum and average water contents over the study period, OC contents, selected soil properties for different diagnostic horizons and soil forms for the piezometers are presented in Table 1.
Table 1: Vertical channel incision, water table characteristics and soil morphological properties for the different piezometers

Soil water levels
Piezometer groups installed near severely incised channels (groups 1, 6 and 8) are associated with deeper maximum, minimum and average water table depths when compared to those of moderately incised (groups 2, 4, 5 and 9) or group 3 with limited incision (Table 1). An exception to this is the piezometers of group 7. The relationship between average water table depth and depth of channel incision is graphically illustrated in Figure 5. When piezometers

of group 7 (Table 1) is excluded from the correlation, a good linear relationship ($R^2 = 0.89$) between water table depth and depth of channel incision exists.

Figure 5: The relationship between average water table depths (cm) and channel incision for 18 piezometers.

Piezometers of group 7 were installed next to some of the most severely incised parts of the stream. The fluctuation in the water table depth measured in these piezometers were however minimal and water tables remained close to the surface throughout the study period.

The period between field visits on 24 April and 2 May was marked by little rain (1 mm) following a two relatively large rainfall events i.e. 26 and 32.8 mm on the 20 and 21st April respectively (Figure 3). This period was selected to illustrate differences in drainage rates from different piezometer groups.

Table 2: Change in water table depths (cm) of different piezometer groups during 8 dry days

The greatest change in the water table depth was observed in group 1 and 8 (Table 2). Both these groups were marked by severe channel incision (Table 1 and Figure 2). The water table in group 7, with deeply incised channels, did not change during the 8 day period. The water table remained close to the surface (1 cm on average) in the piezometers of group 3, with virtually no channel incision, as well. The piezometer groups reflecting moderate incision showed slight decreases during the 8 day drying period (Table 2).

Soil morphology
The soils were classified as either Kroonstad (Kd) or Fernwood (Fw) soil forms (Soil Classification Working Group, 1991). In the Kd an orthic A horizon (*ot*), rich in OC, overlies an E horizon (*gs*) which overlies a G horizon (*gc*). This soil is similar to a Gleysol (WRB, 2006). On shallower soils (piezometer groups 4, 5 and 9) a gc horizon did not form and the *gs* below the *ot* directly overlie impermeable bedrock.

The moist colour of the soils was generally dark, with Munsel colour notation values of 3 or less dominating, and bleached. The dry colours are without exception *'grey'* when considering the definition of grey soil colours in the Soil Classification Working Group (1991). There was not a clear relationship between the moist or dry colour and the degree of channel incision, water table characteristics or even the OC content (Table 1).

There was however an exponentially decreasing relationship between the average OC content of the topsoils of the different piezometer groups and the average water table depths of the respective groups (Figure 6).

Figure 6: Average water table depth (cm) vs. topsoil OC (%) for different groups.

The OC content for the topsoil of group 3, associated with limited incision is the highest approximately 4%, with groups 1, 4 and 6 being the lowest at around 2.5%. The OC contents of the soils are very high with a very small decrease with depth (Table 1).

Brown, red and grey mottles occur in the soils of the study area (Table 1). Grey and red mottles occur in a distribution pattern related to interpedal and biopores. Grey mottles occur in the reduction morphology of subsoil horizons (*gs* and gh) whereas red mottles occur in the *ot* horizons of selected groups. Brown mottles occur frequently, their distribution appears to be random.

Figure 7: Related distribution of grey and red mottles. Green arrows indicate grey zones of Fe depletion (a, b and c), yellow arrows indicate zones of red zones of Fe accumulation (b and c) and d) ironoxide rich water flowing over the surface at HP10 of group 3.

Bleached root channels are predominant in topsoils of piezometer groups with relatively deep water tables i.e. group 1, 6, 8 and 9 (Figure 8-a), as well as in *gs* horizons that are periodically saturated (group 1, 4 and 6). In the latter they occur together with rusty root channels (Figure 8-b&c). Rusty root channels occur in topsoils where the water table is relatively close to the surface (group 2, 4 and 7) as well as in *gs* horizons within the region of saturation. Reduction and depletion indicators on the root channels are absent from *gc* horizons as well as from *gs* horizons that were continuously saturated during the study period (group 3 and 7) and from the *ot* of group 3. Oxidized Fe (orange water) was flowing on the surface at HP10 of group 3 (Figure 8d).

Discussion

Water levels
Water levels are controlled by the balance between addition and removal of water. Both these factors are controlled by the permeability of the soil and difference in hydraulic head. The relationship between depth of water tables and depth of erosion gully is in line with the understanding of changing hydraulic head by lowering the outlet (Figure 5). However, the response of the observations in group 7 does not relate to the degree of drainage implying localised hillslope aquifers supply water at a high rate, balancing the drainage. The constant water levels in the piezometers of group 7 after 8 rain-free days (Table 2) suggest that the supply and release of water from these piezometers were in equilibrium. Localised variation in the supply of water by the hillslope can be explained by fast return flow by the fracture system. This impact of the fractured rock characteristics on the hydrologic response of the soil is expected to be more pronounced in shallow soils and buffered by deeper soils and larger wetlands.

Soil morphology
The formation of soil horizons under water saturated conditions is expected to be limited. The standard concept of the formation of soil horizons requires water flowing from the surface downwards to the saprolite. In spite of stagnant water conditions *ot* and *gs* horizons are visible in both soils and in the Kroonstad a *gc* horizon is also distinguishable. Under saturated conditions and more so under subaqueous conditions in the wet season, water cannot infiltrate surface horizons. It can only enter the profile from the underlying saprolite profile by upward flow (capillary rise) to supply evapotranspiration losses and stream flow (Van Tol *et al.*, 2010). The diffuse transitions between horizons (see uniform colours of horizons in Table 1) of these soils are typical of wetland soils with long duration of saturation (Van Huyssteen et al., 2005) and probably related to an upward water flux.
The very homogeneous morphology is typical of wetland soils indicating long duration of conditions at or near saturation implying a water table at or near the soil surface. Under stagnant saturated conditions homogeneous reducing conditions is expected to stabilise in the soil including the matrix and pores. Typical of chemical homogeneous conditions is diffuse transitions between limited colour variations in the matrix. This explains the bleached and grey colours of the *ot*, *gs* and *gc* horizons of both soil forms.

It must be taken into consideration that most processes of soil formation is active in most soils but that the dominant process is responsible for the dominant morphological feature. Although both gleyic and stagnic colour patterns (WRB, 2006) occur in these soils they dominate in some horizons. A gleyic colour pattern *i.e.* ferrans observed as iron accumulations in red pore linings (interpedal and biopores) in soils with shallow water tables represented by observation groups 1, 4 and 7, are indicative of conditions near saturation (Veneman et al., 1976). The distribution of iron from the matrix to the pore linings is driven by selective supply of oxygen to the soil through macropores. Above the water level near saturation of the soil matrix for significant periods results in reduction of iron in the soil matrix and precipitation of iron in the oxygen supplying macropores. It also explains the presence of red pore linings as rusty root channels form in periodically saturated gs horizons of observation groups 2, 4 and 6 which can form when the water table are slightly lowered. Where recent erosion lowered the water table gleyic colour patterns occur deeper in the soil related to the current water table level as the zone of aeration moved lower down the profiles.

More aerated topsoils of soils with lower water tables are more suitable for vegetation growth and simulates root development and development of reducing conditions in the biopore while oxygenated matrix conditions prevails. Albans of depleted iron and a stagnic colour pattern *i.e.* grey pore linings as recorded in observation groups 1, 6, 8 and 9, where root residues enhance microbiological activity in root pores, reduce the environment, dissolve and deplete the iron to form bleached pore linings to precipitate in an oxygenated soil matrix. The duration of the process limits the pronounced presence of iron precipitation as a quasi-ferran recorded in mature soils (Le Roux and Du Preez, 2004).

The high OC contents is well above the average OC contents of Kroonstad and Fernwood soils and indicative of a constant waterlogged soil water regime more like that of Champagne soils (Le Roux al et., 2013). The generally dark colours of all horizons support the statement. The small decline in OC content with depth is not normal of mineral soils. It can be due to oxidation caused by lowered water table conditions enhancing oxidation of humus in the surface horizon. Alternatively it may indicate the formation of organic soil characteristics.

Conclusions

Soil water levels are inversely correlated to channel incision for most piezometers. Constant supply of water to piezometers of group 7 was in equilibrium with drainage from these piezometers. Soil morphology is a useful indicator of ancient and recent soil water regimes of wetland soils. Although soil morphology is generally considered an ancient indicator of the soil water regime and may be out of phase with current terrain, climate and hydrology, the colour variation observed in the studied soils serves as a sensitive indicator of recent changes and by implication confirm the contribution of soil morphology as valuable indicator of long-term averaged soil water conditions. Future studies should focus on quantification of the redox-potential of the water in relation to soil morphological properties.

References

Coleman JA. (1999). Sustainable management in a disturbed environment: A case study of the Hogsback Working for Water project. Unpublished M.Sc. Dissertation. UKZN, Pietermaritzburg.

Gislason GM. Russell RC. (1997). Oviposition sites of the saltmarsh mosquito, Aedes vigilax (*Skuse*) (Diptera: *Culicidae*), at Homebush Bay, Sydney, NSW - a preliminary investigation. *Australian Journal of Entomology* 36: pp 97-100.

Grundling PL. (1999). Challenges for the IMCD in the conservation of mires and peat lands in Southern Africa (and other developing countries). Council for Geoscience Geological Survey, Pretoria.

Ingram HAP. (1983). Hydrology. In Gore, A.J.P. (Ed.): *Ecosystem of the world 4a. Mires: Swamp, bog, fen and morel*. New York: Elsevier Scientific Publishing Company. pp. 67-118.

Kotze DC, Klug JR, Hughes JC, Breen CM. (1996). Improved criteria for classifying hydric soils in South Africa. *South African Journal of Plant and Soil* 13: pp 67-73.

Kotze DC, Marneweck GC, Ratchelor AL, Lindley DS. Collins NB. (2005). WET EcoServices. A rapid assessment procedure for describing wetland benefits. Mondi Wetlands Project.

Le Roux PAL, Du Preez CC. (2004). Indications of ferrolysis and structure degradation in an Estcourt soil and possible relationships with plinthite formation. *South African Journal of Plant and Soil*, 22: pp 199-206.

Le Roux PAL, Du Plessis MJ, Turner DP, Van der Waals J, Booyens HB. (2013). Field Book for the classification of South African soils. Reach Publishers, Durban.

Lindbo DL, Stolt MH, Verpraskas MJ. (2010). Formation and interpretation of redoximorphic features. In: Stoops (Ed.). *Micromorphological features of soil and regolith*. Elserivier, Amsterdam. pp. 129 – 147.

Loheide SP, Booth EG. (2011). Effects of changing channel morphology on vegetation, groundwater and soil moisture regimes in groundwater-dependent ecosystems. *Geomorphology* 126: pp 364 – 376.

MacEwan RJ. (1997). Soil quality indicators: pedological aspects. In: Gregorich EG and Carter MR (eds.) *Soil Quality for Crop Production and Ecosystem Health*. Elsevier, New York. pp. 143–166.

Mausbach MJ. Richardson JL. (1994). Biogeochemical processes in hydric soils. *Current topics in wetland biogeochemistry* 1: pp 68-127.

Millennium Ecosystem Assessment. (2005). Ecosystems and Human Well-being: Wetlands and Water. Washington D.C.

Mitsch WJ, Gosselink JG. (1993). *Wetlands* (2nd edn). John Wiley & Sons, Inc., New York, NY, USA.

Naiman RJ, Dechamps H, McClain ME. (2005). Riparia: Ecology, Conservation, and Management of Streamside Communities. Elservier Academic Press, Burlington, MA.

Shields Jr FD, Simon A, Dabney S, 2009. Streambank dewatering for increased stability. *Hydrological Processes* 23: pp 1537–1547.

Shields Jr FD., Lizotte RE, Knight SS, Cooper CM, Wilcox D. (2010). The stream channel incision syndrome and water quality, USA. *Ecological Engineering* 36: pp 78-90.

Soil Classification Working Group. (1991). Soil classification: a taxonomic system for South Africa. *Memoirs on the Agricultural Natural Resources of South Africa* No. 15. SIRI, D.A.T.S., Pretoria.

Sprecher SW. (2000). Installing monitoring wells/piezometers in wetlands. *WRAPTechnical Notes Collection* (ERDC TN-WRAP-00-02), U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Steiger J, Tabacchi E, Dufour S, Corenblit D, Peiry JL. (2005). Hydrogeomorphic processes affecting riparian habitat within alluvial channel-Floodplain river systems: a review for the temperate zone. *River Research and Applications* 21: pp 719-737.

Van Huyssteen CW, Hensley M, Le Roux PAL, Zere TB, Du Preez CC. (2005). The relationship between soil water regime and soil profile morphology in the Weatherly catchment, a forestation area in the North Eastern Cape. WRC project Nr. K8/1 317, Water Research Commission, Pretoria.

Van Tol JJ. LE ROUX PAL. HENSLEY M, LORENTZ SA. (2010). Soil as indicator of hillslope hydrological behaviour in the Weatherley Catchment, Eastern Cape, South Africa. *Water SA* 36: pp 513 – 520.

Vepraskas MJ, Wilding, LP, Drees, LR. (1994). Aquic conditions for Soil Taxonomy: concepts, soil morphology and micromorphology. In: Ringrose-Voase AJ and Humphreys GS (Eds). *Soil micromorphology: Studies and management and genesis.* Elserivier, Amsterdam, pp. 117–131.

Vepraskas MJ, Faulkner SP. (2001). Redox chemistry of hydric soils. In: Richardson JL and Vepraskas MJ (Eds). *Wetland Soils: Genesis, hydrology, landscapes and classification*. Lewis Publishers, Boca Raton, Florida, pp 85 – 105.

Vepraskas MJ, Lindbo DL. (2012). Redoximorphic Features as Related to Soil Hydrology and Hydric Soils. In: Lin H (ed) *Hydropedology: Synergestic integration of soil science and hydrology.* Elserivier, Oxford, UK, pp. 143–172.

Veneman PLM, Verpraskas MJ, BOUMA J. (1976). The physical significance of soil mottling in a Wisconsin toposequence. *Geoderma* 15: pp 103–118.

WRB. 2006. World Reference Base for Soil Resources, (2006). A Framework for international Classification, Correlation and Communication. World Soil Resource Report 1003. Food and Agriculture Organization of the United Nations. Rome.

Table 1: Vertical channel incision, water table characteristics and soil morphological properties for the different piezometers

Group	Piezometer	Channel incision (cm)	Water table depth (cm) Maximum	Minimum	Average	Depth (cm)	OC (%)	Munsell colour Moist	Dry	Mottles frequency; size; colour	Root channels	Diagnostic horizon	Soil form
1	HP1/HP4/HP18/HP22	70/70/55/100	54/66/57/62	34/36/42/44	47/57/50/55	0 – 40	2.48	10 YR 3/1	10 YR 5/1	None	Bleached	ot	Kd
						40 – 90	2.38	10 YR 3/1	10 YR 6/1	Few; small; brown	Bleached&Rusty	gs	
						90 – 110	2.28	10 YR 3/1	10 YR 4/1	Few; medium; grey	-	gc	
2	HP 6	40	15	4	11	0 – 40	3.62	10 YR 3/2	10 YR 5/2	Few; small; brown	-	gc	Kd
						0 – 60	3.52	10YR 3/1	10YR 6/1	Many; small; brown	-	gs	
						60 – 160	3.43	10 YR 3/2	10 YR 5/2	Few; small; brown	-	gc	
3	HP7/HP10/HP11/HP12	5/2/2/6	1/1/1/6	1/0/1/2	1/1/1/3	0 – 40	3.97	10 YR 3/1	10 YR 6/2	None	-	ot	Kd
						40 – 80	3.60	10 YR 3/1	10 YR 7/2	None	-	gs	
						80 – 140	2.69	10 YR 3/1	10 YR 6/2	Few; medium; brown	-	gc	
4	HP16/HP17	40/40	15/31	10/24	13/27	0 – 20	2.33	10YR 3/1	10YR 5/1	Many; small; brown	Rusty	ot	Fw
						20 – 40	2.15	10YR 2/2	10YR 6/2	Few; small; brown	Bleached&Rusty	gs	
						0 – 20	3.11	10YR 3/4	10YR 6/4	Few; small; red	Rusty	ot	
5	HP19/HP24	20/29	7/9	1/7	4/9	20 – 40	2.97	10YR 2/1	10YR 5/1	Few; medium; grey	-	gs	Fw

No.	Sample					Depth	Value	Color	Mottles	Condition	Code	Class
6	HP 20	95	81	56	70	0 – 30	2.5 3/1	10YR 5/2	None	Bleached	ot	Kd
						30 – 60	2.2 0 4/3	10YR 6/2	Many; medium; red usty	Bleached&Rusty	gs	
7	HP21/HP23 / HP27	120/95/90	12/9/7	1/3/1	8/6/3	0 – 30	3.0 6	10 YR 5/2	Few; medium; brown	Rusty	ot	Kd
						60 – 100	2.2 0 3/2	10YR 6/3				
						30 – 50	2.9 5	10 YR 6/1	Few; medium; brown	-	gs	
						> 50	-	-	-	-	gc	
8	HP25/HP26	80/88	69/68	49/53	58/60	0 – 30	2.7 1	10 YR 5/1	None	Bleached	ot	Kd
						30 – 70	2.5 8 3/1	10 YR 7/1	Few; small; brown	Rusty	gs	
						70 – 100	2.4 3 2/2	10 YR 5/2	Few; small; grey	-	gc	
9	HP28/HP29	53/53	41/23	27/21	35/22	0 – 30	2.7 1 4/1	10 YR 6/2	None	Bleached	ot	Fw
						30 – 60	2.6 1 4/2	10 YR 7/2	Few; large; brown	Rusty	gs	

Table 2: Change in water table depths (cm) of different piezometer groups during 8 dry days

Group	Water table depth (cm)								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
24 April 2013	50	9	1	20	6	79	6	54	31
02 May 2013	58	14	1	23	8	81	6	63	32
Δ Depth (cm)	**8**	**5**	**0**	**3**	**2**	**2**	**0**	**9**	**1**

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Figure 1: The location of the study area (a & b) and instrumental layout in the study area (c).
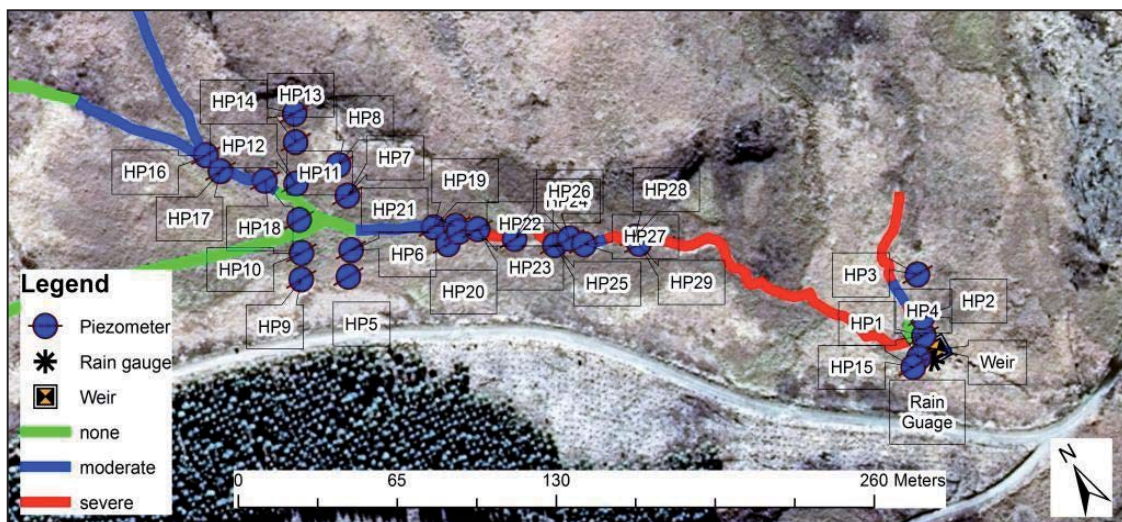
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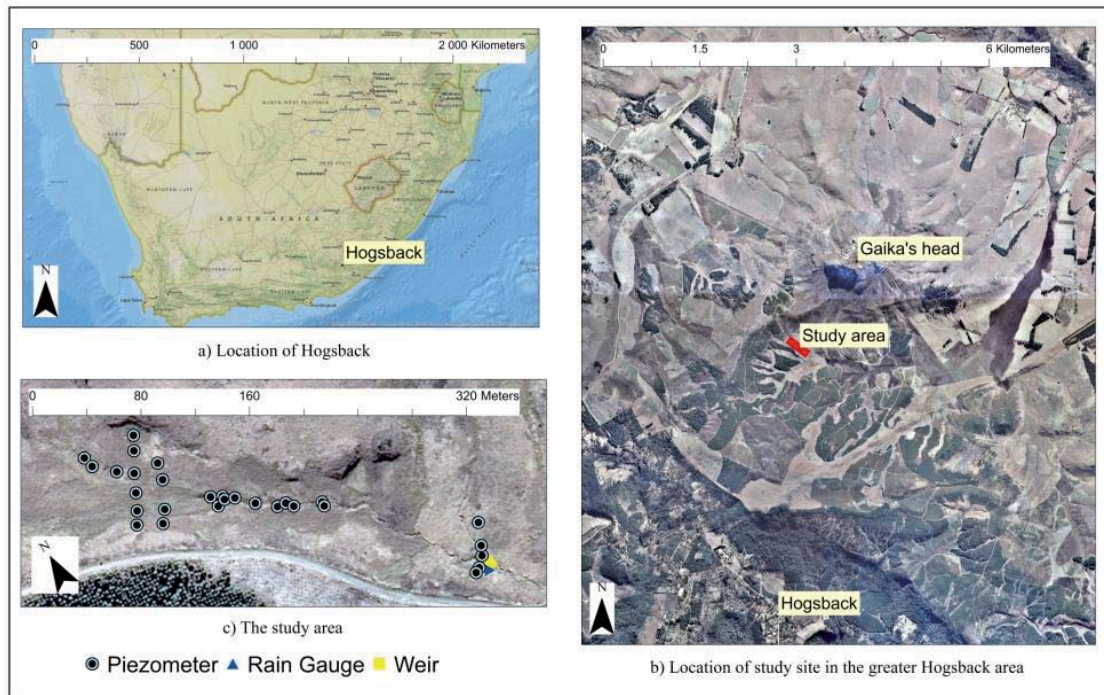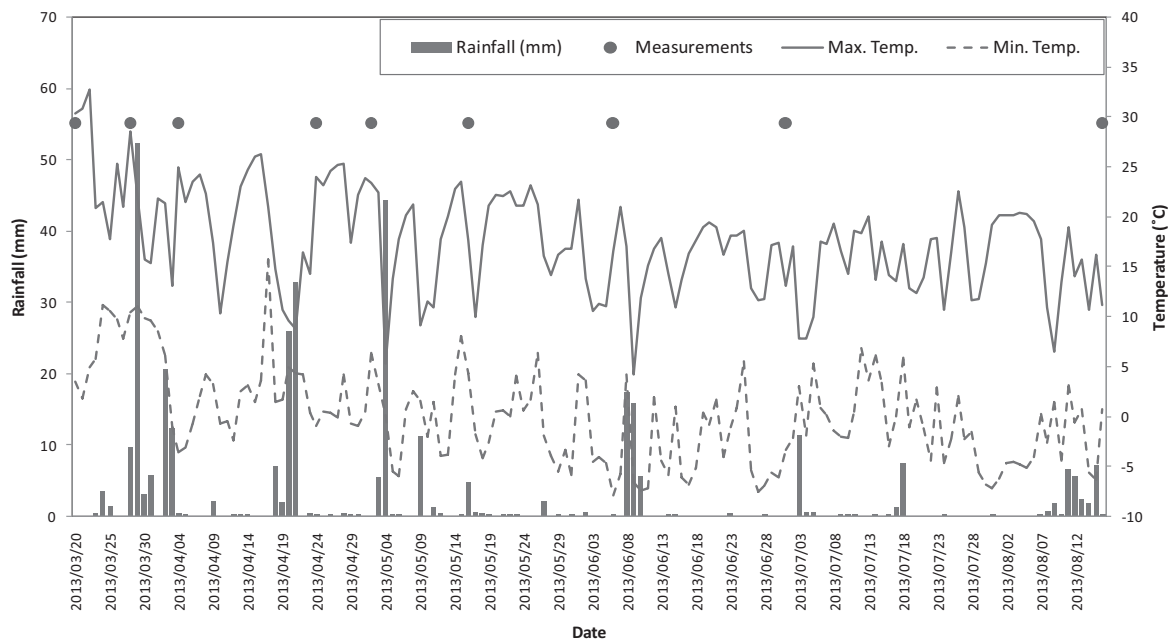
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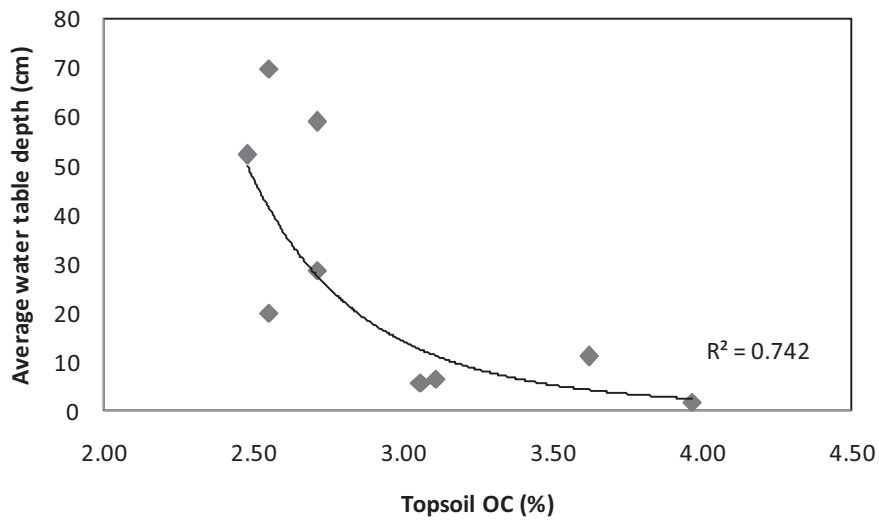
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6.1.4 RESPONSE AND PHOSPHORUS UTILIZATION EFFICIENCY OF GROUDNUT VARIETIES UNDER VARYING SOIL FERTILITY IN NORTHERN UGANDA

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Abstract

Phosphorus (P) is essential in the nutrition, nodulation and therefore, yield of groundnuts. However, it is not clear how responses to and use efficiency of P by source vary across varieties and field types. On- farm experiments were conducted in two districts of the Northern moist farmlands (NMF) of Uganda to evaluate yield response of groundnut varieties to P-sources and rhizobia and phosphorus utilization efficiency (PUE) as affected by heterogeneity. Two different sources of P: single superphosphate (SSP) and triple superphosphate (TSP) with and without rhizobia inoculants were evaluated at two levels of 0 and 15 kg ha^{-1} across fields of good, medium and poor fertility. Three groundnut varieties (Serenut 2, 5R and 6T) were tested and the experiment was laid in a split plot design. Grain yield significantly ($P<0.001$) differed by field type, variety and fertilizer treatment in both districts. Field type x variety resulted in significant difference ($P<0.05$) for grain yield in both districts and in one district (Apac) Variety x Fertilizer also exhibited significant difference ($P<0.05$). PUE ranged from 99.3 to 491.6 kg of grain yield per kg of phosphorus taken up and significantly differed by field type ($P<0.05$) and field type x fertilizer ($P<0.05$) in Apac while in Kole it ranged from 87.5 to 332.7 kgkg^{-1}with varieties only differing significantly ($P<0.001$). We therefore suggest that Serenut 5 be targeted to good, medium and poor fields in both districts and may require TSP in good field and TSP + inoculation in medium and poor fields.

Key words: Phosphorus utilization efficiency, soil fertility heterogeneity, Groundnut, phosphorus sources

Introduction

Groundnut yields continue to remain low and variable on smallholder fields in Uganda. Heterogeneity in soil fertility and poor fertility in particular limited supply of phosphorus is pointed out as one of the major factors limiting groundnuts production (Giller, 2001, Ebanyat *et al.,* 2009). Improving yields of groundnut will require efforts like addition of external phosphorus fertilizer but various sources of phosphorus fertilizer exist and responses to P by source and phosphorus utilization efficiency (PUE) by the different varieties has not been investigated. Approaches that enhance resource use efficiencies like use of varieties with high PUE can also help increase yields of groundnut. The objectives of this study therefore was to determine yield response of groundnut varieties to P-sources and rhizobia as affected by heterogeneity and PUE by groundnut varieties across the differing fertility fields.

Groundnut research efforts aimed at closing the yield gap between 0.56 Mgha^{-1} of dry grain recorded on smallholder farms compared to a potential of 3 Mgha^{-1} (Paga *et al.,* 2002) have focused on breeding high yielding varieties but less on soil fertility management. These efforts have led to release of over seven 'high yielding' and early maturing varieties of groundnut to farmers in Uganda since 2010 and there are other potential genotypes for release (Abate *et al.,* 2012). In order for farmers to gain from adoption of this new varieties there is a need for external

application of phosphorus fertilizers as phosphorus has been identified as a major constraint to production of groundnut in smallholder system but it's not known which source is appropriate for increased productivity of these new varieties. Varieties that are efficient in utilization of applied fertilizer are also not known and research carried out elsewhere has identified soil fertility variability as an essential factor influencing fertilizer utilization efficiencies (Tittonell *et al.,* 2010) and therefore targeting P fertilizer sources to these varieties to fields of varying fertility can potentially contribute to increased productivity of the varieties.

Study description

On-farm trials were conducted in two districts (Apac 01 59N, 32 32E and Kole 02 24N, 32 48E) of Northern Moist Farmlands (NMF) agro-ecological zones where groundnut is mostly produced in Uganda. These areas are located in a sub-humid and relatively warm zone with rainfall well distributed from April to October. It receives majorly mono-modal type of rainfall and it ranges from 750mm to 1600 mm per year. Generally the areas experiences high temperature with an annual average temperature of 25°c and the relative humidity follows the rainfall pattern. Soils are sandy clay and sandy soil general low organic matter and moderate nutrient supply. The trials ran for two consecutive rain seasons, including the second rains of 2012 (2012b) and first rains of 2013 (2013a). Field types of varying fertility poor, medium and good were identified by farmers based on their long term local knowledge of the fertility status of their field prior to experimentation in each of the districts. The treatments were P at levels of 0 and 15 kg P ha^{-1} from two different sources (TSP and SSP) with and without rhizobia applied in fields of good, medium and poor fertility. Each field type was replicated four times in each of the district per season. Three groundnut varieties Serenut 2, Serenut 5R and 6T were planted in a spacing of 45cm x 10cm on plots of 4mx3m and the experiment was laid out in a split plot design with field types (poor, medium and fertile) acting as the main blocks; groundnut varieties acting as main plots on which fertility management were done through applying TSP and SSP fertilizers with/without rhizobia. At flowering, biomass was determined and grain yield at maturity. Grain tissue P contents was measured and used to calculate phosphorus utilization efficiency as described by Dobermann, 1997. Data on grain yield and internal phosphorus utilization efficiency of groundnut varieties were subjected to multivariate analysis because of the variability in soil fertility using the Restricted Maximum Likelihood (REML) algorithm in Genstat Version 12. The fixed terms included field type, varieties, fertilizer treatments and their interaction and random terms included field number and plot number.

Results

Initial soil characteristics of experimental fields

The soils from the experimental fields in Apac and Kole were moderately to slightly acidic and generally classified as sandy clay loam from the particle distribution data (Table 1). Soil organic matter ($P<0.007$), total nitrogen ($P<0.015$) and sand ($P<0.021$) significantly differed by field type in Apac and in Kole soil organic carbon ($P<0.027$), total nitrogen ($P<0.001$), sand ($P<0.001$) and clay ($P<0.006$) showed significant difference between field types (Table 1). The good fields and medium fields had almost similar percentage organic matter and total nitrogen but significantly higher than in poor fields in both districts. In Apac the highest percentage O.M (4.7%) was in medium fields and lowest in poor fields (2.38%) while in Kole the highest

percentage organic matter was in good field (3.829%) and lowest in poor fields (2.327%). Poor fields had the largest composition of sand (65.2%) in Apac and 65.71% in Kole. Generally better chemical properties were recorded on fields classified by farmers as good and medium fields and poorer values in poor fields thus strengthening the idea that farmers have the ability to tell between good and poor fields.

Table 8: Initial soil characteristics for experimental field on good, medium and poor fields in Apac and Kole districts

District/Field type	pH (H$_2$O)	OM %	Tot. N	Bray P1 mg kg^{-1}	K	Ca	Mg	Na	Sand	Clay	Silt
					Cmol$_c$ kg^{-1}				%		
Apac											
Good	6.067	4.58	0.161	18	0.487	15.2	2.82	0.27	59.8	28.2	12
Medium	6.022	4.72	0.157	12.2	0.365	9.2	2.44	0.23	57.5	31.2	11.3
Poor	5.879	2.38	0.113	5.1	0.712	9.8	2.52	0.28	65.2	24.8	10
SED	0.203	0.74	0.016	10.88	0.155	2.98	0.384	0.05	2.71	2.59	1.15
P values	0.632	0.007	0.015	0.506	0.102	0.099	0.596	0.62	0.027	0.063	0.24
Kole											
Good	6.408	3.829	0.175	15.586	1.112	14.25	2.78	0.38	53	37	10
Medium	6.110	3.605	0.153	8.282	0.749	10.13	3.45	0.31	57.25	31.5	11.3
Poor	5.960	2.327	0.102	9.396	0.774	9.57	2.33	0.27	65.71	24	10.3
SED	0.266	0.515	0.008	3.726	0.164	1.962	0.502	0.04	2.709	3.512	1.75
P values	0.259	0.021	0.001	0.123	0.065	0.052	0.104	0.06	0.001	0.006	0.75

Grain yield response to phosphorus source and/with inoculation

In Apac district grain yield of the groundnut varieties differed significantly by field types (P<0.036), fertilizer treatments (P<0.001) and varieties (P<0.001). Field types and variety (P<0.024) as well as variety and fertilizers (P<0.028) interactions were both significantly different. The largest variety yield response to phosphorus sources and/with inoculation application was on the poor fields with apparent yield increases of 81.91% with Serenut 5R followed by Serenut 2 in medium fields 76.77% and lastly Serenut 5R 70.92% in good fields (Table 2) . Phosphorus sources and/with inoculation did not significantly differ from each other

in all the field types. The best yield was obtained by Serenut 5R with rhizobia + TSP (1392.8 kgha^{-1}) in good fields and generally Serenut 2 and 5R produced Significantly higher yields above Serenut 6 for majority of treatments across the field types (Table 2). In Kole district, varieties ($P<0.001$), fertilizer treatment ($P<0.001$) and, field type and variety ($P<0.004$) interaction resulted in significant difference for grain yield. The best yield response to phosphorus sources and/with inoculation application was by Serenut 2 across all field types with the highest apparent yield increases of 64.35% recorded in good fields (Table 3). Significant difference between phosphorus sources and/with inoculation was registered in poor field type by Serenut 2 with rhizobia + TSP producing higher yields above Serenut 2 with rhizobia alone and Serenut 5 with rhizobia + TSP also resulting in significantly higher yield above Serenut 5 with rhizobia alone (Table 3).

Table 9: Average grain yield (kg ha-1) of groundnut varieties at different P levels without and with rhizobia by field type in Apac district for 2012b & 2013a season (n= 24 fields)

Variety/Field type	P levels (kg/ha⁻¹)			Rhizobia + P level(kg/ha⁻¹)			Mean trt	Apparent increase(%)
	0	15(SSP)	15(TSP)	Rhiz	15(SSP)	15(TSP)		
Good								
Serenut 2	876.5	1209.9	1042.3	1107	1094.9	1120.1	1114.84	27.19224
Serenut 5	657.8	1026.7	1091.6	954.7	1155.9	1392.8	1124.34	70.92429
Serenut 6	466.2	636.2	881.5	524	725.6	686.6	690.78	48.17246
Medium								
Serenut 2	616.3	1195.4	957.4	999.6	1220.7	1074.1	1089.44	76.77105
Serenut 5	819.4	1279.3	1318.8	1091	1143.1	1223.7	1211.18	47.81303
Serenut 6	543.6	687.6	852.4	750.9	810.3	780.7	776.38	42.82193
Poor								
Serenut 2	599.2	888.6	1034.8	936.2	770.5	959.1	917.84	53.17757
Serenut 5	500.1	987.6	817.3	778.8	1022	943.2	909.78	81.91962
Serenut 6	404.6	510.8	683.1	521.8	681.1	660.4	611.44	51.1221
SED Field type	=126.5	P<0.036						
SED Variety	=140.1	P<0.001						
SED Fertilizer trt	=141.7	P<0.001						
SED FTxVar	=79.17	P<0.024						
SED Var x Fert	=70.20	P<0.028						

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Table 10: Average grain yield (kg ha-1) of groundnut varieties at different P levels without and with rhizobia by field type in Kole district for 2012b and 2013a season (n= 23 fields)

Variety/Field type	P levels (kg/ha⁻¹)			Rhizobia + P level(kg/ha⁻¹)			Mean trt	Apparent increase (%)
	0	15(SSP)	15(TSP)	Rhiz	15(SSP)	15(TSP)		
Good								
Serenut 2	610	1126.1	1140.8	850.5	1029.9	865.4	1002.54	64.35082
Serenut 5	693.9	1008.8	1111.9	849.8	854.1	933.2	951.56	37.13215
Serenut 6	538	736.1	764	561.8	751.3	846.3	731.9	36.04089
Medium								
Serenut 2	650	991.2	918.7	935.8	1006.7	1093.9	989.26	52.19385
Serenut 5	794.8	1058.8	1202.3	1058.8	1058.7	1215.8	1128.2	41.94766
Serenut 6	668.9	852.7	945.7	835.6	902.3	847.7	876.8	31.08088
Poor								
Serenut 2	565.9	841.5	832.5	686	794.5	930.1	816.92	44.35766
Serenut 5	783.4	959.7	974.4	879.9	1043.3	1123.6	996.18	27.16109
Serenut 6	538.7	768.5	708.2	763	817.7	808.4	773.16	43.5233

SED Field type	=104.2	NS
SED Variety	=111.1	P<0.001
SED Fertilizer trt	=111.5	P<0.001
SED FTxVar	=57.74	P<0.004

Mean trt is mean yield for fertilized treatments. Apparent yield response is the increase of grain yield due to fertilization above the control for each variety and calculated as $\frac{Mean\ trt\ -\ Control}{Control} X\ 100$

SED- Standard error of difference of means
FT - Field type
Var - Variety
Rhiz- Rhizobia
Trt-Treatment

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Phosphorus utilization efficiency (PUE):

Internal phosphorus utilization efficiency of groundnut varieties significantly differed by field type (P<0.05) and only field type x fertilizer interaction was significantly different (P<0.05) (Figure 6) in Apac district. The PUE ranged from 99.3 kg to 491.6 kg of grain yield per kg of phosphorus taken up. The largest PUE was obtained by Serenut 2 with SSP in good fields (491.6 kgkg^{-1}). Serenut 2 and 6 significantly had higher PUE with SSP above Serenut 2 and 6 with TSP in good fields (Figure 1). In the medium fields Serenut 6 had significantly higher PUE with rhizobia + TSP above SSP. In poor fields Serenut 5 had significantly higher PUE a above Serenut 2 and Serenut 6 with application of SSP and also Serenut 6 with rhizobia + SSP had higher PUE above Serenut 6 with SSP alone (Figure 1).
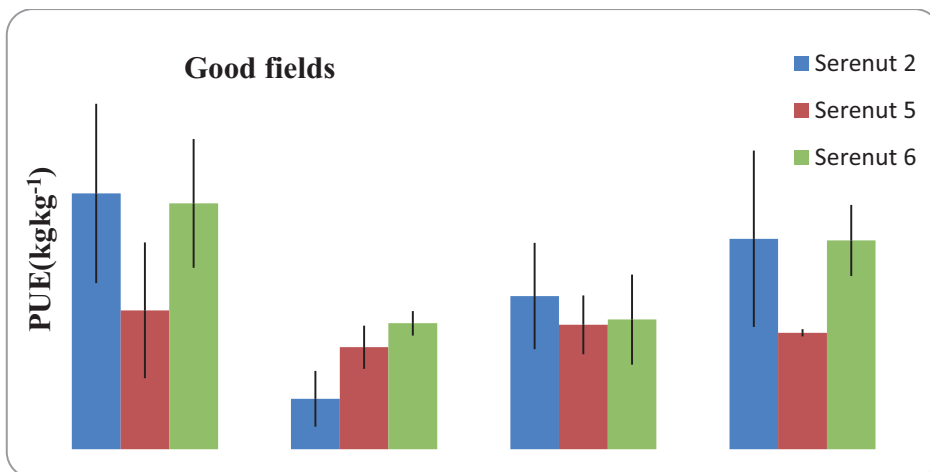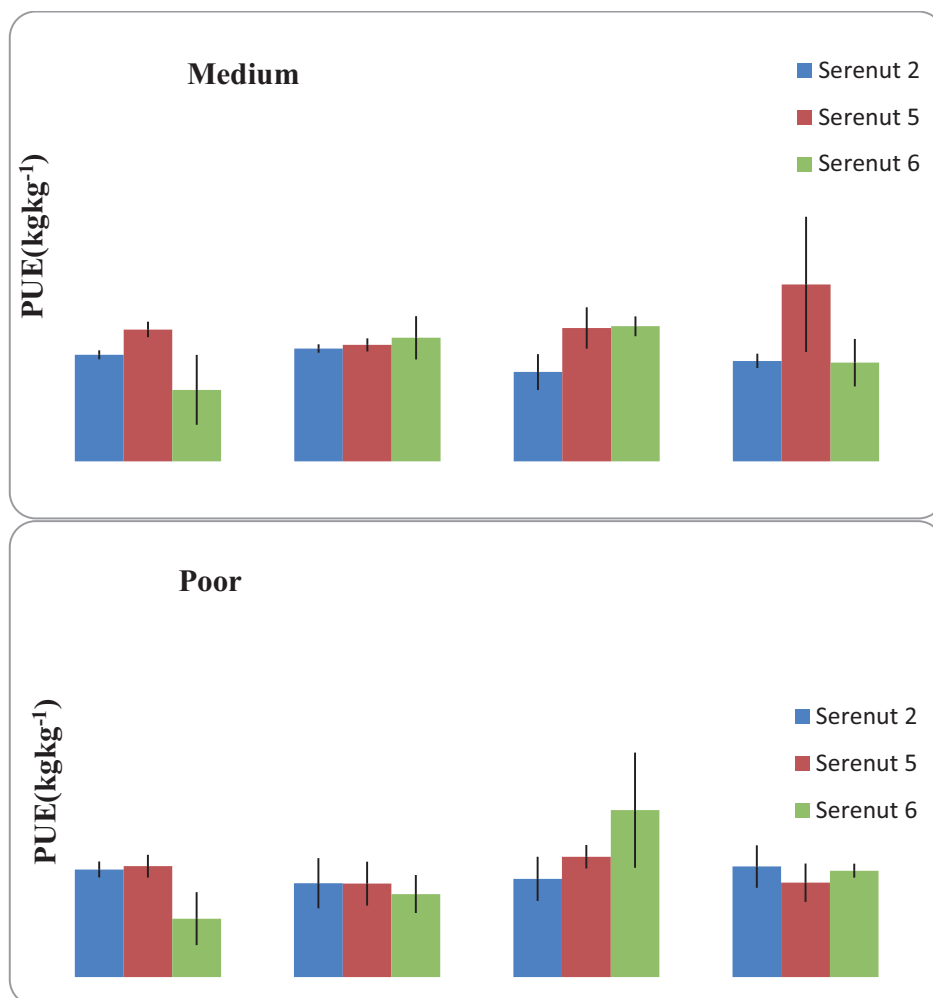
Figure 1: Internal phosphorus utilization efficiencies of groundnut varieties without and with phosphorus sources and inoculation as affected by field type during 2012b and 2013a season in Apac district

In Kole PUE of groundnut varieties only significantly differed from each other by varieties (P<0.001). The largest PUE was obtained in good fields by Serenut 6 with rhizobia + SSP (332.7 kgkg⁻¹) and lowest in poor fields by Serenut 2 with TSP (87.5 kgkg⁻¹). In the good fields rhizobia + TSP with Serenut 6 resulted in significantly higher PUE above Serenut 5 with rhizobia + SSP and rhizobia + TSP respectively. In medium fields Serenut 2 with rhizobia + SSP significantly resulted in higher grain yield per phosphorus taken above Serenut 5 with rhizobia + SSP. Serenut 6 with all treatment except TSP resulted in higher grain per phosphorus uptake above Serenut in poor fields. Only Serenut 6 with TSP and rhizobia + TSP resulted in higher PUE above Serenut 2 (Figure 2).
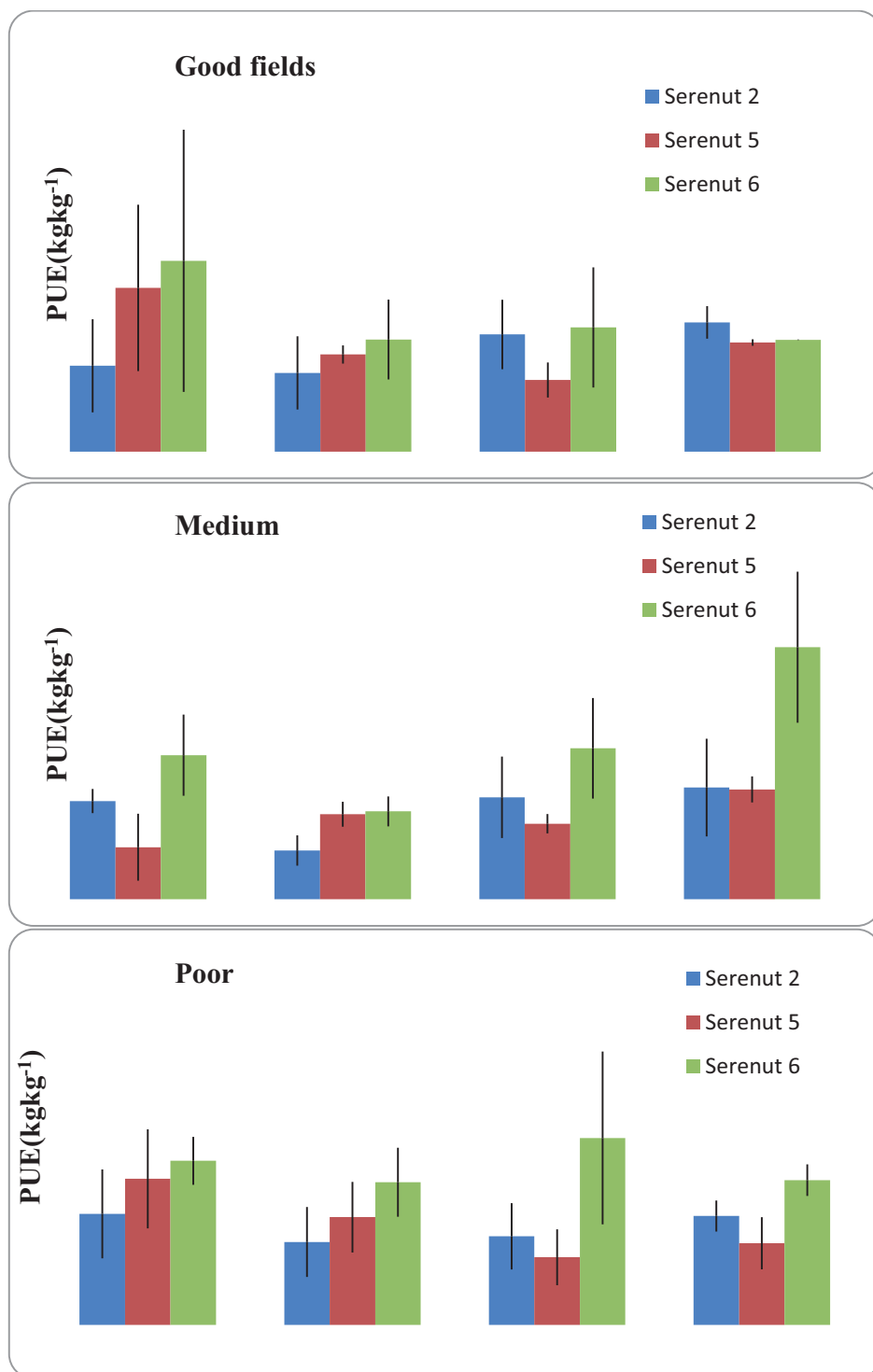
Figure 2: Internal phosphorus utilization efficiencies of groundnut varieties without and with phosphorus sources and inoculation as affected by field type during 2012b and 2013a season in Kole district

Discussion

The results obtained in both Apac and Kole indicated the influence of heterogeneity in soil fertility on grain yield and internal phosphorus utilization efficiency of the groundnut varieties that were established with or without phosphorus sources and/with inoculation. Grain yield differed by field type with better yields in good and medium fields (Table 2 and 3) than in poor fields and this is in line with studies carried elsewhere (Ojiem, 2006 and Ebanyat, 2009) and it further goes to emphasize the sensitivity of groundnuts to fertility status of the soil. Groundnut yield response was influenced by phosphorus sources and/with inoculation application with increase in grain yield observed upon application of phosphorus sources and/with inoculation in both Apac and Kole. Response to phosphorus sources and/with inoculation was highest in poor fields with Serenut 5R (81.919 %) in Apac and highest in good fields with Serenut 2 (64.35%) in Kole. Phosphorus plays an important role in metabolic process necessary for vegetative growth which in turn impacts grain yield (Gobarah *et al,* 2006, Hemalatha *et al, 2013*).

Poor fields in Apac had low phosphorus content and this probably explains why application of phosphorus sources and/with inoculation had better influence on yield than in other field types. In Kole however good fields exhibited the best response to phosphorus sources and/with inoculation application suggesting other factor other than phosphorus deficiency affected groundnut varieties response. Studies carried elsewhere in SSA indicated that soil organic carbon (SOC) affects response to fertilizers (Mtambanywe and Mapfuma, 2005) and it could be the reason as to why poor fields in Kole had poor response contrary to what is expected since the SOC contents were generally low. Groundnut varieties differed with Serenut 5R performing generally better than Serenut 6T and 2 thus strengthening the fact that the new variety is superior to the old varieties because of its resistance to diseases, tolerance to period of drought. Exception was however with Serenut 6T which did not perform well as expected being a new variety and this was due to probably its susceptibility to diseases in the field particularly early and late leaf spot. Internal phosphorus utilization efficiency of groundnut varieties differed by field type in Apac and by varieties in Kole (Figure 1 and 2) and this is in line with studies carried elsewhere (Baleni, T and Schenk, M.K, 2009, Krishna, 1997). The Phosphorus utilization efficiency of the groundnut varieties were also within ranges reported elsewhere (Kakar *et al,* 2002). Results from Apac indicated generally higher phosphorus utilization efficiency values in good fields than in medium and poor fields. Phosphorus deficiency in the soil is known to affect PUE of plants (Rose *et al,* 2011) and that PAE rather than PUE plays a dominant role in determining phosphorus efficiency of the plants (Wang *et al,* 2010).

Its therefore clear that in situation of phosphorus adequacy in the soil PUE becomes more important in determining the phosphorus efficiency of the plants as sufficient phosphorus is supplied as fertilizers (Rose *et al,* 2012) and this probably explains the difference observed in Apac with higher PUE under condition of phosphorus adequacy (good fields) and lower PUE under condition of phosphorus deficiency (medium and poor fields). PUE is believed to be under genetic control and thus suggesting the possibility of variation among crop species and genotypes within a given species for PUE (Wang *et al,* 2010). Higher PUE is accredited to efficient and larger rates of re-translocation and reuse of stored phosphorus during either vegetative and reproductive growth periods in plants (Youngdahl, 1990 and Wang *et al,* 2010). This may explain the significant difference in PUE observed between the groundnut varieties in Kole. Serenut 6T had generally the best PUE followed by Serenut 5R and finally Serenut 2

implying that Serenut 6T was efficiently converting the absorbed phosphorus in to agronomic yield. Generally response of grain yield and phosphorus utilization efficiency of groundnut varieties to phosphorus source and/with inoculation application was strongly influenced by heterogeneity in soil fertility. Serenut 5 is best targeted to all the field types in both districts but will need phosphorus + inoculation with rhizobia in medium and poor fields while in good field it may require only phosphorus fertilizer preferable supplied as TSP. TSP has a higher grade analysis (46% P_2O_5) compared to SSP (22% P_2O_5) and thus would be much cheaper to use since phosphorus sources did not differ significantly in this field type.

Results from this study also indicated significant difference between groundnut varieties and field type for PUE however it fell short of pointing out clearly what was causing the difference particularly variety variation. There is therefore a need for further comphrensive research to establish the genetic basis for the difference as this would be key in breeding and developing phosphorus efficient groundnut cultivars required for development of agronomic practices that are more phosphorus efficient.

Acknowledgments

Reference

Abate, T., Ugen, M., Okello, D.K., Obong, Y., Silim, S., and Rao, N.V.P.R.G., 2012. A monthly publication of the Tropical Legumes II project. Bulletine of Tropical Legumes. Available at http//www.icrisat.org/tropicallegumesII.

Balemi T., Schenk M.K. (2009). Genotypic difference of potato in carbon budgeting as amechanism of phosphorus utilization efficiency, *Plant Soil* 322: 91–99.

Dobermann, A. 2007. Nutrient use efficiency–measurement and management. Pp 1-28. In Fertilizer Best Management Practices. IFA International Workshop on Fertilizer Best Management Practices (FBMPs). 7-9 March, 2007. Brussels, Belgium.

Ebanyat, P., 2009. Aroad to food? Efficacy of nutrient management options targeted to heterogeneous soilscapes in the Teso farming system Uganda. PhD Thesis, Wageningen University, The Netherlands. 217p.

Fageria, N. K., and V. C. Baligar. 1997. Phosphorous—use efficiency by corn genotypes. Journal of Plant Nutrition 20: 1267–1277.

Giller, K.E., 2001. *Nitrogen Fixation in Tropical Cropping Systems*. 2nd Edition, CA International, Wallingford, UK.

Gobarah, M. E., Mohamed, M. H. and Tawfik, M. M. 2006. Effect of phosphorus fertilizer and foliar spraying with zinc on growth, yield and quality of groundnut under reclaimed sandy soils. *Journal of Applied Science Research,* 2**,** 491-496.

Hemalatha, S., Praveen rao, V., Padmaja, J. and Suresh, K. 2013. An overview on role of phosphorus and water deficits on growth, yield and quality of groundnut (*Arachis hypogaea* L.). *International Journal of Applied Biology and Pharmaceutical Technology,* 4**,** 188-201.

Kakar, K. M., Tariq, M., Taj, F. H., and Nawab, K. (2002). Phosphorus use efficiency of soybean as affected by phosphorus application and inoculation. *Pak. J. Agron*. 1, 49–50.

Krishna, K.R. 1997. Phosphorus uptake and utilization efficiency in peanut. *Peanut science*. 24: 1-6.

Mtambanengwe, F., Mapfumo, P., 2005. Organic matter as an underlying cause of soil fertility gradients in smallholder farms in Zimbabwe. *Nutrient Cycling in Agroecosystems* 73, 227-243.

Ojiem, P. 2006. Exploring socio-ecological niches for legumes in western Kenya smallholder farming system. PhD Thesis, Wageningen University, The Netherlands. 167p.

Page, W.W., Busolo-Bulafu, C.M., vander Merwe, P.J.A., Chancellor, T.C.B., 2002. Groundnut Manual for Uganda: Recommended Groundnut Production Practices for Smallholder Farmers in Uganda. Natural Resources Institute, Chatham, UK, p. 17.

Rose T. J., Wissuwa M. (2012). "Rethinking internal phosphorus utilization efficiency (PUE): a new approach is needed to improve PUE in grain crops," in *Advances in Agronomy*, Vol.80 ed. Sparks D. L., editor. (New York: American Society of Agronomy and Academic Press;) 183–215.

Rose, T. J., Rose, M. T., Pariasca-Tanaka, J., Heuer, S., and Wissuwa, M. (2011). The frustration with utilization: Why have improvements in internal phosphorus utilization efficiency in crops remained so elusive? Front. *Plant Nutr*. 2, 1–5.

Tittonell, P., Muriuki, A., Shepherd, K.D., Mugendi, D., Kaizzi, K.C., Okeyo, J., Verchot, L.V., Coe, R., Vanlauwe, B. 2010. The diversity of rural livelihoods and their influence on soil fertility in agricultural systems of East Africa–A typology of smallholder farms. Agricultural Systems 103:83-97

Wang, X., Shen, J., and Liao, H. (2010). Acquisition or utilization, which is more critical for enhancing phosphorus efficiency in modern crops? *Plant Sci*. 179, 302–306.

Youngdahl, L.J. (1990). Differences in phosphorus efficiency in bean genotypes. *Plant Nutr.,* 13, pp. 1381–1392

6.1.5 EFFECTS OF TILLAGE PRACTICES AND ORGANIC CROPPING SYSTEMS ON CROP YIELD IN YATTA SUB- COUNTY KENYA

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Abstract

The study was conducted, in semi-arid Yatta sub-county, to evaluate the influence of tillage practices, cropping systems and organic inputs on crop yield. It was carried out between October 2012 to February 2013 short rain season and April 2013 to August 2013 long rain season. Randomized Complete Block Design with a split-split plot arrangement replicated thrice was used. Main plots were tillage practices; Oxen plough, tied ridges and furrows and ridges. Split-plots were cropping systems; mono cropping, intercropping, and crop rotation while split-split plots were organic inputs; Farm Yard manure, Minjingu Rock Phosphate, combined Minjingu Rock Phosphate + Farm Yard manure, and control. Test crops were sorghum and sweet potatoes with Dolichos (*Dolichos lablab*) and chickpea (*Cicerarietinum*L) either as intercrops or in rotation. Plant sampling was done by harvesting the grain and tuber and yield determined by weighing. There was a significant (P≤0.05) increased in yield with application of combined Minjingu Rock Phosphate + Farm Yard manure of 16.27 t/ha and 1.38 t/ha for sweet potatoes and sorghum mono crop respectively under TR. There was a significant (P≤0.05) increased yield of chickpea and dolichos under combined tied ridges, intercropping of sorghum with chickpea (1.44 tha[-1]) and dolichos (1.38 tha[-1]) with application of combined Minjingu Rock Phosphate + Farm Yard manure during SRS of 2012. Improved yield of sorghum and sweet potatoes attained with the combined TR, mono cropping with application of combined Minjingu Rock Phosphate + Farm Yard manure.

Key words: cropping systems; organic inputs; semi arid; tillage practices, yield;

Introduction

Sweet potato (*Ipomoea batatas L*) is among the world`s most important and under- exploited crop. It is commonly referred to a subsistence, food security, or famine relief crop (Scott and Maldinado, 1999). In addition sweet potato provides good ground cover, and is usually cultivated with little or no fertilizer (Lusweti *et al.,* 1999). In Africa, sorghum is largely a subsistence food crop. It is crucially important to food security in Africa as it is uniquely drought resistant among cereals and can withstand high temperatures, grow in areas of annual rainfall 500-700mm per year. Noted also is that sorghum is an important crop in East Africa (Taylor *et al.*, 2010).Sorghum (*sorghum bicolor L.*) economically rated as the fifth most important cereal after maize, wheat, barley, and rice. It is a drought resistant and performs well on a range of poor soils with low rainfall often out-yielding most cereals in hot and dry environments. It is particularly adapted to agroecological zones of Kenya, which are arid and semi-arid. These include the semi-arid areas of Eastern Kenya, the coastal, the waterlogged areas (Kameri-Mbote, 2005). Sorghum and sweet potato are crops that were widely grown by the resource poor farmers in the ASALs of

Kenya for subsistence and as a source of income (Macharia, 2004). Sweet potato and sorghum are typically hardy and adapted to the local climate, thus making them very valuable.

To the contrary farmers in the arid and semi arid lands areas cultivate a variety of crops of which the main ones are maize, beans, green grams and cowpeas under rain-fed agriculture and horticultural crops such as oranges, mangoes, bananas, tomato, onions, kale, pawpaw and citrus (KARI-NDFRC, 1995). The farmers in Yatta Sub County have abandoned the traditional crops, which have the potential to contribute to food security, nutrition, health, income generation, and environmental services (NEMRI, 2009). These crops are drought resistant and can withstand high temperature unlike the introduced crops. Planting of drought-resistant crops reduces the risk of total loss during drought as a result of overreliance in one crop. Intercropping generate beneficial biological interaction between crops increasing grain yield and stability, more efficient use of available resources and reducing weed pressure (Kadziuliene 2009). Well-managed crop rotations increase soil organic matter to sufficient levels help to moderate soil moisture, retain moisture in dry conditions, and allow excess moisture to drain away in wet seasons. Shifting crop types also helps vary water demand within the soil profile. The deep-rooted crops following shallow crops can access moisture reserves as well as capture any nutrients that have leached below the shallower root zones before they reach groundwater (Kadziuliene 2009).

Many techniques have been tried to utilize rain water of these are ridges and furrows and tied ridges with mulching is one of the most effective measures (Li *et al.,*2000). In addition Farmyard manure acts as an alternative source of fertility enhancement for inorganic fertilizer as they release nutrients slowly and steadily over long periods and improve the soil fertility status by activating the soil microbial biomass (Ayuso *et al.,* 1996, Belay *et al., 2001*). It contains all the nutrients needed for crop growth including trace elements.

The current study investigated the effects of tillage practices, cropping systems and organic inputs on crop yield in Yatta sub-county, Kenya.

Materials and methods

Study Site

The study was carried out in Yatta sub-county, Kenya (longitude -1.4667 ºS, latitude 37.8333°E, 944m asl). The sub-county falls under agro- ecological zones IV, which is, classified as semi-arid lands (Jaetzold and Schmidt, 2006). The soils in Yatta Sub County are a combination of Acrisols and Luvisols with Ferralsols (WRB, 2006). In most places, they have topsoil that is loamy sand to sandy loam, sandy clay to clay with low nutrient availability (Kibunja *et al.,* 2010).

It has a semi-arid climate with mean annual temperature varying from 18ºC to 24ºC and experiences bimodal rainfall with long rains season commencing early April to May (about 400 mm) and short rains season commencing from early October to December (500 mm). Most of the farmers in the sub county are small-scale mixed farmers. Crops grown in the area include maize, beans, pigeon pea, green grams, sorghum, and cowpea (Macharia, 2004).

Treatments and Experimental design

The treatments were tillage practices (Oxen plough, tied ridges and, furrows and ridges), cropping systems (mono cropping, intercropping, and crop rotation) and organic inputs (farmyard manure, rock phosphate, and combined Farmyard manure and rock phosphate) and control.

The experiment was in a Randomized Complete Block Design with split-split plot arrangement. The main plots (150 by 60metres) were; tillage practices (Oxen plough, tied ridges and furrows, and ridges). Split plots (10 by 4metres) were cropping systems (mono cropping, intercropping, and crop rotation) and split-split plots (2.5 by 1metres) were organic inputs (farmyard manure, rock phosphate and combined Farmyard manure and rock phosphate). A control (no organic input applied) was also included as a split-split plot. The test crops were sweet potatoes (*i pomeabatatas*l.lam) and sorghum (*sorghum bicolor l.*) with Dolichos (*Dolichos lablab)* and chickpea Chickpea (*Cicerarietinum*L.) either as intercrops or in rotation.

Field Practices

Land was prepared manually using oxen plough in late September and planted in October short rain season 2012 and April long rain season 2013. Tillage practices (tied ridges and furrows and ridges) were constructed during planting with measurements according to crop spacing. Manure was broadcasted at a rate of 5t/ha and minjingu rock phosphate (MRP) at 498 Kg/ha equivalent to 60 Kg P/ ha and mixed thoroughly with the soil before the vines and seeds were placed in the holes. Sweet potatoes (wabolinge variety) were propagated through cuttings of 30 cm long at spacing of 90 cm between rows and 30 cm within rows. Weeding was done 5 weeks after planting and harvesting was done after 6 months when the leaves were yellow and dry. Harvesting was done using a sharp hoe by removal of all tubers (Mureithi, 2005). Sorghum (serendo variety) was sown at spacing of 75 cm by 30 cm while dolichos and chickpea were planted at a spacing of 30 cm within the sorghum and sweet potato rows. Weeding was done after 5 weeks of planting. Harvesting was done after three months when it had reached physiological maturity.

Plant sampling

Plant sampling for the grain and tuber was done at the crop maturity within the middle rows and two rows left on the sides during the harvesting stage for sorghum and for sweet potato by harvesting within a one metre square area selected using 1 m^2 quadrant was harvested. The grain yield was determined by weighing the grains in Kg/m^2 whereas for the sweet potato yield was determined by weighing the tuber in Kg/m^2. This was then converted into tha^{-1} using the formula:

Grain/tuber yield (tha^{-1}) = $\underline{10000m^2 * kgha^{-1}}$ /1000kg

Area in m^2

Statistical analysis

Data was subjected to general analysis of variance using Genstat statistical software (Payne *et al.,* 2005b). Means were separated using least significant difference at a probability level of 5%.

Results and discussion

Results

Dolichos (*Lablab purpureus*) and chickpea (*Cicer arietinum L.*) yield

There was a significant (P≤0.05) increased yield of chickpea and dolichos for combined tied ridges, intercropping of sorghum with chickpea (1.44 tha$^{-1)}$) and dolichos (1.38 tha$^{-1)}$) with application of MRP+FYM during SRS of 2012 (table 1). The yield of the legumes also increased under the intercropping or rotation with sweet potato as compared to with sorghum under tied ridges with the application of MRP+FYM. Accordingly intercropping chickpea and dolichos with sweet potato (1.54 tha^{-1}) and (1.48 tha^{-1}) while with sorghum (1.38 tha^{-1}) and (1.44 tha^{-1}) respectively during the SRS of 2012(Table 14).

Dolichos and chickpea grain yields were significantly greater in the LRS of 2013 (1.48 tha^{-1}) across treatments compared to SRS of 2012 (1.38 tha^{-1}) intercropping sorghum with dolichos (table 1).

Sorghum (*sorghum bicolor L.*) and sweet potato (*Ipomoea batatas L*) yield

There was a significant (P≤0.05) high yield for combined tied ridges, mono cropping and MRP+FYM led to improved yield (1.38 tha^{-1} and 16.27 tha^{-1}) sorghum and sweet potato respectively as compared to furrows and ridges (1.31 tha^{-1} and 15.67 tha^{-1}) and oxen plough (1.29 tha^{-1} and 16.17 tha^{-1}) during SRS 2012 this was attributed to increased moisture content under tied ridges as compared to oxen plough and furrows and ridges (Table 2 and 3)

There was an increase in the yield of sweet potato and sorghum in dolichos rotation (14.81 tha^{-1} and 1.44tha^{-1}) whereas the lowest was noted in the intercrop (13.61 tha^{-1} and 1.07 tha^{-1}) during LRS 2013. Combined TR, mono cropping sorghum and MRP+FYM had a higher yield during the long rain season (1.38tha^{-1} and 16.27 tha^{-1}) as compared to short rain season (1.39 tha^{-1} and 17.29 tha^{-1}) as noted in (Table 2 and 3).

Discussion

Reduced crop yield under intercropping was due to higher competition between two plants for light, nutrients and soil moisture leading to a noticeable low yield under the intercrop whereas higher yield under rotation was due the breaking of diseases and pests cycle as a result of change in crop type .This could also be due to lack of competition of nutrients, water and light with the legume cover crop (Wanderi *et al.,* 2003). In other studies, many justifications have been presented for yield increase in crop rotation Rathke *et al., (*2005) due to pests and diseases control when crops are rotated, increasing soil biological activity Larkin, (2008), and rising water use efficiency Christen and Sieling, (1995) are the important reasons for increasing grain yield in crop rotation. Application of crop rotation along with increasing soil organic matter increases biodiversity and soil biological community Kamkar and Damghani, (2009).

 Increased yield for long rain season to prolonged rainfall during the long rain season, which translated to a higher yield. This also implies that under such prolonged rainfall the crops utilize the nutrients. The higher grain yields in the LRS of 2013 were as a result of improved soil

nutrient status and soil moisture content in soil due to residual effect of the of the organic inputs MRP+FYM and FYM and its subsequent uptake by the crops. (Buresh *et al.,*1997*) reported* elevated available N,P, K and organic carbon content in soil due to residual effect of the amendments applied such as farmyard manure and its subsequent uptake by the crops. Chickpea seed yield was reported by Lopez *et al*. (2004) to strongly depend on rainfall during flowering and seed filling stages, In Northern Ethiopia, Brhane *et al*. (2006) found sorghum (*Sorghum bicolour* L. Moench) yield to be increased by 62% with tied-ridging compared with flat planting. Adoption of tied-ridging for small-scale sorghum production in Africa was found to increase farm income by 12% (Brhane *et al*. 2006).

The retained soil cover under intercropping of sweet potato reduces evaporative loss, thereby retaining the soil moisture for longer crop use. Increased dolichos and chickpea yield under combined TR, intercropping sorghum chickpea was attributed to this increased soil moisture content and improved soil nutrient status due to the application of MRP+FYM, intercropping and tied ridges as compared to oxen plough and furrows and ridges. Tied ridges conserve soil moisture that was then availed for crop consumptive use. Crop roots absorb this available moisture for growth and development, giving the crop under this treatment better performance in terms of grain yield. Kumar et al. (2000) observed that availability of higher amounts of moisture during various stages of crop growth resulted in better crop growth and thus improved yield.

Conclusion

Combined Tied-ridging, rotation of sweet potato and sorghum with dolichos with application of FYM+MRP led to an increase in crop yield. Integrated use of farm yard manure + minjingu rock phosphate with tied ridges and crop rotation would be a better and practical approach to sustain soil fertility and crop productivity.

References

Ayuso MA, Pascal JA, Garcia C, Hernandez T. 1996. Evaluation of urban waste for agricultural use. Soil Sci. Plant Nutr., 42:105-. 111.

Aziz T, Ullah S, Sattar A, Nasim M, Farooq M, Khan MM. 2010. Nutrient availability and maize (*Zea mays*) growth in soil amended with organic manures. Int. J. Agric. Biol 12 (4), 621-624.

Belay A, Classens AS, Wehner FC, De-Beer JM. 2001. Influence of residual manure on selected nutrient elements and microbial composition of soil under long-term crop rotation South Afr. J. Plant and Soil. 18:1-6.

Boateng SA, Zichermann J, Kornahrens M. 2006. Poultry manure effect on growth and yield of maize. West Africa J. Appl. Ecol., 9: 1-. 11.

Brhane, G., C.S. Wortmann, M. Mamo, H. Gebrekidan, and A. Belay. 2006. Micro-basin tillage for grain sorghum production in semiarid areas of Northern Ethiopia. Agronomy J. 98: 124-128.

Buresh RJ, Smithson PC, Hellums DT. 1997. Building soil phosphorus capital in Africa. In: Buresh RJ.,Sanchez PA., Calhoun F. Replenishing Soil Fertility in Africa, SSSA Special Publication. (51):111-149. Madison, WI: SSSA; ASA.

Heluf Gebrekidan and Yohannes Uloro Ale, 2002. Yield response of Sorghum to tied ridges and planting methods on Entisols and Vertisols of the eastern Ethiopian highlands.

Journal of Agriculture and Rural Development in the Tropics and Subtropics 104, No 2 (2003).

Hirzel J, Matus I, Novoa F, Walter I. 2007. Effect of poultry litter on silage maize (*Zea mays* L.) production and nutrient uptake. Spain J. Agric Res. 5 (1), 102-109.

Iqbal M, Hassan AU, Ali A, Rizwanullah M. 2005. Residual effect of tillage and farm manure on some soil physical properties and growth of wheat (*Triticumaestivum* L.). Int. J. Agri. Biol., 7: 54-57.

Kadziuliene, Z., Sarunaite, L., Dereikyte, I., Maiksteniene, S., Arlauskiene, A., Masilionyte, L., Cenuleviciene, R. And Zekaite, V.,2009. Qualitative effects of pea and spring cereals intercrop in the organic farming systems. *Agron. Res.* **7**(2): 606-611.

Kamkar B, Mahdavi Damghani A 2009. Principles of sustainable agriculture. Ferdowsi University Press. In Persian. 345 pp.

Kameri-Mbote, P. 2005. Regulation of GMO crops and food. Case study of Kenya.

Kibunja CN, Mwaura FB, Mugendi DN 2010. Long-term land management effects on soil properties and microbial populations in a maize-bean rotation at Kabete, Kenya. Afr J Agric Res.

Kumar J, 2000. Pulses: Towards a quantitative leap. In "Hindu Survey of Indian Agriculture", pp. 49-52.

Li Z.A., Weng H., Yu Z.Y. 1995. The impact of human activities on the soil nitrogen mineralization in artificial forests. Chinese Bulletin of Botany, *12*: 142–148.(in Chinese)

Lopez-Bellido, L., R. J. Lopez-Bellido., J. E. Castillo and F. J. Lopez-Bellido 2004.Chickpea response to tillage and soil residual nitrogen in continuos rotation with wheat. *Field Crops Research 88(2/3):191-200.*

Lusweti C.M., Nkonge C., Nandasaba J., Wanjekeche E., Lobeta T. and Rees D. 1999. "On-farm evaluation of promising Sweet Potato varieties in the NARC Kitale mandate region". Mini paper for end of KARI/DFID NARP II Project Conference pp. 261.

Macharia, P. 2004. Kenya. Gateway to land and water information: Kenya National Report. FAO (Food and Agriculture Organization). http://www.fao.org/ag/agL/swlwpnr/reports/y_sf/z_ke/ke.htm.

Marschner P. 2011. Marschner's mineral nutrition of higher plants. *3rd* edn. *London*: *Academic Press*, 135–178.

Muhammad D, Khattak RA. 2009. Growth and nutrient concentration of maize in press mud treated saline-sodic soils. Soil Environ. 28:145–155.

Mullins CE (2000). Hardsetting soils. In 'The Handbook of Soil Science' (Ed ME Fraser), pp. G65-G85 (CRC Press: New York).

Rathke G.W., Christen O., Diepenbrock W., 2005. Effects of nitrogen source and rate on productivity and quality of winter oilseed rape (Brassica napus L.) grown in different crop rotations. *Field Crops* Research 94 (*2005*) 103–113.

Rees RM, Ball BC, Campbell CD, Watson CA. 2000. Sustainable management of soil organic matter. *CAB International*, *Wallingford*, pp 393–412.

Scott G.J. and Maldonado L. 1999. CIP sweet potato facts. A compendium of key Figure and analysis for 33 sweetpotato-producing countries. International Potato Center (CIP). Lima,Peru. (brochure).

Shirani H, Hajabbasi MA, Afyuni M, Hemmat A. 2002. Effect of farm manure and tillage systems on soil physical properties and corn yield in central Iran. Soil and Tillage Research. 68: 101-108.

Taylor JRN, Emmambux MN. 2010. Developments in our understanding of sorghum polysaccharides and their health benefits. Cereal Chemistry, 87(4), pp 263-271.

Wanderi, S.W., Mburu M.W.K. and Silim S.N. 2008. Light and water use in maize (*Zea mays)*-pigeon pea (*Cajanus cajan)* intercrop under semi–arid conditions of Kenya. In: Proceedings of the 10th KARI Biennial scientific conference, 12- 17th November, 2006.Nairobi.

Appendix i: Tables

Table 11: Effects of tillage practice, cropping, cropping systems and organic inputs on of dolichos and chickpea yield during SRS of 2012 and LRS of 2013

PLOTS	TP	CS	CROPS	CROP	SRS 2012 CTRL	MRP	FYM	MRP+ FYM	LRS 2013 CTRL	MRP	FYM	MRP+ FYM
SOR PLOTS	FR	Intercropping	SOR/CP	CP	1.23^{f}	1.28^{fg}	1.29^{fg}	1.31^{fgh}	1.34^{e}	1.38^{efg}	1.39^{efg}	1.41^{gh}
		Intercropping	SOR/DOL	DOL	1.21^{defg}	1.23^{gh}	1.25^{gh}	1.31^{ghi}	1.32^{e}	1.33^{e}	1.35^{ef}	1.39^{efg}
		Crop Rotation	CP-SOR	CP	1.13^{def}	1.16^{def}	1.17^{def}	1.23^{gh}	-	-	-	-
		Crop Rotation	DOL-SOR	DOL	1.05^{bc}	1.14^{def}	1.18^{defg}	1.23^{gh}	-	-	-	-
	OP	Intercropping	SOR/CP	CP	1.06^{bc}	1.08^{cd}	1.09^{cd}	1.15^{def}	1.16^{a}	1.18^{a}	1.20^{ab}	1.25^{c}
		Intercropping	SOR/DOL	DOL	1.19^{efg}	1.26^{fg}	1.28^{fg}	1.29^{fg}	1.29^{d}	1.36^{ef}	1.38^{efg}	1.39^{efg}
		Crop Rotation	CP-SOR	CP	1.27^{gh}	1.32^{ghi}	1.33^{ghij}	1.41^{jk}	-	-	-	-
		Crop Rotation	DOL-SOR	DOL	1.04^{abcd}	1.12^{def}	1.16^{def}	1.22^{defg}	-	-	-	-
	TR	Intercropping	SOR/CP	CP	1.34^{ghij}	1.37^{ghij}	1.39^{ghij}	1.44^{jk}	1.43^{gh}	1.46^{i}	1.48^{ij}	1.49^{ij}
		Intercropping	SOR/DOL	DOL	1.19^{efg}	1.33^{fgh}	1.36^{fghi}	1.38^{fghi}	1.29^{d}	1.43^{gh}	1.46^{i}	1.48^{ij}
		Crop Rotation	CP-SOR	CP	1.17^{efg}	1.29^{ghi}	1.34^{ghij}	1.39^{jk}	-	-	-	-
		Crop Rotation	DOL-SOR	DOL	1.01^{a}	1.1^{de}	1.13^{def}	1.19^{defg}	-	-	-	-
SP PLOTS	FR	Intercropping	SP/CP	CP	1.33^{f}	1.38^{fg}	1.39^{fg}	1.41^{fgh}	1.44^{e}	1.48^{efg}	1.49^{efg}	1.51^{gh}
		Intercropping	SP/DOL	DOL	1.31^{defg}	1.33^{gh}	1.35^{gh}	1.41^{ghi}	1.42^{e}	1.43^{e}	1.45^{ef}	1.49^{efg}
		Crop Rotation	CP-SP	CP	1.23^{def}	1.36^{def}	1.27^{def}	1.33^{gh}	-	-	-	-
		Crop Rotation	DOL-SP	DOL	1.15^{abcd}	1.24^{def}	1.28^{defg}	1.33^{gh}	-	-	-	-
	OP	Intercropping	SP/CP	CP	1.16^{abcd}	1.18^{de}	1.19^{de}	1.25^{def}	1.26^{a}	1.28^{a}	1.30^{ab}	1.35^{c}
		Intercropping	SP/DOL	DOL	1.29^{f}	1.36^{fg}	1.38^{fg}	1.39^{fg}	1.39^{d}	1.46^{ef}	1.48^{efg}	1.49^{efg}
		Crop Rotation	CP-SP	CP	1.37^{gh}	1.42^{ghi}	1.43^{ghij}	1.51^{jk}	-	-	-	-
		Crop Rotation	DOL-SP	DOL	1.14^{abcd}	1.32^{def}	1.26^{def}	1.32^{defg}	-	-	-	-
	TR	Intercropping	SP/CP	CP	1.44^{ghij}	1.47^{ghij}	1.49^{jk}	1.54^{jk}	1.53^{gh}	1.56^{i}	1.58^{ij}	1.59^{ij}
		Intercropping	SP/DOL	DOL	1.29^{a}	1.43^{fgh}	1.46^{fghi}	1.48^{fghi}	1.39^{d}	1.43^{gh}	1.56^{i}	1.58^{ij}
		Crop Rotation	CP-SP	CP	1.27^{def}	1.39^{ghi}	1.44^{ghij}	1.49^{jk}	-	-	-	-
		Crop Rotation	DOL-SP	DOL	1.11^{abc}	1.2^{de}	1.23^{def}	1.29^{defg}	-	-	-	-

Legend: SOR-sorghum, SP-sweet potato, DOL-dolichos, CP-chickpea, TP-tillage practice, TR-tied ridges, FR-furrows and ridges, OP-oxen plough, FYM-farm yard -manure, MRP-minjingu rock phosphate, CTRL-control, LRS-long rain season, SRS-short rain season, CS-cropping

system. Dash (–) indicates in Rotation SP/SOR were harvested during LRS 2013. Means followed by the same letters in the same season are not significantly different at P ≤ 0.05.

Table 2 : Effects of tillage practice, cropping systems and organic inputs on sorghum yield during SRS 2012 and LRS 2013

TP	CS	CROPS	CROP	SRS 2012 CTRL	SRS 2012 MRP	SRS 2012 FYM	SRS 2012 MRP+ FYM	LRS 2013 CTRL	LRS 2013 MRP	LRS 2013 FYM	LRS 2013 MRP+ FYM
FR	Intercropping	SOR/CP	SOR	0.92^{ab}	0.97^{abc}	0.94^{abc}	0.98^{abc}	0.91^{a}	0.92^{ab}	0.94^{ab}	0.97^{ab}
	Intercropping	SOR/DOL	SOR	0.95^{abc}	0.98^{abc}	0.99^{abcd}	1.01^{abcd}	0.93^{ab}	0.94^{ab}	0.95^{ab}	1.01^{abc}
	Mono cropping	SOR	SOR	1.23^{f}	1.28^{fg}	1.29^{fg}	1.31^{fgh}	1.21^{defg}	1.23^{gh}	1.25^{gh}	1.31^{ghi}
	Crop Rotation	CP-SOR	SOR	-	-	-	-	1.13^{def}	1.16^{def}	1.17^{def}	1.23^{gh}
	Crop Rotation	DOL-SOR	SOR	-	-	-	-	1.05^{abcd}	1.14^{def}	1.18^{defg}	1.23^{gh}
OP	Intercropping	SOR/CP	SOR	0.81^{a}	0.95^{abc}	0.96^{abc}	1^{abcd}	1.06^{abcd}	1.08^{de}	1.09^{de}	1.15^{def}
	Intercropping	SOR/DOL	SOR	0.87^{a}	1.07^{abcde}	1.17^{f}	1.27^{fg}	0.93^{ab}	1.12^{def}	1.22^{defg}	1.38^{jk}
	Mono cropping	SOR	SOR	1.19^{f}	1.26^{fg}	1.28^{fg}	1.29^{fg}	1.27^{gh}	1.32^{ghi}	1.33^{ghij}	1.41^{jk}
	Crop Rotation	CP-SOR	SOR	-	-	-	-	0.94^{ab}	1.01^{abc}	1.05^{abcd}	1.1^{de}
	Crop Rotation	DOL-SOR	SOR	-	-	-	-	1.04^{abcd}	1.12^{def}	1.16^{def}	1.22^{defg}
TR	Intercropping	SOR/CP	SOR	0.86^{a}	0.87^{a}	0.88^{a}	0.94^{ab}	0.91^{ab}	0.94^{abc}	0.95^{abc}	0.98^{abc}
	Intercropping	SOR/DOL	SOR	1.01^{abcd}	1.03^{abcd}	1.04^{abcd}	1.06^{abcde}	0.99^{abc}	1^{abc}	1.01^{abc}	1.07^{de}
	Mono cropping	SOR	SOR	1.19^{a}	1.33^{fgh}	1.36^{fghi}	1.38^{fghi}	1.17^{def}	1.29^{ghi}	1.34^{ghij}	1.39^{jk}
	Crop Rotation	CP-SOR	SOR	-	-	-	-	1.01^{abc}	1.1^{de}	1.13^{def}	1.19^{defg}
	Crop Rotation	DOL-SOR	SOR	-	-	-	-	1.34^{ghij}	1.37^{ghij}	1.39^{jk}	1.44^{jk}

Legend: SOR-sorghum, SP-sweet potato, DOL-dolichos, CP-chickpea, TP-tillage practice, TR-tied ridges, FR-furrows and ridges, OP-oxen plough, FYM-farm yard -manure, MRP-minjingu rock phosphate, CTRL-control, LRS-long rain season, SRS-short rain season, CS-cropping system. Dash (–) indicates in Rotation legumes were harvested during SRS of 2012. Means followed by the same letters in the same season are not significantly different at P ≤ 0.05.

Table 3 : Effects of tillage practice, cropping systems and organic inputs on crop yield during SRS 2012 and LRS 2013

TP	CS	CROPS	SRS 2012				LRS 2013			
			CTRL	MRP	FYM	MRP+ FYM	CTRL	MRP	FYM	MRP+ FYM
FR	intercropping	SP/CP	8.45a	12.17bc	13.42bcd	13.41bcd	13.61abcd	15.04defg	15.52gh	15.62gh
	Intercropping	SP/DOL	9.25a	12.33bc	13.35bcd	13.35bcd	11.62a	12.84abc	13.25abc	13.24abc
	Monocropping	SP	15.2bcdef	15.53bcdef	15.67bcdef	15.77bcdef	16.17ghi	16.53ghij	16.69ghij	16.79jk
	Crop rotation	CP-SP	-	-	-	-	11.87a	13.04abc	13.44abcd	13.43abcd
	Crop rotation	DOL-SP	-	-	-	-	11.97a	13.15abc	13.54abcd	13.54abcd
OP	intercropping	SP/CP	12.56bc	13.89bcd	14.33bcde	14.32bcde	13.61abcd	15.04defg	15.52gh	15.62gh
	Intercropping	SP/DOL	10.72b	11.85b	12.23bc	12.33bc	11.62a	12.84abc	13.25a bc	13.24a bc
	Monocropping	SP	14.7bcde	15.03bcde	15.17bcdef	15.27bcdef	16.17ghi	16.53ghij	16.69ghij	16.79jk
	Crop rotation	CP-SP	-	-	-	-	11.5a	12.68abc	13.07abc	13.17abc
	Crop rotation	DOL-SP	-	-	-	-	11.75a	12.92abc	13.32a bcd	13.31abcd
TR	intercropping	SP/CP	11.17b	12.34bc	12.74bc	13.14bcd	12.1 ab	13.37abcd	13.8abcd	14.23de
	Intercropping	SP/DOL	12.9bc	13.53bcd	13.67bcd	13.77bcd	13.98de	14.66def	14.81def	14.81def
	Monocropping	SP	15.7bcdef	16.03bcdef	16.17bcdef	16.27bcdef	17.27jk	17.63jkl	17.79jkl	17.89jklm
	Crop rotation	CP-SP	-	-	-	-	11.95a	13.12abc	13.51abcd	13.61abcd
	Crop rotation	DOL-SP	-	-	-	-	12.08a	13.26abc	13.65abcd	13.75abcd

Legend: SP-sweet potato, DOL-dolichos, CP-chickpea, TP-tillage practice, TR-tied ridges, FR-furrows and ridges, OP-oxen plough, FYM-farm yard -manure, MRP-minjingu rock phosphate, CTRL-contro, LRS-long rain season, SRS-short rain season, CS-cropping system. Dash (-) indicates in rotation legumes were harvested during the SRS 2012 whereas sweet potatoes and sorghum were harvested during the LRS 2013, Means followed by the same letters in the same season are not significantly different at P ≤ 0.0

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POSTER PRESENTATATIONS

1. EMBRYO RESCUE AFTER HYBRIDIZATION WITH SORGHUM

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Abstract
Striga hermonthica causes significant losses in maize yield throughout sub-Saharan Africa. Attempt to manage the weed by physical weeding is time consuming, tedious and often unsuccessful. Use of tolerant crop cultivars is a practical and efficient approach in management of *Striga*. Genes responsible for systemic acquired resistance (SAR) against the pernicious root parasite *Strigahermonthica*naturally found in some sorghum cultivar are associated with bio-fortified cell walls characterized by enhanced lignification, hemicellulose and phenylpropanoids deposition. In this study, hybrid embryo rescued *in vitro* after reciprocal crossing of susceptible farmer preferred maize with a resistant sorghum cultivar will be regenerated. Pre-embryos produced from interspecies parents that are fertilization compatible abort if allowed to develop because of genotypic incompatibility. To address this, immature hybrid zygotic embryos from cross-pollinated sorghum and maize kernels will be dissected and cultured on various MS media using basic tissue culture techniques. Preliminary regeneration studies already show that five maize inbred lines readily regenerate in tissue culture and are therefore candidates in reciprocal crossing with *Striga* resistant sorghum cultivarN-13.
Key words: Interspecies hybridization, systemic acquired resistance (SAR).

2. FIRST REPORT OF POTATO CYSTS NEMATODES (*Globodera rostochiensis*) IN KENYA

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Abstract
Irish potato (*Solanum tuberosum*) is an important crop in Kenya ranking second after maize. This crop supports Kenyan economy and address issue of food insecurity. Potato production is constrained by pests and diseases. However, plant parasitic nematodes (PPN) have not been considered a major threat to potato production in Kenya. *Globodera rostochiensis* is categorized by EPPO as A2 quarantined crop pest. It causes up to 80% yield loss and sometimes total crop failure. A survey of PPN associated with potatoes was conducted in four potato growing areas in Nyandarua County with an aim of identifying and reporting presence

of potato cyst nematode. Soil samples were collected various farms for nematode extraction. Nematode second stage juvenile (J2) were extracted from the soil samples using modified Baermann funnel technique while cysts were extracted using various modified techniques. Morphological characteristics of cysts and J2 were studied using compound microscope. The identity was confirmed by multiplex PCR test where DNA was extracted from cysts and the DNA amplified using two species specific primers, PITSp4 for *G. pallida* and PITSr3 for *G. rostochiensis* in combination with STI5 universal primer. PCR was run; PCR products were purified and sequenced at the Inqaba Biotech in South Africa and results confirmed in Germany. The generated sequences were compared with published sequences in NCBI database. Morphological description of the cyst and J2 from all the four samples matched those of *G. rostochiensis*. Ribosomal DNA-ITS sequence data were matched with all other available data sources in Gene Bank and had up to 99.5% match with *G. rostochiensis*. To our knowledge, this is the first report of PCN in Kenya. Further work is ongoing to study the occurrence, distribution, density and pathogenicity of the same, in various potato growing areas in Kenya.

Key words: *Globodera rostochiensis*, multiplex PCR, Potato cyst nematode

3. EFFECT OF WITHHOLDING IRRIGATION WATER AFTER COMPLETE HEADING ON SEED QUALITY TRAITS IN MWEA, KIRINYAGA – KENYA

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Abstract

Asian rice (*Oryza sativa*) and African rice (*Oryza glaberrima*) which originated from Asia and West Africa, respectively are staple food for a large part of the world's human population. Rice in Kenya is customarily grown in large scale rice irrigation schemes but the threat of climate change continues to impede its production especially due to drought resulting in water scarcity. The summation of all factors that contribute to seed performance including water availability is termed as quality seed. A research with the objective of investigating the effect of withholding irrigation after complete heading on seed quality was conducted in two sites namely Kenya Agricultural Research Institute (KARI)-Mwea and Mwea Irrigation Agricultural Development (MIAD)-Mwea. A split plot arrangements in a Randomized Complete Block Design (RCBD) with three replicates were used. Water withholding regimes (0, 10, 15, and 20 in terms of what?) after complete heading were the main plots while varieties (Nerica-1, Nerica-4, Nerica-10 and Basmati-370) were the sub plots. For the control (regime 0) water was supplied throughout the growth cycle. Data on germination on filter paper and sand, seed dormancy, 1000-seed weight, seedling length, abnormal seeds and seedling vigor index were recorded. ANOVA with SAS program version 9.2 was used to analyze the data. Results from the study indicated significant differences ($p < 0.05$) on seed quality variables across sites. Withholding water 20 days after complete heading produced significantly ($P < 0.05$) better quality seeds (in terms of what? Specify).

Water applied in paddy rice may be effectively rationed thereby increasing the acreage and production of rice while improving the quality of the seeds.

4. MORPHOLOGICAL CHARACTERIZATION OF GUAVA (*Psidium Guajava*) ACCESSIONS FROM A MOTHER BLOCK AT KENYA AGRICULTURAL LIVESTOCK RESEARCH ORGANIZATION IN CENTRAL KENYA

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Abstract

Genetic diversity exists in guava accessions in germplasm mother block at horticultural research institute (HRI) Muranga. This diversity has been demonstrated by the growth characteristic, fruit flesh colours and other traits observed in the 14 accession collected from different ecological regions of Kenya. However many of these guava accessions have not been characterized with regard to their fruit morphological traits, which is a prerequisite base for selection and breeding for most suitable varieties in terms fresh/processing fruit qualities and for future variety identification. The present study was conducted to establish a fruit morphological characterization data base for the 14 guava accessions at Kandara Horticulture research Centre. Twenty uniform mature guava fruits were harvested from four plants in each accession. Guava descriptors developed were used for the fruit characterization, including qualitative and quantitative traits. Data on fruit length, fruit width, fruit weight and outer flesh width was collected using a fowler electronic digital Vanier caliper and percentage sugar content was measured using a hand sugar refractometer. Data on number and seed weight of 100 seeds was done using an electronic weighing balance. The data was cleaned and analyzed using the SAS version 9.1 program for analysis of variance. The Student-Newman-Keuls (SNK) test for mean separation was then used on different variables. The results showed that there were significant differences between accessions, $p < 0.0001$. .Accessions T4 had highest means in fruit weight of 73.82gm followed by T2- 66.34gm and T5 with 59.627gm.The same accessions were superior in fruit length, inner flesh width and the percentage sugar content was T4 at 13.13 %, T2- 13.00 %, and T5- 12.00% respectively. The outer fruit color was yellow and inner flesh colour was pale pink. Accessions T4, T2 and T5 were found to be consistent in desirable fruit traits and recommended for further experiments. The results of this study will be used as a data base for further variety selection, molecular characterization and identification.

Key word: Guava accessions, fruit characterization, variety selection, morphological traits

5. SOME PHYSICAL PROPERTIES OF SELECTED SUDANESE WATERMELON FRUITS AND THEIR SEEDS

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Abstract

This study was carried out at the University of Kordofan- Elobied Sudan during the period of March-June 2014. The study aimed at determining some physical properties of fruits and seeds of four local cultivars of watermelon namely *kordofani*, *gishta*, *mokhtat* and *sifinja*. Study results revealed that the average fruit weight ranged from 4.37 to 7.57 kg, average fruit volume from 3.47 to 8.37 l, average fruit length from 22.07 to 47.50 cm, average fruit width from 18.80 to 37.65 cm, average fruit crust thickness from 8.00 to 18.67 cm and average fruit pulp weight from 2.44 to 4.95 kg. The study findings also showed that average total number of seeds varied from 598 to 798, average wet seed weight from 69.74 to 119.31 g, average dry seed weight from 27.81 to 68.27 g, average 100 seed weight from 3.51 to 8.98 g, average number of spoiled seeds from 11 to 46 and average weight of spoiled seeds from 0.13 to 0.57 g. Statistical analysis revealed that there were significant differences (P≤0.05) among the averages of all tested physical properties for fruits and their seeds. The study concluded that cultivar *gishta* was the best regarding the fruit properties where cultivar *kordofani* was the best concerning the seeds characteristics depending on physical properties.

Keywords: Physical Properties, Watermelon, Number, Weight, Volume, Length, Width, Thickness

6. UPSCALING POTATO BASIC SEED PRODUCTION: CAN THE USE OF STEM CUTTING AND HYDROPONIC TECHNOLOGY INCREASE POTATO PRODUCTION IN KENYA--- A REVIEW

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Abstract

Stem cutting in potato (*Solanum tuberosum*. L.) has enhanced exponentially the quantities of seeds produced in the Kenyan national potato programme due to the possibility of transplanting many stems at high density either from *in vitro* plantlets cuttings, stem cuttings and conventional seed tuber cuttings to produce small, disease free high quality tubers for subsequent field multiplication. The performance of seed tubers harvested from potato plants grown from *in vitro* plantlet cuttings, stem cuttings and conventional seed tuber cuttings are discussed explicitly with reports showing performance of seed tubers produced from stem cuttings as better in respect to plant growth, tuber number and tuber yield per hill as compared to seed tubers obtained from *in vitro* or conventional method. This has therefore

shown its high potential utilization in upscaling the basic seed production in Kenya. At Kenya Agricultural and Livestock Research Organization (KALRO), Tigoni, a rapid cost effective technique of stem cutting was developed for enhancing basic seed production. To ensure that the potato subsector plays its rightful role in increasing seed production deficit that is curtailing its increased yield production, it is necessary that seed production challenges along the value chain be tackled in a sustainable manner since the farmers still practice the same agronomic methods that were adopted in the 70s when the cultivation acreage was big. Therefore, this review paper outlines the progress achieved in the use of stem cuttings and hydroponics technology for production of high quality basic seed potato in Kenya.

Key words: Hydroponics, Stem-cuttings, In vitro, Plantlets

7. EFFECTS OF SELECTED SOIL WATER CONSERVATION STRATEGIES ON MAIZE YIELD STABILITY IN FARMER MANAGED TRIALS IN EMBU AND THARAKA-NITHI COUNTIES, KENYA

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Abstract
Smallholder farmers in Embu and Tharaka-Nithi counties have experienced a decline in crop yields in the recent decades due to continuous cropping without addition of adequate fertilizers and manures, and nutrient loss through crop harvest, soil erosion and leaching. The problem is intensified by low and erratic rainfall, low inherent water storage (by the soils) and poor water harvesting techniques that cause high rate of runoff leading to low soil profile water recharge and loss of essential soil nutrients. We set up on-farm trials to determine effects of selected soil water conservation (SWC) strategies on maize yield stability. The research was carried out in Mbeere South and Meru South sub-counties for four consecutive cropping seasons: short rains 2011, long rains 2012, short rains 2012, and long rains 2013. The experimental design was an unbalanced randomized complete block design with three SWC treatments replicated four times while the control treatment was practiced by all farmers. Treatments included mulching (MC), tied ridging (TR), minimum tillage (MT) and conventional tillage (CT). Data was subjected to analysis of variance using the mixed procedure in SAS 9.2 in which the factors site (2 levels), season (4 levels) and treatment (4 levels) and their interactions were considered as fixed effects, and farmers nested within season considered as a random effect. Compared with CT, yields were more stable under TR and MC with residual variances of 107.4 Mg ha^{-1} and, 183.3 Mg ha^{-1} respectively in Mbeere South. Mulching, MT and TR indicated yield stability with residual variances of 17.2 Mg ha^{-1}, 39.6 Mg ha^{-1}, and, 155.2 Mg ha^{-1} respectively in Meru South. There was statistical significance at $p<.0001$ in treatment by site interaction. Findings highlighted stable yields under TR and MC in Mbeere South while MC and MT were the best fit options in Meru South.

Key words; On-farm, Yield stability, Rain-fed production

8. EFFECTS OF INTEGRATED SOIL FERTILITY MANAGEMENT AND TIED-RIDGING ON SELECTED SOIL PROPERTIES AND CROP YIELDS IN MERU COUNTY, KENYA

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Abstract

Low soil fertility and the associated nutrient limitations for crop growth, limited availability of resources to farmers, nutrient mining, and drought have been acknowledged as pervasive constraints in smallholder farming systems in the region. Apart from soil nutrient loss, majority of smallholder farmers in central highlands of Kenya depend on rain-fed agriculture hence water stress is also a limiting factor to crop production. The general objective of the study is to evaluate the effect of integrated soil fertility management options and tied ridging on selected soil properties and crop yields in Meru County. It is part of a 3-year AGRA funded project entitled: *Scaling-up soybean and climbing bean production using a value chain approach in maize-based systems of the Central Highlands of Kenya.* The study is on-going at Kigogo, Meru South sub-County. The field experiment design is a split plot arranged in randomized complete block design replicated four times. Soil and water conservation with or without tied ridging is the main factor while ISFM technologies (manure + fertilizer, Tithonia biomass + fertilizer, mineral fertilizer) is the sub factor. Yield parameters under consideration are above ground biomass and dried grain yield for both maize and soybean. To evaluate the residual effects of the treatments on soil properties, pair-wise comparison of the initial and final soil chemical and physical properties will be analyzed at the end of the study. The output of this study would be invaluable to extension service providers, governments, bureaucrats and people in regional natural resource management groups in planning, designing and evaluating effective and efficient ISFM and SWC programs and projects at local, regional and national scales. This would in turn result in positive spin-offs in farmers' adoption of ISFM and SWC technologies.

9. CROP PRODUCTION BY LOCAL FARMERS IN THE FORESTS IMPROVED THE NATURAL REGENERATION ON DRYLAND OF SUDAN

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Abstract

The survival of natural forests in Sudan is facing a great challenge due to the conflict to secure food for ever increasing population on the account of their diminishing stocked areas and the efforts to manage them to sustain their environmental and economic values and services that are hardly considered by the politician and strategic planners. Each argument is striving to scrub out the other without providing evidence denying the achievement of both simultaneously. Therefore, this study investigated the effect of cropping on the natural

regeneration stocking density and performance. The natural regeneration was systematically sampled in four compartments in natural forests of *Acacia seyal*. One was left uncultivated and the other three were cultivated for either two, three or four years. Inventory of natural regeneration was carried out accordingly. Significant regeneration was found surviving on all compartments but it was denser where it succeeded cultivation. It was 750 seedlings ha^{-1} in uncultivated compartment and 1000 – 4000 seedlings ha^{-1} in cultivated ones. Moreover, the regeneration was vigorous and taller following the cultivation. The results underlined the oversight understanding of the negative impact of cropping on regeneration of natural forests and favored its integration in the restocking programs. This could solve the conflict on land and encourage the participation of the local communities in the management of forests as well as contributing in food security.

Keywords: Regeneration, Cropping, *Acacia seyal*, Integration

10. ASSESSMENT OF GENETIC VARIABILITY WITHIN GERMPLASM OF SWEET YELLOW PASSION FRUIT (*Passiflora edulis Sims f. flavicarpa Deg*)

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Abstract

Sweet yellow passion fruit (Passiflora edulis Sims f. flavicarpa Deg) is a hybrid fruit recently developed by KARI, incorporating the desired traits of the purple and yellow passion fruit varieties. KPF 4 is the most preferred line of sweet yellow passion fruit. Genetic variation is a phenomenon brought about by factors such as mutation, a permanent change in chemical structure of a gene, which leads to phenotypic variations. Recent observations have encountered abnormally shaped fruits of KPF 4 orchards in Embu County with successive seasons yielding abnormally shaped fruits. The fruits appear malformed, reduced in size and do not meet the quality requirements for both local and export markets. Preliminary experiments on bacterial infections as possible cause of these abnormal shapes have tested negative. A study is being conducted to determine the cause of the malformations, focusing on genetic factors. The study will employ Inter simple sequence repeats (ISSR), a powerful molecular marker system, that is used to analyse diversity by demarcation and estimation of genetic base of species. Populations will be developed with leaves collected from KPF 4 plants from different locations, including plants producing abnormally shaped fruits. Ten leaves will be randomly selected from each population and their genomic DNA extracted using slightly modified Doyle and Doyle Method (1990) and amplified with ISSR primers. Amplification will be done in a thermocycler applied Biosystem while electrophoresis will be performed in 2% w/v Agarose gel and stained with ethidium bromide and analyzed under UV illumination. Diversity of polymorphic markers will be analyzed using POPGENE software. A dendrogram will be constructed based on dissimilarity matrix using software mega 4.1. The results will be used to draw conclusions on the genetic stability of the sweet yellow passion and form the basis for future breeding efforts of this crop.

11. MORPHOLOGICAL CHARACTERIZATION, WATER STRESS AND NUTRIENT MANAGEMENT OF YELLOW PASSION FRUITS (*Passiflora Edulis, F. Flavicarpa.* Deg) IN MBEERE DISTRICT, EMBU COUNTY

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Abstract

Passion fruit has emerged as an important high value horticultural crop in Kenya. The yellow passion has gained wide adoption in Mbeere district due to its apparent adaptation to the hot arid conditions and a ready market for the fruit. Nevertheless, the current production levels of yellow passion fruit are low due to poor agronomic management, declining soil fertility levels and erratic rainfall patterns. Analysis of soil and assessment of plant behavior under varying amount of nutrients is requisite in optimization of nutrient requirements for passion fruit plants. In addition, based on the fact that each nutrient has a specific role in the physiological functions of plants, imbalances often result in characteristic symptoms, which permit the identification of the cause of the disorder. To establish the correct cause of the disorders requires knowledge of the symptoms and its cause which should be determined in both open and controlled experiments. The primary objective of this study is to assess water and nutrient management of yellow passion fruit grown by farmers in Mbeere District. The study will also carry out morphological characterization to determine the genetic structure of the cultivated populations to identify promising parents that can generate hybrids with favourable characteristics such as drought tolerance. The study will set up on-farm experiments with selected farmers in Mbeere District and a control experiment under greenhouse conditions at Kenyatta University. Active participation of the farmers will be encouraged with part of the data collection being carried out by the farmers themselves. The results will contribute to increased efficiency in resource utilization, enhanced production and profitability of yellow passion value farming.

12. POPULATION DYNAMICS AND INDIGENOUS PARASITOID GUILD OF TOMATO LEAF MINER (*Tuta Absoluta*) IN LOITOKTOK, KAJIADO COUNTY KENYA

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Abstract

Tmato (*Solanum lycopersicum*) is one of the most important vegetable crops in Kenya. However, tomato leaf miner (*Tuta absoluta*) has led to the decline of its production. Most farmers are not aware of the presence of pest in the country which has limited their ability rapidly respond with appropriate control management options. A survey was done within in October –November 2014 in Kajiado County to determine the incidence, spread and damage caused by the pest on tomato. The results show the pest is already fully established in the region and has caused extensive damage, with many farms having incurred total loss. Most farmers seem to have been caught by surprise by the rapid advance of the pest and are not aware of the best control strategy. In follow up stages of the population dynamics of the pest and the occurrence of natural enemies of *Tuta absoluta* will be investigated. The results will be used to develop and promote adoption and implementation of sustainable control method of the pest, emphasizing biological control strategies.
Key words: tomato, *Tuta absoluta*, Loitoktok, population dynamics, parasitoids

13. EVALUATION OF TOMATO CULTIVARS FOR RESISTANCE TO BACTERIAL WILT-ROOT KNOT NEMATODES DISEASE COMPLEX IN KENYA

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Abstract

Tomato (*Solanum lycopersicum*) is one of the most important vegetable crops in Kenya. The bacterial wilt-root knot nematodes disease complex has however led to decline in production and yield of this crop. Most farmers are not aware of the occurrence of the disease complex which has further exaggerated its status as they continue to apply inappropriate management options. Five tomato cultivars (two local and three from World vegetable centre) were evaluated in a screen house for resistance to bacterial wilt and root knot nematodes singly and as a complex. Potted tomato plants were inoculated with *Meloidogyne* spp. and *R. solanacearum* either singly or as combined inocula, and assessed against an un-inoculated control, which contained sterile soil only. The experiment was arranged in randomized complete block design replicated four times. Data on plant growth parameters and disease

parameters was recorded. A significant (P≤0.05) variation in response against *Meloidogyne* spp. and *R. solanacearum* infection in the tomato cultivars tested was recorded. Results revealed that two of the tested tomato cultivars were resistant to the disease complex and the other three cultivars were susceptible. This study recommends that tomato cultivars resistant to bacterial wilt-root knot nematodes disease complex should be popularised among growers so as to reverse observed losses in yields.

Keywords: Tomato, Bacterial wilt-root knot nematodes disease complex, Resistant cultivars.

14. ACCEPTABILITY AND SUITABILITY OF THREE LIRIOMYZA SPECIES AS HOST FOR THE ENDOPARASITOID HALTICOPTERA ARDUINE FOR CLASSICAL BIOLOGICAL CONTROL IN VEGETABLE PRODUCTION SYSTEMS OF KENYA

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Abstract

Prior to the introduction of *Halticoptera arduine* Walker (Hymenoptera; Eulophidae), we conducted laboratory trials to evaluate its acceptability and suitability in three *Liriomyza* species in Kenya. Two-day-old naïve mated female parasitoids were released on host plants infested by 2nd and 3rd larvae in two experimental set ups with varying parasitoid rates and exposure periods. Parasitoid searching time, oviposition encounters, developmental period, parasitism rates, female ratio, survival, mortalities and body size were recorded as indicators of host acceptance and suitability. Results indicated that the three hosts were accepted for oviposition, parasitation and development of the parasitoid. *H. arduine* significantly encountered host larvae faster on *L. sativae* than on *L. trifolii* (P<0.0006, F=7.9809). Parasitoid development from egg to adult was significantly short in *L. huidobrensis* (19.3±0.96 d) than *L. sativae* (21.2±0.16) and L. trifolii (22.9±0.27). Significantly higher number of parasitoid F1 offspring were obtained from L. sativae and L. trifolii than from L. huidobrensis (P<0.0001, F=30.3788) where females were significantly more from L. huidobrensis (51.9±8.4%) than L. sativae (44.1±4.9%) and L. trifolii (41.1±5.5%). Parasitoid survival during development was significantly high (P<0.042, F=5.739) in L. trifolii and L. sativae than in L. huidobrensis. In two hours experiment, parasitism rate caused by parasitoid was significantly high in L. trifolii (22.0±1.82%) and L. sativae (18.3±1.13%) than in L. huidobrensis (14.0±3.5%) but in 24 hours, L. huidobrensis had significantly higher parasitism rates (44.1±4.6%) than L. trifolii (28.0±3.9%). Non-reproductive mortality was significantly high in L. huidobrensis than L. sativae and L. trifolii (P<0.0049, F=8.9451). Female parasitoids were generally bigger than their male counterparts when reared on L. huidobrensis. Our results suggest that these three major Liriomyza species in East Africa are acceptable and suitable to H. arduine as a candidate for biological control. The implication for the environmentally friendly management of Liriomyza leafminers in Kenya is discussed.

15. ROOT DEVELOPMENT DOES NOT AFFECT REGENERATION OF DOUBLE NODE CUTTING IN TEA PROPAGATION

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Abstract

Gaps in tea farms and plantations resulting from poor planting material, storms, accidental mechanical operations and pests lead to monumental yield losses. Conventionally, single node cuttings have been used for infilling of such gaps in the past; however they take very long to regenerate and eventually cover the gaps and are also expensive compared to normal seedlings. Therefore, double node cuttings can offer a faster and robust alternative for production of the infilling material. However, the fear has been that there is great demand for photosynthates for recovery and regeneration of shoots from more nodes and this may lead to competition between roots and shoots for assimilates. A study to evaluate potential of different types of tea node cuttings as planting material was therefore conducted at Kangaita and Kagochi farms of the Kenya Tea Development Agency in Kirinyaga and Nyeri Counties of Kenya, respectively. The regeneration of single node and double node cuttings from three popular commercial tea cultivars (TRFK 31/8, TRFK 6/8 and AHP S15/10) was assessed in relation to their root and shoot development in the nursery until transplanting at 8 months. The objective was to establish alternative ways of rapidly generating suitable tea planting materials compared to conventionally used single node cutting propagules. Parameters such as biomass and length were evaluated as a measure of root and shoot development. The results showed that double node cuttings had more vigor in generation of new shoots which triggered early root development with evident variation among the test clones. Clone TRFK 31/8 was more superior in root development while clone AHP S15/10 showed superior ability to produce two shoots. The study confirms that indeed there was no adverse competition between root and shoots for assimilates and demonstrates that double node tea cuttings can be used to generate robust planting material both for new fields and infilling since such cuttings exhibited superior attributes in shoot and root development than the traditionally used single node cuttings. It is recommended that this technique be adopted and more studies be done using cuttings with more nodes.

Key Words: Root development, Tea, Double node cutting, Regeneration

16. FOOD WASTE AS A POTENTIAL SOURCE OF ELECTRICAL ENERGY

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Abstract

Food waste is an untapped energy source which mostly ends up rotting in landfills, thereby releasing greenhouse gases into the atmosphere. Major generators of food wastes include hotels, restaurants, supermarkets, residential blocks, cafeterias, airline caterers and food processing industries. Food waste is one of the least recovered materials in the municipal solid waste stream and is one of the most important materials to divert from landfills. Food waste is one of the largest category of municipal solid waste (MSW) sent to landfills. According to a recent survey by UNEP, Nairobi with a population of 4.0 million generates 3,200 tons of waste daily. This constitutes 51.5 % of solid waste generated, making it the largest waste stream sent to landfills. Only 850 tons reach Dandora dumpsite while the rest remain unaccounted. Studies have shown that the proportion of food waste in municipal waste stream is gradually increasing and hence a proper food waste management strategy need to be devised to ensure its eco-friendly and sustainable disposal. The objective of this study was to assess the possibility of mitigating large emissions coming from the dumpsite by recycling biodegradable waste by producing potential electrical energy. Data was collected using questionnaire which was administered to market dwellers and agricultural suppliers and the city council environmental office. Market questionnaires were the main data collection method and the tool used for the study. Both qualitative and quantitative data was collected from the study. The study shows that through a potential bio-digester 100 tons of food waste per day can be converted into enough natural gas fuel to replace 1 million gallons of conventional diesel fuel per year. Additionally, anaerobically digesting 100 tons of food waste per day, five days a week, provides sufficient power for approximately 1,000 homes for a year. Hence, theoretically 3200tons of waste can provide for 32000 homes. This would contribute to more affordable power while reducing landfill waste and its pollutant effect. Recommendations of the study include; having the county government and licensed garbage collectors come up with methods to sort waste at the source in order to make the process easier while the Kenyan government starts the constructing a bio-digester power plant that can be used to generate electricity.

17. EFFECT OF TRICHODERMA STRAINS' DOSES IN THE MANAGEMENT OF BACTERIAL WILT (Ralstonia Solanacearum) IN TOMATO (Lycopersicon Esculentum)

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Abstract

Bacterial wilt is the most difficult diseases to manage in tomatoes because it has no chemical cure, has many alternate hosts in crops and weeds. The pathogen survives in soil and plant debris for a long time even in the absence of host plants, thus making cultural practices such as crop rotation ineffective. Cases where the entire crop yield is lost to this disease are very common. Biological control is increasingly becoming an important method of disease control. The fungus *Trichoderma* spp. are among the most promising bio-control agents of plant diseases. Two Trichoderma strains (*Trichoderma harzianum* and *Trichoderma asperellum*) were evaluated for their effect on bacterial wilt (*Ralstonia solanacearum*) in the screen house at Makerere University Research Institute, Kabanyolo. Polythene bags containing about 6kgs sterile soil mixed with half kilogram manure were placed in the screenhouse. Trichoderma strains inoculum was then applied in two doses, *T. harzianum* 1g and 2gms/lt water and a control and *T. asperellum*1.6mls and 3.2mls/lt water and a control, two weeks before transplanting. Tomato seedlings var. Onyx were transplanted and after transplanting, every tomato plant was inoculated with 10mls of standardized bacterial solution equivalent to $9x10^8$ bacterial cells per ml (McFarland turbidity standard). Results showed that there were significant (P=0.039, 0.038) differences between the treatments 49 days after transplanting and bacterial wilt inoculation. Plants treated with *T. harzianum* at the high rate (2g/lt) had the least mean disease incidence (6.6, 13.4) in seasons one and two respectively.It was concluded that dosage of *Trichoderma* strains has an effect on bacterial wilt management.
Key words: *Trichoderma harzianum, Trichoderma asperellum,* biocontrol*,* inoculum, Onyx

18. EFFECT OF DATE OF HARVEST AND REFRIGERATION ON GERMINATION OF CHAMOMILE (*Matricaria recutita*) SEEDS

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Abstract

Chamomile (*Matricaria recutica*) is a daisy-like medicinal plant belonging to *Asteraceae* family. It is among the most highly sought after and used medicinal plants in folk and traditional medicine. The plant is categorised in the list of Herbs and species by the Export Processing Council of Kenya. Commercial production of chamomile is constrained by several

factors; key among them the quality of seeds. The present study was carried out with the key objective of determining the influence of age and storage method (refrigeration) on germination of chamomile seeds. Samples weighing 0.08g were obtained from seeds of 56, 31, 24 and 0 days after harvest. One group was placed in the refrigerator for ten days before planting, while the other group was planted on a seedbed without prior refrigeration. Germination was observed and recorded daily over an eight day period. Seeds planted without refrigeration 31, 56, 24 and 0 days after harvest germinated after four, three, four and seven days, respectively. It was observed that germination was delayed by one day for seeds harvested 56, 31 and 24 days prior to refrigeration. Seeds that were refrigerated immediately after harvest did not germinate at all. The germination rate decreased significantly when seeds were stored under refrigeration. It is therefore recommended that seeds should not be preserved by refrigeration and the age of seeds for planting should be extended to around two months after harvest for better results.

Key words: Chamomile (*Matricaria recutica*), Refrigeration, Germination

19. ADVANCES IN BREEDING STRESS TOLERANT, MARKET DEMANDED CANNING BEANS IN KENYA

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Abstract

Productivity of canning beans in Kenya has declined drastically in the last four decades due to susceptibility to drought, diseases and lack of adapted high yielding varieties with grain quality characteristics required by the processing industry. Specific objectives of this study were to evaluate locally developed bean lines for tolerance to drought stress, susceptibility to diseases, yield potential and canning characteristics. About 150 advanced bean lines of seven market classes, previously selected from a genetically diverse nursery of 445 lines for agronomic traits, were further evaluated for drought tolerance under moisture stressed and no-stress conditions at Kabete and Thika for two seasons in 2011 and 2012. Twenty-nine agronomically superior lines were subsequently evaluated for canning attributes. Results showed there were significant differences in drought tolerance, yield potential, resistance to disease and canning quality among the lines. Drought stress reduced grain yield of the bean genotypes by 18 to 31%. Several new lines out-yielded local and international drought checks by as much as 100% in drought stressed conditions. Grain yield under stress was positively associated with pod partitioning index (r=0.89***), pod harvest index (r=0.40**), and stem biomass reduction (r=0.32**). Fourteen new lines were rated superior to industrial standard check variety Mex 142, for agronomic potential, drought tolerance, combined resistance to angular leaf spot, rust, anthracnose, bean common mosaic virus, culinary and canning characteristics. These new lines have the potential of increasing productivity, incomes of smallholder farmers, and ensure regular supply and diverse value added products for the processing industry.

Key words: dry bean, canning characteristics, drought tolerance, disease resistance, pod harvest index

20. EFFECTS OF NITROGEN AND PHOSPHORUS MINERAL FERTILIZER ON SORGHUM BICOLOR L. MOENCH N UPTAKE IN SEMI-ARID EASTERN KENYA

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Abstract

Soil fertility degradation remains the major biophysical cause of declining per *capita* crop production on smallholder farms in sub-Saharan Africa. Improving the nutrient management of soils is therefore important in subsistence farming in the tropics as they are very often depleted of nutrients especially due to unfavorable weather conditions. This study aimed at evaluating the effect of N and P fertilizer on sorghum N uptake at Kampi ya Mawe in Makueni county and Katumani in Machakos County in semi-arid Eastern Kenya. The experiment was a factorial arranged in Randomized Complete Block Design with two factors: Phosphorus and Nitrogen both at four levels, 0, 25, 50 and 75 kg/ha. Nitrogen concentration in sorghum tissues was significantly higher at seedling stage with respect to various treatments both at Kampi ya Mawe (p= 0.003) and Katumani (p= 0.001). Whereas N in grains (maturity stage) at Kampi ya Mawe was slightly elevated above that at heading stage, at Katumani changes in tissue N concentration were generally minimal. The N concentration in tissues was significantly (p= 0.001) higher after N application than the control and after P application at Kampi ya Mawe. This was, however, not the case at Katumani where the interaction of N and P gave highest N concentration in the tissues compared to the other treatments. The application of P tended to depress N concentration in tissues especially at Kampi ya Mawe to levels less than even in the untreated control. The results of this study are essential to farmers as a guide to ensure timely fertilizer application in order to ensure optimum utilization of nutrients by sorghum crop during growth. Further studies are needed to establish the relationship between nutrient uptake by sorghum and different fertilizer rates in semi-arid regions of the country.

Key Words: Crop production, nutrient uptake, soil fertility, *Sorghum Bicolor (L) Moench*

21. EFFECT OF DIFFERENT MAIZE (*Zea mays* L.) – SOYBEAN (*Glycine max* (L.) Merrill) INTERCROPPING PATTERNS ON YIELDS, LIGHT INTERCEPTION AND LEAF AREA INDEX IN EMBU WEST AND TIGANIA EAST SUB COUNTIES

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Abstract

Field trials were conducted at the field units of the Embu Agricultural Training Center and Kamujine Dispensary in Embu and Meru Counties, Kenya, during 2012 long rain (LR) and short rain (SR) seasons to determine the effects of different maize-soybean intercropping patterns on yields, light interception and leaf area index. The main treatments were four maize – soybean intercropping patterns (conventional-1maize:1soya; MBILI-2maize:2soya; 2maize:4soya; 2maize:6soya) and two sole crops of maize and soybean. The experimental design was a randomized complete block design with four replications. The results showed that the maize-soybean intercropping patterns had significant effect on maize stover and grain yields during both seasons and sites. The MBILI treatment recorded significantly higher stover and grain yields than all other treatments. During the long rain 2012, the soybean yields were reduced by 60 and 81% due to theintercropping with maize, at Embu and Kamujine, respectively; whereas during the 2012 SR, the yieldswere reduced by 52 and 78% as effect of intercropping with maize at Embu and Kamujine sites,respectively. The intercropping patterns affected significantly ($p<0.0001$) the photosynthetically activeradiation intercepted and the leaf area index at both sites. From the results of this study, the use ofMBILI maize-soybean intercropping pattern can be recommended to the farmers of central highlands ofKenya because it gave efficient resources use and higher yields.

Key words: Intercropping patterns, maize-soybean, leaf area index (LAI), photosynthetically active radiation (PAR), central highlands, Kenya

22. EFFECTS OF DIFFERENT MAIZE (*Zea mays* L.) – Soybean (*Glycine max* (L.) Merrill) INTERCROPPING PATTERNS ON YIELDS AND LAND EQUIVALENT RATIO

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Abstract

In central highlands of Kenya, the low soil fertility and inability to replenish it are amongst the major constraints affecting the productivity of maize and cash crops, leading to hunger and poverty. The adoption of ISFM technologies such as maize-soybean intercropping system is being promoted as one of the options to address low crop productivity among the farmers. This study intended to determine the effects of maize-soybean intercropping patterns on yieldsand to quantify the LER of different maize–soybean intercropping patterns in the two contrasting sites.The experiment was arranged in a randomized complete block design (RCBD) with four replications. The treatments were four maize (M)–soybean (S) intercropping patterns (conventional=1M:1S; MBILI-MBILI=2M:2S; 2M:4S; 2M:6S) and two sole crops of maize and soybean, respectively. The results showed that in both sitesduring the both seasons maize stover and grain yields ware significantly affected by the intercropping pattern. During 2012 LR at Embu site the MBILI treatment produced significantly higher stover and grain yields (13.12 t ha^{-1}, $p=0.0001$ and 6.11 t ha^{-1}, $p<0.0001$, respectively) than all other treatments. During 2012 SR, still the MBILI treatment had recorded significantly the highest stover and grain yield (7.62 t ha^{-1}, $p<0.0001$ and 5.62 t ha^{-1} $p=0.0467$, respectively) than all other treatments. During 2012 LR at Kamujine site the conventional treatment produced significantly the highest stover yield (3.87 t ha^{-1}, $p=0.0461$) than only the 2M: 6S treatment. During 2012 SR at Kamujine site, the MBILI treatment had recorded significantly the highest stover and grain yield (6.55 t ha^{-1}, $p=0.0005$ and 3.55 t ha^{-1} $p=0.0006$, respectively) than all other treatments. During both seasons in both sites, the soybean yield was significantly affected by the intercropping pattern. During the 2012 LR, the yields were reduced by 60 and 81% due to the intercropping with maize, at Embu and Kamujine, respectively; whereas, during the 2012 SR, the yields were reduced by 52 and 78% as effect of intercropping with maize, at Embu and Kamujine, respectively. During both seasons at both locations, the partial LERs values were significantly affected by the intercropping patterns ($p<0.0001$).

Key words: Maize-SoybeanYields, land equivalent ratio, Intercropping patterns, Central Highlands, Kenya.

23. RAIN-FED AGRICULTURE ADAPTATION TO CLIMATE CHANGE VARIABILITY FOR SORGHUM PRODUCTIVITY IN SEMI-ARID AREAS OF EMBU COUNTY

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Abstract
The lower parts of Embu County in Eastern Kenya are characterized by poor crop due to rainfall distribution in semi-arid areas; among other factors leading to declining poverty levels due to declining food security. Rain-fed agricultural productivity has continually declined due to unpredictable and unreliable rainfall patterns in these areas. The decline in crop productivity has been as a result of inadequate understanding of intra-seasonal rainfall variability to develop optimal cropping calendar. A study was carried out to assess the effect of various water harvesting and integrated soil fertility management technologies for enhanced sorghum (*Sorghum bicolor* (L.) Moench) and cowpea (*Vigna unguiculata* L.) productivity in Mbeere South sub-county of Embu County. A field experiment was laid out in Partially Balanced Incomplete Block Design (PBIBD) with a total of 36 treatments replicated three times. The treatments of tied ridges and contour furrows under sorghum alone and intercrop plus external soil amendment of 40 kg P /ha + 20 kg N /ha + manure 2.5 t/ha had the highest grain yield of 3.1 t/ha. The soil fertility levels and water harvesting technologies differed significantly from one another (p = 0.0001) in terms of sorghum and cowpea grain yield. Generally, all the six experiment controls had the lowest grain yields as low as 0.3 t/ha to 0.5 t/ha. Therefore, integration of 40 Kg P /ha + 20 kg N /ha + manure 2.5 t/ha under various water harvesting technologies could be considered as an alternative food security initiative towards climate change mitigation Mbeere South Sub-County, Embu County in Eastern Kenya.
Key words: Climate change, food security, soil amendments, semi-arid areas and Embu County.

24. PHYSICO-CHEMICAL PROPERTIES OF NATURAL COFFEE FOREST SOILS IN ETHIOPIA

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Abstract:
The study was conducted with the aim of characterizing soil physio-chemical properties under natural coffee forests that hosted diverse species of fauna and flora, including the indigenous coffee gene pools in Ethiopia. For this, the fragmented natural coffee forest areas

in southeast (Harenna) and southwest Ethiopia (Berhane-Kontir, Bonga and Yayu) were studied. At each area, soil samples from three sub-sites and two profile depth were collected and analyzed under standard laboratory settings for some physio-chemical properties such as soil bulk density, particle distribution, water contents and soil organic matter, soil reaction and major plant nutrients. A nested experimental design in three replications was used to run the analysis of variance for the most relevant soil parameters considered. Highly significant differences were observed among the natural coffee forests in the distribution of silt and soil bulk density. In contrast, the proportion of clay particles did not show significant differences, thought the average results followed the order of Harenna>Berhane-Kontir>Bonga>Yayu forest. There were highly significant variations in soil permanent wilting point and available water holding capacity. Forest soils were comparable for most soil chemical parameters, except Mg, CEC and C: N ratio. Significant variations were noted between the top-surface and sub-surface soils at all areas, partly indicating the effect of human interference in managing coffee forests. At Harenna, surface soil had significantly higher total nitrogen and soil organic matter contents than sub-surface soil. The decline in available phosphorus with increase in soil depth was also significant at the Harenna and Yayu forests. The findings demonstrate the vulnerability of forest grown coffee landscapes to human-induced disturbances coupled with changing climate. The study also advocates the need for understanding and managing soils for sustainable conservation and utilization of the unique Ethiopian natural coffee forest environments for the future worldwide coffee sector.
Key words: Biosphere reserve, certification, deforestation, forest coffee, soil management

25. ASSESSEMENT OF SPECIES RICHNESS, COMMUNITY STRUCTURE AND DIVERSITY OF MIOMBO WOODLAND IN MOCUBA DISTRICT, MOZAMBIQUE

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Abstract

Miombo woodland occupies the greater portion of the Zambezian phytocorion. There is an increased interest in the academic world with regards to tree species richness and diversity within this woodland with the aim of determining the potential for biodiversity conservation. This study assessed species richness, community structure and diversity of Miombo woodland in Mocuba District, using both traditional phytosociological analyses. Plant inventory was carried out in 16 systematically selected sample plots of 50 x 20 m. A total of 841 individuals were recorded and 103 species belonging to 31 families were identified. Families with the most species and number of individuals were Fabaceae and Euphorbiaceae. *Brachystegia spiciformis* and *Pterocarpus angolensis* were the most important species in terms of IVI. Almost 83% of the species were randomly distributed in the sampled hectare,

both for the vertical and horizontal structure. Density and basal area were estimated at 525 ± 23 trees.ha^{-1} and 26.25 m².ha^{-1}, respectively. The Shannon-Wiener index (H') found was of 3.03 and the evenness (J) 0.86. The non-parametric richness estimators yielded minimum estimates of species richness varying from 35.4 to 47.4 species. The diameter distribution of the community adjusted by Meyer equation showed the typical trend of the inverted "J" and showed strong human intervention in grades 20-25 cm.

Keywords: Floristic and Phytosociology; Specie diversity; Miombo woodland.

26. EFFECTS OF EXPLANT SOURCE ON SOMATIC EMBRYOGENESIS OF (C. *arabica* var. Ruiru 11 and Batian)

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Abstract

In vitro plant regeneration involves varying the nutrient salts, gelling agents and especially plant growth regulators to grow callus, stimulate axillary shoot proliferation and rooting, and induce shoot organogenesis and somatic embryogenesis. It is well known that different genotypes will often not respond in the same way when cultured on the same medium. This has required countless empirical studies on medium optimization for different species or even cultivars of the same species. However, *in vitro* growth and morphogenesis are also governed by properties of the explant. The aim of this study was to evaluate the effects of explant source on somatic embryogenesis by comparing embryogenesis frequency on *in vitro* versus *ex vitro* derived explants. Leaf explants were harvested and cultured on Murashige and Skoog (MS) media supplemented with different concentrations of cytokinins Benzyl amino purine (BAP) at 4.4, 8.8, 13.3, 17.7, 22.0 µM and Thidiazuron (TDZ) at 4.5, 9.0, 13.6, 18.2, 22.7 µM seperately, 100 mg/l myo-inositol 3% sucrose and gelled with 0.3% gelrite. The results show significant differences among explant type in induction of somatic embryos. Ruiru 11 *in vitro* explants cultured on media supplemented with TDZ at 13.6 µM gave the highest mean of embryos per in vitro explants, 6.49±0.73 compared to 13.6 µM which gave 3.44±1.07 of *ex vitro* explants. However, 22.7 µM TDZ gave the highest percentage of embryogenic cultures of 90% from Ruiru 11 *in vitro* explants. This results advance prospects for massive propagation of coffee through somatic embryogenesis.

Key words; Somatic embryogenesis, *in vitro, ex vitro*

27. EVALUATION OF THE CERES-MAIZE MODEL USING PLANTING DATES AND NITROGEN APPLICATION RATES IN ZAMBIA

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Abstract:

A field experiment was conducted during the 2013/2014 season to evaluate the effect of planting date and nitrogen application rate on maize (*Zea mays* L.) biomass and grain yield at the Field Research Station of the School of Agricultural Sciences, University of Zambia, Lusaka, Zambia (15º 23.6859' S, 28º 20.226' E; 1,261 m asl). The experimental design was a split plot with three replicates, three planting dates (Nov 24, Dec 8, and Dec 22) assigned as main plots and two nitrogen application rates (112 and 168 kg N ha^{-1}) assigned to sub-plot. Aboveground biomass was measured at vegetative and reproductive stages. Soil water profiles were monitored using the Diviner 2000 Probe. The Generalized Likelihood Uncertainty Estimation (GLUE) programme was used to estimate the genetic coefficients for the CERES-maize model. Grain yield, tops (aboveground biomass) weight, vegetative weight, stem weight, leaf weight, leaf area index (LAI) and soil water content were evaluated using d-stat, forecasting efficiency (EF), coefficient of variation, root mean square (RMSE) and normalized RMSE. The model's prediction of plant emergence (±1 days), time to anthesis (≥-3≤±1 days) and maturity (≥-4≤6 days) was good. Simulation of tops weight (d=0.96, EF=0.86), vegetative weight (d=0.93, EF=0.79) and leaf number (d=0.94, EF=0.80) were reasonably accurate. The simulation accuracy of leaf weight (d=0.59, EF=-3.17), stem weight (d=0.52, EF=-2.95) and LAI (d=0.54, EF=-0.65) was considered low under the local conditions. The model's simulation of grain yield was fair (NRMSE =21.4%) while soil root water availability demonstrated that substantial potential yield may have been lost due to water stress. The results showed that the model can be used to accurately determine optimum planting date, biomass yield and nitrogen application rate under the local condition with reasonable accuracy.

Key words: GLUE, calibration, prediction, RMSE, d-stat, forecasting efficiency

28. POD YIELD, POD QUALITY AND DISEASE RESISTANCE OF NEW TROPICALLY ADAPTED VEGETABLE RUNNER BEAN LINES

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Abstract

Runner bean (*Phaseolus coccineus* L), also known as butter bean, has shown considerable promise as a high value export crop. However, its productivity is severely constrained by high production costs due to lack of tropically adapted short-day vegetable varieties that do not require extended artificial lighting to stimulate flowering and pod formation, that are resistant to major diseases and with market preferred pod traits. The objective of this study was to evaluate new locally developed short-day vegetable runner beans for pod quality, pod yield and resistance to diseases. Fifty new vegetable runner bean lines and one commercial variety were evaluated at Ol-Joro-Orok and Kabete Field Station during the long rain season of 2014. Ten pods per plot were randomly selected and evaluated for pod length, pod curvature, pod yield and disease resistance for diseases such as rust (*Uromyces appendiculatus*), angular leaf spot (*Phaeoisariopsis griseola*), anthracnose (Colletotricum lindemuthianum) and common bacterial blight (*Xanthomonas campestris* pv. *Phaseoli*). The pods were graded according to fresh produce standard commercial classes. Pod yield was determined as the cumulative weight from all the harvests. A disease score of 1 to 9 was used to determine the disease severity according to Schoonhoven and Pastor (1987). Visual evaluation was used to score other diseases which were not applicable to disease score of 1 to 9 such as powdery mildew. The data was subjected to ANOVA and the means separated by least significant difference (LSD) test at P=0.05.

Results showed significant differences among the test lines for pod yield, pod quality and disease resistance. Most of the new lines were far much better by about 16,000kg ha^{-1} in pod yield than the commercial variety, White Emergo. e.g. KAB-RB13-1-105/2 (18,354kg ha^{-1}) and KAB-RB13-380-55 (17,163kg ha^{-1}) while White Emergo produced 896 kg ha^{-1}. At least thirty new lines had straight pods and met market pod length requirement of 18cm. Most of the new lines were resistant to angular leaf spot, anthracnose, common bacterial blight and rust diseases while the commercial variety was susceptible to angular leaf spot, common bacterial blight and powdery mildew.

High pod yield, pod quality and disease resistance of these lines can contribute to increased productivity, reduction in production costs and enhance competitiveness of local products in regional and export markets.

Key words: vegetable runner bean, pod yield, pod quality and disease resistance.

29. ASSESSMENT OF SWEET POTATO PROPAGULES FOR INFECTION BY VARIOUS VIRUSES IN EAST KAMAGAK LOCATION-HOMABAY COUNTY

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Abstract

Sweet potato, *Ipomea batatas* (L) Lam is an important subsistence food crop as well as cash crop in East Kamagak location and is also very popular in the major cities in the country including Nairobi. Sweet potato also does well with little agronomical management practices and provides household food security because it stores well in the soil as a famine reserve crop. However sweet potato production is constrained by virus infection. At least 13 viruses are reported to infect sweet potato naturally of which most of them are insect transmitted. The study aimed at screening and selecting virus free germplasm. A survey was conducted using questionnaire which aided in germplasm collection. Twelve genotypes were used for the study. The collected germplasm was virus indexed using visual scoring with severity of infection ranging from 1-9, serological and molecular detection. During the survey SPFMV and SPCSV were found to be common. Virus-free accessions were planted using Randomized Complete Block Design in three replicates. Harvesting was done 6 months after planting. The germplasm was again subjected to molecular detection of virus to ascertain whether the materials remained virus free and to detect new infections. All the germplasm tested positive for sweet potato feathery mottle virus (SPFMV) but negative for SPMMV, CMV, SPCSV and SPCFV an indication that SPFMV is a common virus in sweet potato and does not significantly affect sweet potato yield. Analysis of variance showed that Nyakowino, Nyawo, Zapallo and SPK004 total yield were significantly different at $p < 0.05$ with a range between 68.00-12.33.Sweet potato should be screened for viruses in commercial production.
Key words: Germplasm, *Ipomea batatas*, Indexing, Virus free, Serological, Moleculer

30. INTERACTIVE EFFECT OF GOAT MANURE, PHOSPHATE FERTILIZER AND LIME ON SOIL FERTILITY IN EMBU COUNTY, KENYA

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Abstract

Nutrient mining resulting from crop uptake and erosion; and soil acidity, which makes plant nutrients less available through different means such as phosphorus fixation and impairment of biological mediated processes in the soil, continuous to hamper crop growth and yields. A study was conducted to evaluate the interactive effects of manure, lime and phosphorus fertilizer on soil chemical properties in an acid soil. The study consisted of 5 treatments: manure (0 and 5 ton.ha^{-1}), lime (0 and 2 ton.ha^{-1}) and P fertilizer (0 and 30 kg P_2O_5 ha^{-1}). The experiment was laid out in a randomized complete block design (RCBD) with 4 replicates in

plots of 4.0 m x 4.5 m. Integrated application of manure, lime and phosphate fertilizer positively affected soil chemical properties by increasing soil pH, exchangeable Ca, Mg and K; and reduced exchangeable acidity. The same combination recorded the highest soil cations exchange capacity (CEC) and harvest index and is thus considered the best option to improve soil fertility and increase yields of soybean in the region.

Keywords: Manure, Lime, P fertilizer, Soil pH, Exchangeable acidity, CEC.

31. PRODUCTION AND MARKETING OF ARABICUM AS A BUSINESS. A CASE OF SMALL-HOLDER FARMERS IN NYERI AND KIAMBU COUNTIES, KENYA

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Abstract
Floriculture is one of the fastest growing subsectors in the agriculture sector and is key in achieving part of Kenya's vision 2030. In 2012 the subsector contributed Ksh. 42.9 billion accounting for 48% of the domestic value of horticulture. The sub-sector directly employs over 500,000 people directly and indirectly hence a major employer. Arabicum is one of the leading summer flower mainly produced by smallholder farmers in Kenya. It was ranked 4th overall among the cut flowers that were highly valued in 2012. It contributed 0.33% of the domestic value of floriculture. The total area under Arabicum production is estimated to be 139.72 ha with production 2892.59 tons of flowers per year. The area under production increased by 51.87% in 2012 compared to 2011. The major counties in production of the flower are Kiambu (81.08%), Nakuru (11.66%), Kirinyaga (3.38%) and Nyeri (2.68%). In this study, 28 farmers from Nyeri and Kiambu counties were interviewed. Majority of farmers (83%) planted Arabicum in small sizes land (0.01 to 0.25) acres. Most of them (64%) earned less than Ksh.10,000 per season from Arabicum sales. About 73% of the farmers were organized into marketing organizations. Around 57% of the farmers did not keep records. Major challenges faced were disease (bulb rot), low prices, sales to one particular buyer and fluctuation of prices in the export markets. There is need for relevant departments especially in the counties to address these challenges given that the flower is a cash crop to majority of the farmers. With declining land sizes of land in the two counties Arabicum is an ideal crop for income generation.

Keywords: Horticulture, Arabicum, Marketing system, Small- holder

32. ADAPTATION OF SELECTED SOIL AND WATER CONSERVATION PRACTICES TO THE SOUTH SUDAN ZONE OF BURKINA FASO

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Abstract

With current changes in climate there is a need to adapt soil and water conservation practices to the South Sudan zone Burkina Faso. This study was conducted to assess the impact of no-till, tied ridging; ripping and conventional tillage combined with soil fertility management options on sorghum yield in Nadion. The treatments were laid out in a split plot design on a lixisol with a slope of 1.5%. The tillage practices were ranged in main plots and soil fertility management options in the sub-plots. The soil moisture was monitored weekly using the Time Domain Refractometer method and the soil bulk density was evaluated 30 days after planting. Both the sorghum grain and biomass yields were assessed. The tied ridging and zero tillage increased. Application of sorghum straw residues a improved soil water content with additional 20% water content. Conventional tillage decreased soil bulk density at the plowing depth. Combination of compost, NPK, and Urea increased sorghum yield by 74%. The combination of NPK and urea increased it by 50% and the compost increased it by 29% compared to the control (zero input). Conventional tillage led to decrease in yield compared to zero tillage after two years experiment. The zero tillage combined with compost, NPK and urea increased sorghum yield by 28% compared to tied- ridging with the same fertility management options after two years. The results showed that the tied ridges that did not work 20 years ago in the south Sudan zone is now suitable

Key words: Tillage methods, fertility management, soil water content, sorghum yield

33. EVALUATION OF Hyk® FOLIAR FERTILIZER ON GROWTH, YIELD AND QUALITY OF FRENCH BEANS (cv. Organdi)

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Abstract

French beans (*Phaseolus vulgaris L.*) are a major vegetable export crop in Kenya and a significant income earner to small scale farmers. French beans are grown for processing, including canning and freezing, and demand is steadily increasing. Poor growth vigor is one

of the factors that hinder the realization of high yields and pods of high quality. There is therefore need to develop/ identify new products to increase productivity. The objective of this study was to evaluate a newly introduced concentrated inorganic formulation (Hyk®), for its effect on growth vigor, yield and quality of French bean variety Organdi. Hyk® was applied to the plants at different stages of plant growth in Kirinyaga and Murang'a Counties and evaluated against the commonly used foliar fertilizers Nitro spray® and Calmabon®. The study was laid out in complete randomized design and was replicated three times. Data was collected at 50% flowering and included number of flowers, height of the plant, length and width of the leaves. The Hyk® treated plants had a higher growth rate attaining an average height of 39 cm compared to the control's 37 cm. Hyk® treated plants also had improved yield and quality of the pods, producing over twice the yield of the control treatments. Cost benefit analysis showed that application of Hyk® to French beans yielded a positive net return. The results show that Hyk® foliar fertilizer can be recommended for use in French bean production.

Key words: Hyk®, French beans, foliar fertilizer, flowering.

34. INCREASING REGENERATION RATE OF TWO SWEET POTATO (Ipomoea batatas L.) CULTIVARS ON LOW COST TISSUE CULTURE MEDIA

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Abstract
The cost of tissue culture has been identified as a constraint to uptake of high quality planting materials. Efforts have been going on to develop low cost TC technologies that can help to reduce the cost of seedlings and hence increase adoption. This study was carried out at Kenyatta University aiming to optimize regeneration of two sweet potato cultivars by supplementing low cost media (LCM) with plant growth regulators (PGRs) and to assess somaclonal variations in the regenerated plantlets using morphological features. Nodes of cultivars KEMB 36 and KSP 36 were cultured on LCM supplemented with PGRs as follows; BAP/IAA; 0.1/0.01, 0.2/0.015, 0.3/0.02, BAP/NAA; 0.1/0.01, 0.2/0.015, 0.3/0.02, KIN/IAA; 0.1/0.01, 0.2/0.015, 0.3/0.02, KIN/NAA; 0.1/0.01, 0.2/0.015, 0.3/0.02 and a control with no PGRs. Each treatment had five replicates in a split plot experimental design. The data was subjected to analysis of variance (ANOVA) using SPSS and the means of the number of shoots, nodes, leaves and roots were separated using Tukey's test. The effect of the treatment depended on the genotype, with a significant interaction determined at $P \leq 0.05$. For both cultivars, untreated control produced the highest mean number of nodes, leaves, roots and plantlet height. Regeneration performance of plantlets weakened with increase in concentration of PGRs. Survival rate of 100% was recorded in BAP 0.2/NAA 0.015 for KEMB 36 and in BAP 0.2/IAA 0.015 for KSP 36. There were significant differences

(P<0.05) in the means of leaf length and leaf width but no significant differences (P>0.05) for the means of petiole length, petiole diameter, and stem diameter. Leaf shape and color intensity were maintained for the two cultivars. The conclusion is that sweet potatoes have enough endogenous growth regulators to break the dormancy of the auxiliary buds. Callus formed vigorously with increase in PGRs concentration for both cultivars suggesting a potential to induce somaclonal variations in the two cultivars.

Keywords; *low cost tissue culture media (LCM), plant growth regulators(PGRs), sweet potatoes, cultivars, somaclonal variations*

35. EFFECTS OF PHOSPHORUS DEFICIENCY ON SECONDARY METABOLITES AND AFRICAN NIGHTSHADE DISTRIBUTION IN KISII, SIAYA AND KAKAMEGA COUNTIES, KENYA

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Abstract

African Indigenous Vegetables form an integral part of the Kenyan diets, among the most commonly consumed being the African nightshade. These vegetables contain important phenolics that have medicinal values and good health promoting attributes. The abundance of these phenolic substances has strongly been associated with phosphorus use efficiency. In order to investigate African nightshade distribution, a purposive survey was done in three counties and 70 farmers randomly interviewed on information on the indigenous vegetables grown using semi-structured questionnaires in Kisii and Siaya counties of Kenya in February 2014. *Solanum scabrum* had 79% distribution whereas *Solanum villosum* had 21%. A field experiment was done in a Randomized Complete Block Design (RCBD) with split plot arrangements. The two nightshade accession constituted the main plot and the P (0, 20, 40 and 60 kg/ha) levels represented the subplot. Preliminary results on plant height, fresh weight, number of secondary buds, leaf and root area were determined. All the above parameters were significantly (p<0.05) affected in both season 1 and 2 by P levels. Results showed an increase in yield (fresh weight, number of secondary buds, leaf and root area) as Phosphorus level increased upto 6.5 t/ha for *Solanum scabrum* and 6.75 t/ha for *Solanum villosum* after which there was either no further increase in growth or a decline in growth with further phosphorus level increase. Deficiencies of other nutrients can limit crop response to phosphorus hence the decrease of growth under phosphorus level 60 kg/ha is as a result of Copper and Zinc deficiency. *Solanum scabrum* had high yield than *Solanum villosum* when P supply was optimum. Therefore P at the rate of 40 kgP/ha is highly recommended for optimum yield of African nightshade and any additional P result in plant luxury

consumption.Analysis on Total Phenolic Content is under way. Results obtained will be used to educate farmers and extension personnel about ways of improving productivity of African nightshade.

Key words: African nightshades, growth, Phosphorus levels, yield

36. URBAN AGRICULTURE MODELS HAVE BECOME A REALITY

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Abstract
Urban agriculture involves production of various crops and raising of animals alongside their complimentary activities with intention of improving livelihoods. The Urban agriculture concept was brought about by the need to improve the quality of life for both urban poor and the resource rich population with main challenge lying in how to integrate different production systems for sustainable production in a small space.

Over the years 2009 to 2014, observational studies through research innovations as seen by the agricultural service providers during the agricultural shows have shown that urban agriculture needs to adopt various techniques that save on space and maximise on production. As such six models have evolved over the years ranging from lateral gardens to vertical production systems that require less space. These models include laid down gardens, mixed home gardens, multi-storey gardens, tyre-gardens, hanging baskets and multi-functional storey gardens. As a result of the diversity, the innovative consideration for multiple usage, these models are being disseminated and their adoption by most show goers has revolutionised backyard farming to commercial farming level resulting in income, proper utility of space, aesthetics, environmental conservation and improved lifestyle through accessibility to a variety of agricultural products.

Key words: Urban agriculture, six model gardens, innovations, impacts

37. AN EVALUATION OF BORON FERTILIZATION METHODS ON COTTON GROWTH (*Gossypium hirsutum* l.) IN SELECTED SOILS FROM ZAMBIA

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Abstract
Cotton is a cash crop which supports over 150,000 households in Zambia and contributes over US$ 60 million to the country's economy. However, the production of cotton in Zambia is seriously affected by boron deficiency in soils. Furthermore, application of boron to soils presents challenges of leaching and fixation while foliar application sometimes results in

phytotoxicity and leaf burn. The objective of the study was to determine the most effective method to apply boron to cotton. The 'Nutrient Priming' technology was evaluated for its ability to improve boron nutrition in cotton. A pot experiment was carried out on sandy loam and loamy sand soils collected from three major cotton growing areas of Zambia. Cotton plants were grown in the greenhouse for thirteen (13) weeks. Treatments were seed priming, soil and foliar boron application. Foliar application of boron significantly ($p \leq 0.01$) increased boron concentration in cotton leaves by 179.1 % compared to soil application. Cotton plants grown from primed seeds contained 7.7 mg/kg boron, suggesting that early vigorous growth and establishment of cotton from primed seeds did not result in sufficient uptake of boron from the soil. Deficiency symptoms were exhibited in cotton plants grown from primed seeds while those that received foliar application of boron exhibited boron toxicity symptoms. Good crop performance was obtained when boron was applied to the soil and cotton was well supplied with boron through this method. The mean boron concentrations in these plants were in the normal range of 20-70 mg/kg and higher biomass yield was obtained from this method. Therefore, application of boron through the soil appears to be the most effective method of supplying boron to cotton plants grown on the Alisols and Acrisols of Zambia.

38. EFFECT OF CONSERVATION AGRICULTURE PRACTICES ON TOTAL AND LABILE SOIL CARBON AND NITROGEN POOLS UNDER CONTRASTING AGROECOSYSTEMS IN EASTERN UGANDA AND WESTERN KENYA

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Abstract

Sustainable land management practices such as conservation agriculture (CA) are required to improve soil quality and crop productivity under smallholder agroecosystems in the tropical highlands of East Africa. In this study, we assessed the impact of three tillage systems: conventional tillage (CT), minimum tillage (MT) and no-till (NT) combined with three cropping systems: conventional maize-bean intercrop (CP), maize-bean intercrop relayed with mucuna (ROT1), and maize-bean-mucuna strips in rotation (ROT2) on soil quality indicators in four contrasting agroecosystems in eastern Uganda and western Kenya. At each site, total and labile soil carbon and nitrogen pools and the associated biological quality indices: microbial metabolic quotient (q_{CO2}), mineralization quotient (q_{min}) and microbial quotient (q_{mic}) were evaluated 2 years after project implementation. Our results indicate that soil organic carbon (SOC) was consistently higher under MT compared with CT and NT. In

Tororo, the interaction of tillage and cropping system had a significant effect on SOC (p<0.01), while mineral nitrogen was significantly influenced by cropping system (p < 0.05) indicating the importance of leguminous cover crops in N fixation. The q_{mic} ratio was also significantly impacted by the interactive effect of tillage and cropping system in Trans Nzoia with the conventional maize-beans intercrop system under CT having the highest ratio. Similar but non-significant trends were observed in the other sites indicating the importance of CA practices in nutrient cycling, carbon (C) sequestration and sustainable management in agroecosystems.

Keywords: Conservation agriculture, Minimum tillage, No-till, Carbon pools, N pools

39. EFFECTS OF AGRICULTURAL PRACTICES AND MAIZE VARIETIES YIELD AT BÀRUÉ AND NHAMATANDA DISTRICTS OF MOZAMBIQUE

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Abstract
Maize yields are low in Mozambique due to limited adoption of agricultural technologies and modern inputs. The objective of this study was to determine effects of conservation agriculture on crop yields for smallholder farmers' in Mozambique. This was carried out through field experiments and a survey. The experiment was carried out in Bàrué and Nhamatanda districts during the 2010-2011 and 2011-2012 cropping season. Experimental set up was Randomized Complete Block Design (RCBD) with split plot arrangement. Main plots were tillage practices (no – ploughing, Jab-planter, planting basins and conventional ploughing) and sub-plots were five maize varieties (ZM309, ZM401, ZM523, ZM625 and Matuba). Soil inputs were 100 kg/ha of N-P-K and 100 kg/ha of urea applied as top dressing. Field data was subjected to ANOVA analysis using Statistix version 10. The survey was used to determine the tillage practices and maize varieties preferred by farmers. Plots under conservation tillage (Planting Basins and Jab-planter) performed better than conventional notably on maize yields, plant population, biomass and number of cobs. Based on the results of this study it is recommended that jab-planter and basin tillage practices and ZM401, ZM523 and ZM625 maize varieties should be adopted.
Key words: Maize varieties, Conservation Practices and Conservation agriculture.

40. EVALUATION OF THE SUSTAINABILITY OF CROP RESIDUE USES IN SMALLHOLDER CEREAL-LEGUME-LIVESTOCK FARMS IN THE DRY SAVANNAS OF WEST AFRICA

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Abstract

Crop residues are vital resources for improving the productivities of cereal-legume-livestock systems in savannahs of West Africa. The competing demands for their uses as fodder or soil amendments present a tradeoff between increasing crop yields and sustaining livestock productivity. An agricultural sustainability framework was used to evaluate the ecological benignity, economic viability, social acceptability and sustainability of five crop residue allocation options at Cheyohi (Ghana), Sarauniya (Nigeria) and Garin Labo (Niger). The crop residue allocation options were: 0, 25, 50, 75 and 100 % of haulm with 0, 75, 50, 25 and 100 % of stover, respectively, as soil amendment or fodder. The most environmentally friendly options were the allocation of 75 % haulm and 25 % stover as soil amendment at Cheyohi (ecological benignity index = 6.2) and Garin Labo, (ecological benignity index = 6.8) and the total retention of crop residues (100 % haulm and stover as soil amendment) at Sarauniya. The allocation of 25 % haulm and 75 % stover as soil amendement was the most economically viable option at Cheyohi and Sarauniya (economic viability index = 7.0). At Garin Labo however, the removal of all crop residues for use as fodder was the most economically viable option (economic viability index = 9.9). The total retention of crop residues on field while being the most acceptable option to farmers at Cheyohi (social acceptability option = 6.8) was the least acceptable option to farmers at Sauraniya (social acceptability option = 4.9) and Garin Labo (social acceptability option = 4.5).The most sustainable crop residue allocation options were the use of 75 % of haulm and 25 % of stover as soil amendment Cheyohi and total removal of crop residues for use as fodder at Sarauniya and Garin Labo.

41. SOIL FERTILITY AND MICROBIAL BIOMASS DYNAMICS UNDER DIFFERENT CROPPING SYSTEMS IN GHANA: IMPLICATION FOR FOOD SECURITY

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Abstract

Soil fertility decline is a major problem confronting crop production in Ghana. On many smallholder farms in the country, nutrient mining and soil losses compounded by erratic rainfall pattern due to climate change are threating food security. A study was carried out on a Ferric Acrisolin the semi-deciduous forest zone of Ghana to examine soil fertility and microbial biomass dynamics under different cereal - based cropping systems as affected by integrated nutrient management and to establish the implication for crop productivity and food security. Three different cropping systems such as maize/soybean intercropping, maize/cowpea rotation and continuous maize cropping systems were evaluated. These constituted the main plots of the experiment which was laid out in a split- plot arranged in a randomized complete block design. The subplots consisted of application of fertisol, chemical fertilizer (NPK 15-15-15), chemical fertilizer + fertisol and a control (no amendment). Soil chemical properties such as nitrate – N, ammonium – N, organic carbon, available phosphorus and exchangeable potassium which are indicators of soil quality were determined in three consecutive cropping seasons. Soil microbiological properties (microbial biomass carbon, nitrogen and phosphorus) were also evaluated alongside crop yield under each cropping system. The results of the study indicated a general build-up of microbial biomass under the cropping systems over the study period. Phosphorus was immobilized in microbial biomass at the peak of crop growth but was released shortly for crop uptake. On the average, microbial biomass N contributed 2.5 and 2.6 % to the total N in soils under amendments and cropping systems, respectively. Nitrate – nitrogen levels exhibited Birch effect which was characterized by immobilization of the nutrient in amended plots. Decline in available phosphorus under the amendments during the cropping season followed the A-value concept but did not significantly lead to reduction in crop yield. Integrated application of fertisol and chemical fertilizer under the cropping systems significantly and positively ($p < 0.05$) impacted soil chemical properties more than sole applications of either amendment. Maize, cowpea and soybean grain yields were significantly higher ($P < 0.05$) under integrated application of fertisol and chemical fertilizer. Maize grain yield increased tremendously from the first major cropping season to the last major cropping season beyond its average potential yield indicating that efficient nutrient management coupled with cropping diversity could lead to sustainable crop production and enhanced food security of small holder farmers.

Keywords: Cropping diversity, chemical fertilizer, fertisol, food security, soil fertility

42. EVALUATING THE CAPACITY OF COMPOST BASED BIOFERTILIZER IN ENHANCING SOIL CHEMICAL PROPERTIES AND YIELD OF EGGPLANT (*Solanum melongena*)

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Abstract

This study conducted under field and green house conditions sought to assess the potential of compost based biofertilizer in influencing soil chemical properties and enhancing the yield of eggplant. Four treatments; 5 t/ha compost, 2.5 t/ha compost, 100% NPK (recommended rate 50:30:30) and control were used for both experiments. Under field conditions, the highest number of fruits (38.9), biomass weight (896 kg/ha) and fruit yield (7347 kg/ha) were all produced by 5 t/ha compost treatment. Furthermore, the 2.5 and 5 t/ha application rates of the compost produced fruit yields which were 35 % and 80 % respectively higher than the control treatment. Results of the soil test after harvest showed that 100 % NPK amended plots recorded the highest significant marginal increases (N, P and K) relative to the control and compost treatments. Results of the green house studies showed that the highest fruit yield was produced by 5 t/ha compost treatment which was 59% more than the control. The recommended rate of NPK (50:30:30) gave the highest shoot biomass weight followed by the 5 t/ha compost treatment.

43. ASSESSING THE ACCESS OF INFORMATION AND COMMUNICATION TECHNOLOGIES BY GREENHOUSE TOMATO FARMERS IN BAHATI-NAKURU COUNTY

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Abstract:

Kenya's development challenges have been unemployment, poverty, food insecurity and slow economic growth. The agricultural sector which accounts for 62 % of the total national employment with 630,000 formal sector jobs and 3.7 million small and micro enterprise sector jobs can contribute towards overcoming such challenges. Adoption of productive and sustainable technologies exemplified in the greenhouse technology makes the sector to be more productive. The technology aims at increased crop production using environmentally controlled conditions. Even though the phenomenon of greenhouse production is aimed at increasing production per unit area of land, tomato farmers in Bahati (Nakuru County) are still recording low yields in their greenhouses. Part of this is due to the existing greenhouse information access pathways which have been reported to be slow, costly and inaccessible. The purpose of this study was to assess the use of communication technologies for information access by greenhouse tomato farmers in parts of Nakuru County. A survey methodology with ex-post factor research design was undertaken with a study population of 116 greenhouse tomato growers. The data collected through a validated and reliable

questionnaire were analysed using inferential statistics including ANOVA and Chi-square with SPSS computer software. Research questions were tested and interpreted at 5 % level of statistical significance. The study established that majority of the greenhouse tomato farmers were aware and used radio and television to access information on greenhouse management. A test to determine the influence of farmer characteristics on the use of ICTs for information access indicated that such farmer characteristics have a statistically significant influence in the use of ICT use among the farmers at 5 % level of significance. Findings from this study showed that there was a statistically significant difference in the yields of tomato among the ICT users and non-users.

44. CHARACTERIZATION OF ORGANO-CHLORINE POLLUTANTS IN NGWERERE PERI URBAN WATERSHED OF LUSAKA, ZAMBIA

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Abstract:
The overall objective of the study is to establish the threat of organo-chlorine contamination and associated risk of human exposure associated with consumption of contaminated agro produce and to develop a framework for management and mitigation of organo-chlorine pollution in smallholder crop production systems. The specific objective of this study will be to characterize the point and non-point sources and nature of organo-chlorine pollutants within Ngwerere watershed in Lusaka, Zambia. The methodology to be used in this will include a desk appraisal of soil maps, land cover/land use (LC/LU) (1: 50 000) and reports. The soil data collection and analysis for the study will be carried out between November 2014 and January, 2015. Two soil sampling methods will be used; stratified grid sampling around areas of contamination and stratified random sampling on other areas. Exploratory holes will be dug in grids at 100 m spacing. Sampling depths of 0 – 25 cm will be used. Sediments will be collected at 0 - 5 cm and 15 - 20 cm depth below surface using sediment corers. Sampling points will be geo-referenced. Laboratory analysis for determination of OCs residue type and concentration levels will be conducted on soil, sediment and water samples. A LC/LU map will be produced from Landsat 7 mosaics using maximum likelihood method. Digital maps and field survey data will be used for ground truthing. A map on OC contamination will be produced. Identified OCs will be grouped according to suspected source, i.e. either industrial, pesticide or industrial and pesticide. The most prevalent OCs will be studied in detail.

45. CONTRIBUTION OF PIGEON PEA ROOTS TO NITROGEN YIELD IN THE PIGEON PEA-GROUNDNUT INTERCROP SYSTEM

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Abstract

A study aimed at the assessment of the contribution of pigeon pea roots to N yield for the pigeon pea was carried out at Chitedze Agricultural Research Station (S 13^0 59' 23.2", E033^0 38' 36.8"), Malawi in the 2012/2013 cropping season. Ten treatments, replicated three times were laid in a randomized complete block design. Two pigeon pea varieties, long (ICEAP 04000) and medium duration (ICEAP 00557) and groundnut (CG 7) were grown as monocultures and intercrops. The intercrops involved planting either of the pigeon pea varieties with groundnut. Some of the plots were treated with triple super phosphate (TSP) at the rate of 25 kg P ha^{-1}. Analysis of soil samples collected in all treatment plots indicate that the soil had low fertility, having low organic carbon (1.4 %), low cation exchange capacity (CEC) (NH$_4$OAc) (3.5-3.6 cmol (+) kg^{-1} soil) and low N (0.12 %), while plant available phosphorus (Mehlich 3) was marginally adequate both in the top and sub soil (μ=21.5 mg P kg^{-1} and 22.1 mg P kg^{-1}). Assessment of pigeon pea root biomass indicated a mean yield range of 507 - 605 kg ha^{-1}. This translated to N yield of 5.7 kg N ha^{-1} to 7.7 kg N ha^{-1}, a modest contribution to the soil N pool. Though modest, this contribution cannot be overlooked since the nutrient even after immobilization, a temporally state, largely is available for uptake by succeeding crops in a rotation system as it does not get complexed in the soil as is the case with phosphorus.

46. RESPONSE OF SOYBEAN (*Glycine Max* L.) TO RHIZOBIA INOCULATION AND MOLYBDENUM APPLICATION IN THE NORTHERN SAVANNAH ZONES OF GHANA

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Abstract

The exploitation of legume-rhizobium symbiosis is a low and sustainable technical solution compatible with the socio-economic conditions of smallholder farmers in SSA. Three on-

station trials were carried out at the experimental fields of CSIR-Savannah Agricultural Research Institute (SARI), to ascertain the effectiveness of some commercial microbial inoculant and micronutrient fertilizer for improvement of soybean productivity in the Northern savannah zones of Ghana. The treatments used for the study were Teprosyn Mo, Legumefix and its combination. Experimental plots measured 4.5 m x 4.5 m. The treatments were laid out in a Randomised Complete Block Design (RCBD) with three replications. A significant (p < 0.05) response to Legumefix on soybean nodule dry weight was observed in Kpongu and Manga but not Nyankpala. At harvest, Teprosyn Mo + Legumefix, Legumefix and Teprosyn Mo increased soybean grain yield by 205.62%, 135.54% and 110.24% respectively over the control in Manga. In Nyankpala, the application of Legumefix and Teprosyn Mo + Legumefix increased soybean grain yield significantly by 22.43% and 42.10% respectively relative to the control while no significant response was observed among treatments on soybean grain yield in Kpongu. Teprosyn Mo + Legumefix were the most economically viable treatment in Manga

47. POTATO PRODUCTION IN THE HOT AND DRY PARTS OF KENYA: APPROPRIATE VARIETIES OR AGRONOMIC PRACTICES?

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Abstract
In Kenya, potato is the second most important crop after maize in terms of production and consumption. The crop is grown mainly by small scale farmers as a cash and food crop and therefore plays an important role in food and nutrition security. Potato is a cool season crop and grows best between 15 and 18^0 C and soil pH of 5.5. The potato has been grown traditionally in the high potential areas of the country which are characterized by cool temperatures with high rainfall of at least 1000 mm per annum and are situated at altitudes between 1500 and 3500 meters above sea level. With the increasing population and consequent diminishing land sizes in these areas, there has been migration to the lower, warmer and drier areas, where the migrants have moved with their cropping systems including the potato. Over eighty percent of Kenya's landmass is hot and dry and therefore unsuitable for arable farming especially for production of cool season crops like potato. Yet, these are the areas that frequently experience famine and most inhabitants are poor. Although a short duration crop such as potato can go a long way in solving the crisis, most of the locally available potato varieties do not do well under high temperatures. Measures such as planting of heat-tolerant varieties that are currently being researched on by CIP, late maturing varieties, cultural practices such as mulching, changing the planting dates and proper earthing up may contribute to alleviating the situation. This review paper looks at ways that can be employed to allow for profitable production of potatoes in the hot and dry parts of Kenya.
Key words: Agronomy, Appropriate varieties, Hot areas, Potato production.

48. SAMPLING SCHEME FOR MAPPING VARIABILITY OF SOIL HYDRAULIC PROPERTIES IN AN AGRICULTURAL AREA IN TANZANIA

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Abstract

Management of water in cropping systems necessitates a characterisation of spatial variability of soil hydraulic properties (SHPs) (water retention and hydraulic conductivity). Digital soil mapping (DSM) provides a toolset of statistical methods for mapping SHPs over landscapes. Designing a spatial sample is an important first step in DSM. This study addresses the problem of designing an efficient sampling scheme for mapping SHPs by combining both direct measurements of SHPs and cheaper measurements of soil physicochemical properties. A stratified random sampling design was adopted. The strata are 100 compact geostrata of equal area constructed by k-means clustering of pixels constituting the study area, using the spatial coordinates of the pixels as classification variables. This method was implemented in the (add-on package spcosa of the statistical software R). One location was randomly selected from each geostratum generating 100 master locations. The 100 geostrata were then collapsed into 50 pairs of geostrata based on their geographical distance. Two neighbouring geostrata formed a pair, with two selected sampling locations. At one of these pairs, both SHPs and soil texture were measured generating a sub-sample of 50 calibration locations. At the remaining 50, only soil physicochemical properties (texture and organic carbon) were measured. Calibration locations data will be used to calibrate a regression model relating SHPs to soil texture. This sampling design leads to an even spread of sampling locations across the study area, desirable for mapping with a spatial interpolation method.

49. GROUNDNUT PRODUCTION IN CHISAMBA DISTRICT: THE FARMERS` PERSPECTIVE

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Abstract

The study to determine the perceptions of the smallholder farmers on groundnut production, use of fertilizers and cropping systems was conducted in Chisamba District. Chisamba District is located about 50 km north of Lusaka, in the Central province of Zambia. The District covers 2978.5 km2 and is located between latitude 14o 30' and 15o00' S and longitudes 28o00' and 28o30' E. The multi stage sampling technique was adopted for the selection of respondents. The first stage was purposive selection whereby the two agricultural blocks, Chisamba and Muswishi were selected. The second stage involved purposive

selection of the six agricultural camps from each block while, the third stage involved selection of the agricultural zones. A list of all the zones in an agricultural camp was written, cut into labeled pieces of paper and then these were used in randomly selecting the zones from a bag using the lottery method. Questionnaires were then administered to smallholder farmers who grow groundnuts in each particular zone. Data collected from 164 respondents was analysed using Statistical Package for Social Scientists (SPSS, 16). Results show that 71 % of groundnut production in Chisamba District was undertaken by female smallholder farmers. The study revealed that about 91 % of the smallholder farmers in the District recycled seeds from the previous seasons. There was low level of acceptability of the new varieties amongst the smallholder farmers in the District. The farmers were more familiar with old varieties and most of them (57 %) preferred Natal Common mainly because it was drought resistant and matures early therefore, it can be planted twice in one agricultural season. Poor agronomic practices such as late planting, and either late or no weeding contributed to the poor yields of groundnuts in the District. About 90% of the farmers in the District perceived crop rotation as a sustainable technology in improving both soil productivity and groundnut and maize yields in Chisamba District. The perceptions of all the respondents were that groundnuts did not require application of fertiliser because the crop fixed its own.

50. ISOLATION OF GENES CONFERRING DROUGHT TOLERANCE IN TEA (*Camellia sinensis* L. O. Kuntze)

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Abstract

Tea, *Camellia sinensis*, is a widely consumed beverage worldwide. Tea growing areas in Kenya often experience drought periods which causes accumulated soil water deficit. These adversely affect tea production and hence the need to develop drought-adapted tea cultivars that can withstand the stress. Development of such cultivars can be facilitated by an understanding of genetic mechanisms underlying tolerance of the tea plant to water deficit achieved through transcriptome analysis of tea tissues. Tea plants respond to water deficit through poorly understood molecular processes. A study was designed to use the next generation sequencing technique to identify genes putatively conferring tolerance in the tea plant. Drought tolerant (TRFCA SFS150) and susceptible (AHP S15/10) tea cultivars, both 18-months old, were each separately exposed to water stress (18% SMC) or control conditions (34% SMC) for three months. RNA isolated from fresh shoots were reverse transcribed and sequenced on Roche 454 high-throughput pyrosequencingplatform. The quality reads generated were assembled and the contigs obtained were annotated using BLAST searches against similar proteins in the *Arabidopsis* proteome and blast2go against

non-redundant database to determine gene ontologies. Drought-related genes including; heat shock proteins (*HSP70*), superoxide dismutase (SOD), catalase (cat), peroxidase (*PoX*), calmoduline-like protein (*Cam7*) and galactinol synthase (*Gols4*) were induced in plants exposed to drought. Additionally, the expressions of HSP70 and SOD were higher in the drought tolerant relative to the susceptible cultivar under drought conditions. Loci with known functional links to physiological and biochemical features of drought response appear to mediate tolerance to drought in *C. sinensis*. The loci present potential molecular markers for drought tolerance that can be explored through functional genomics to better understand molecular mechanisms underlying drought tolerance in *C. sinensis*.

51. GENE EXPRESSION IN WATER STRESSED TEA PLANTS COMPARED WITH PLANTS GROWN UNDER OPTIMAL CONDITIONS

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Abstract

Drought poses significant threat to tea growth and productivity directly affecting the economies of tea producing countries where the industry is a major source of revenue. Plants have evolved a host of response mechanisms to drought to enable them survival. However, limited information exists on the molecular response of tea to drought stress. State the objective of the research. Clonal plants were subjected to progressive drought by withholding irrigation for 30 days, while control plants were irrigated continuously. Changes in soil moisture content, leaf relative water content and relative electrolyte leakage were determined. Analysis of subtracted cDNA libraries prepared using the RNA isolated from leaves of irrigated plants and drought stressed plants identified cell rescue and defense as a significant response mechanism to drought stress in tea. Gene expression patterns over time and in different plant tissues indicated that adaptation to drought partly involves membrane and protein stabilization machinery. Further, closer gene cluster network was observed between stem and leaf expression patterns indicating the operation of a mechanism to protect the metabolic machinery under drought stress. Selected genes were up-regulated by different abiotic stresses providing valuable resource for drought improvement in tea.

52. WATER STRESS EFFECT ON DISTRIBUTION AND ANTIOXIDANTS CONCENTRATION OF AFRICAN NIGHTSHADES IN KISII AND SIAYA COUNTIES OF KENYA

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Abstract

African Nightshades (*Solanum* spp) are an important source of antioxidants such as lycopene, phenolics, and vitamin C in human diet, and have been linked with reduced risk of prostate and various other forms of cancer, heart diseases as well as helping to boost the immune system of HIV/AIDS patients. The aim of the study was to determine water stress effect on the total antioxidant capacity and total phenolics in the two selected African nightshade (*Solanum scabrum* and *Solanum villosum*), and establish the distribution of the different African Nightshade accessions in Siaya and Kisii Counties of Kenya. The study involved farmer field visits, GPS mapping of present nightshades and distribution of semi- structured questionnaires to farmers. Experiments were conducted both in the field and greenhouse, and it involved daily watering, watering on the third day and watering on the sixth day. The total antioxidant capacity was studied using DPPH radical scavenging method and the total phenolic content by Folin-Ciolcalteu method. Preliminary results showed that water stress not only affects the different growth parameters in nightshades (leaf area, shoot height, shoot biomass, root biomass and number of secondary buds) but also the antioxidant capacity and phenolic contents. However the effect seems to vary among plant organs, with black nightshade (*Solanum villosum*) having a higher concentration of both the phytochemicals in the shoots while giant nightshade (*Solanum scabrum*) having higher concentration of the same on the roots. This can be explained genetically and with the plants morphology which always has a direct effect on plants biochemistry. From the study it can be concluded that different watering regimes affect the growth of both black and giant nightshade varieties. The varieties were found to be sensitive to water stress especially if watering is delayed to the fifth day. Water deficit reduced the number of secondary buds, leaf area and shoot height, which consequently reduced biomass production. Maintenance of root growth during water deficit is an obvious benefit to maintain adequate plant water supply. Watering the plants once after two and five days demonstrated that these plants are very sensitive to drought; hence for good growth they need to be watered at least after every two days.

Keywords: DPPH- 1 diphenyl-2-picrylhydrazyl, Antioxidants, phenolics, radical scavenging activity.

53. GENETIC VARIATION FOR WATER UPTAKE, COOKING TIME AND FLATULENCE CAUSING FACTORS IN COMMON BEAN

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Abstract

Genotypic variation is a pre-requisite for developing fast cooking, low flatulence bean varieties for domestic consumption and canning. However, little has been done to determine variation for these traits in bean cultivars grown in eastern Africa. The objectives of this study were to determine water uptake, cooking time and concentration of oligosaccharides associated with flatulence in commercial bean varieties and new breeding lines. Study materials were 10 commercial varieties, seven recently developed biofortified cultivars and 17 advanced lines representing the Andean and Mesoamerican gene pools and the major market classes grown in east, central and southern Africa. Water uptake was determined 6, 12, 18 and 24 h after soaking beans in distilled water. Cooking time was determined using a Matson cooker placed in a stainless steel pan containing 1.4 l of tap water maintained at 94 ± 0.5ºC. Verbascose, stachyose and raffinose were extracted twice from ground raw and cooked bean milks using a 3:7 v/v methanol-water mixture and quantified on a high pressure chromatography system using analytical grade standards. Data was analyzed using Genstat statistical software (v15). Results showed there were highly significant genotypic and duration of soaking effects on water absorption ($P<0.001$). Water absorption after 12h of soaking varied from 53.7% (Kenya Afya) to 154.9% (KCB13-10). Seventeen genotypes had higher water absorption than Mex 142. Among commercial varieties only KAT B1 and KAT B9 had higher water absorption than Mex 142. There were significant differences in cooking time among the test lines and market classes. Duration of cooking varied from 26 minutes (KCB 13-10 and *Kenya Cheupe*) to 105.9 minutes (KAT56). Mex 142 cooked in 47.3 minutes. Correlation between soakability and cooking time varied from r=0.03 for speckled sugar, to r=-0.82** for red kidney. There were significant differences in total oligosaccharide, raffinose and stachyose concentration among the genotypes. However, differences in verbascose concentration were not significant. Cooking significantly influenced concentration of total oligosaccharides, raffinose and stachyose. Total oligosaccharide concentration varied from 4.1 % (*Kenya Almasi*) to 5.89% (*Kenya Madini*) with a mean of 4.96%. Raffinose concentration varied from 0.40% (KCB13-08) to 0.05% (GLP 2). Stachyose concentration varied from 2.3% (*Kenya Almasi*) to 4.2% (*Kenya Madini*). Most genotypes showed only traces of verbascose except KCB13-05 (0.028%), KCB 13-06 (0.47%), *Kenya Majano* (0.049%) and GLP 1004 (0.15%). This implied that flatulence in the study genotypes was largely due raffinose and stachyose. The results indicated that there is adequate variation for water uptake, cooking time and oligosaccharide concentration to facilitate selection for fast cooking, low flatulence beans of diverse market classes, which can promote consumption of dry beans.

54. AGENT BASED MODELING APPROACH FOR SIMULATING SOIL LOSS FROM AGRO-ECOSYSTEM IN SEMI-ARID NORTHERN GHANA

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Abstract:

Soil protection is one of the numerous ecosystem services provided by vegetation cover. Soil loss is not only limited to transformation from forest or woodland to other land-uses/ covers. It may occur when there is transformation from one agricultural land-use/cover to another. However, soil loss due to agricultural land-use change has not been properly addressed in Western Africa. Soil loss results in decline in soil fertility and decrease in the volume of reservoirs and water bodies due to siltation. In addition, accompanied loss in soil carbon has implication for climate change. Under agricultural land-use change adaptation scenario, this study simulated soil loss in semi-arid northern Ghana using multi-agent simulation (MAS) approach. General household and land use data were obtained from 186 sampled households. Sampled household were categorized using K-mean cluster analysis (KCA), and two household (agent) types were identified. The agent types differed according to their assets (human, natural and financial). The first agent type (Ag-1) consisted of 111 farm households, while the second agent type (Ag-2) consists of 75 farm households. Relevant spatial data (eg. Land-use, topographic features, soil features etc) were generated in Geographic Information System. Determinants of crop choices of each agent types (Ag-1 and Ag-2) were generated by regressing (logistic) crop choices with household and plots characteristics. Generated spatial data were imported into MAS environment and crop choice model and agricultural yield dynamic model were programmed in the MAS environment. Agent's choice with respect to maize credit (maize credit scenario) was simulated in the MAS environment, and potential soil loss was compared with baseline scenario. Findings from this study show that annual simulated soil loss was lesser under maize credit scenario as compared to baseline scenario.

55. DEPLOYMENT OF A LOW COST WIRELESS REPROGRAMMABLE DRIP IRRIGATION CONTROLLER IN TANZANIA

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Abstract

Drip irrigation controllers already exist and are imported from outside Tanzania; however, they are costly and difficult to repair in case of a breakdown. This paper presents a drip

irrigation controller that can be locally made and be used in African countries, particularly in Tanzania using site specific irrigation techniques of scheduling and monitoring. Achievement of high quality products for horticultural crops needs strict monitoring of irrigation water. The device is a solar-powered controller that uses low cost electronic devices to automatically irrigate and to determine when and how much to irrigate. Under this project, the controller has been developed, tested, improved, price determined and finally it is expected to be commercialized. It is running using PIC18F4585 microcontroller and the WiFly wireless module. It can be controlled using android application installed in the phone and also it is reprogrammed wirelessly using boot loading technique. It can accurately irrigate with at least 98% accuracy and collect data with at least 99% accuracy. The reliability of the instrument depends on existence of supplied power, whenever the power is available then the system uptime is 100%. The controller is evaluated under different conditions to achieve the water control needed by the farmer. The controller produced data that reveals the field conditions and can reveal good soil moisture percentage threshold for the plants in comparison to water holding capacity of the soil profile. The controller performed satisfactorily for commercialization.

56. PREPARATION AND APPLICATION OF SOME NITROGENOUS DERIVATIVES OF GUM ARABIC AS PLANT GROWTH PROMOTERS

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Abstract

The study was carried out to determine the effect of adding gum and some of their nitrogenous derivatives to the Winka seeds. Derivatives of arabic acid, arabamide, ammonium arabate, derivative of high protein and deri-vative of low protein were prepared. The physiochemical parameters for these derivatives were examined and comparisons carried out. The results showed that there were no significant differences between the derivatives in specific rotation and in emulsifying stability. However, there were significant differences between these derivatives in pH, except between arabamide and aminoarabate with nitrogen. These derivatives were added in concentration of either 5 % or 10 % to pots containing Winka seeds while to other pots only water was added. The experiment duration was 10 weeks. The results showed that there was significant difference in the number of plant leaves which were treated with these derivatives. The highest number of leaves was reported for plants treated with arabic acid. There was a significant difference in plant height, the highest being reported for plants to which arabic acid were added. The shortest height was reported for plants to which only water was added. Concerning the dry matter production, significant differences between these treatments were noticed. The highest value was reported for plants which were treated with arabic acid. The lowest value was reported for plant to which only water was added.

Key words: Winka seeds, nitrogenous derivatives, Arabic acid, arabamide, ammonium arabate.

57. EFFECT OF FERTILIZER AND SPACING ON YIELD AND QUALITY OF COURGETTES (*Cucurbita Pepo*)

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Abstract

Courgette or Zucchini has become a popular cucurbit vegetable in Kenya. It is easy to grow, quick maturing, nutritious and versatile in utilization. Production is mainly in areas close to urban markets and crop management pratices are based on broad recommendations. A preliminary study was initiated on-station at KALRO-Murang'a to determine zone specific Nitrogen and Phosphorous nutrition and spacing requirements. Three NP levels (0 control, 144kgN+69kg P_2O_5/ha, 192kg N+ 92 kg P_2O_5/ha) and three spacings (60x60cm, 90x90cm, 120x120cm) were tested on courgette variety Ambassador F1. Crop vigour increased with widening spacing and increasing levels of N fertilizerwith an optimum at the widest spacing of 120x120 cm and highest levels of NP fertilizer (122kgN+92 kg P_2O_5/ha). Though the significantly highest (p ≤0.05) number of fruits per plant were obtained at the widest spacing, highest yields (p≤0.05) were obtained where the crop was closer spaced at 60 x 60 cm and with NP fertilizer application at either the second or the highest level. The bulk of fruits harvested at the optimum fertilizer and spacing treatment were in the small to medium-sizegrade category. The results require confirmation in a repeat season and diversification to other potential production zones.

Key words: Courgette, NP Nutrition, Spacing, fruit yield, quality

58. SIGNIFICANCE OF MATHEMATICAL SCIENCES TO SUSTAINABLE FOOD PRODUCTION: A PERSPECTIVE OF NORMAL HILBERT SPACE OPERATOR

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Abstract

Mathematics is a subject that is related to and is directly linked to other disciplines e.g. economics, agricultural sciences, business etc. Mathematics has very important roles to the society and daily life applications and needs. One of the most important areas of study in mathematics with applications to food production is operator theory which involves Hilbert space operators. Studies on Hilbert space operators have been carried out by several researchers and mathematicians with interesting results obtained with regard to food

production. A normal operator is one of the operators under concern with interesting characters. Properties of normal operators have not been exhausted hence this calls for intense characterization of these operators. A great concern is the norm inequality involving these operators. In this paper, we give a detailed study of the norm property of normal operators when they are self-adjoint. The objectives of the study are to: establish norm inequalities for normal operators; characterize normal operators and; determine applications of normal operators to food production. The methodology involved the use of tensor products as a mathematical and technical approach in determining these norm inequalities. The results show that the norm of a normal operator is equal to the norm of any other operator when the operator is self-adjoint. A matrix of several horticultural crops as elements is constructed and its norm obtained. Results further show that cheap food can be obtained without tilling easily. The results obtained are very important in enhancing production of food and also in formulating policies with regard to food production practices.

Keywords: Hilbert space, Normal operators, Selfadjoint, norm inequality, Food production, Matrix.

59. ASSESSMENT OF SOYBEAN AGRONOMIC SYSTEMS, SEED HANDLING AND QUALITY IN EASTERN KENYA

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Abstract
The demand for soybeans in the Kenyan market is high yet production is low due to among other things lack of a well-organized soybean seed production system. The purpose of the study was to determine the farm soybean seed production, handling and storage systems, preference of utilization, marketing and seed quality preference in key growing areas of Meru South Sub-county, Eastern Kenya. Purposive sampling, key informant interviews and focused discussion group was used to collect data using questionnaires. The study sample consisted of 309 respondents from soybean growing farmer households in agro-ecological zones UM2 to LM4. 30 Samples of farm-saved seed was randomly collected for quality analysis. The research findings were analyzed using SPSS. The study established that 78% of farmers are above 40 years old, majority of whom (65%) have primary or no education; soybean is newly introduced mainly by the Ministry of Agriculture, with 82.3% having ≤3years experience, with gazelle as the preferred variety. Cultivation is by hand hoeing (98.4%) grown as a pure crop mainly in the short rains in small uneconomic quantities of ≤0.25 acres; due to lack of assured markets, poor seed system, unaffordable farm inputs and limited domestic utilization. The yields are low (0.3 T/ha) due to poor crop management and weather changes leading to

crop failure. The crop is mainly grown for own use (74% of farmers) and seed is maintained through farm-saved-seed and exchange with neighbors. Seed is hand threshed, sun dried and stored in-house mainly in synthetic gunny bags (89%) for 3-8 months. Farm saved seed quality varied with source, with higher altitudes showing greater viability. The study therefore recommends that; establishment of source of quality seed, streamlining marketing andpromoting utilization of soybean will enhance production of the crop. Maintaining seed in cooler highlands prolongs viability in storage.

Key words: soybean, farm saved seed, viability.

60. ECONOMIC EVALUATION OF INTEGRATED PEST MANAGEMENT TECHNOLOGY FOR CONTROL OF MANGO FRUIT FLIES IN EMBU COUNTY, KENYA

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Abstract

Mango is the third most important fruit in Kenya in terms of area and total production. Mango is mainly grown by smallholder farmers as a source of food to meet their dietary (vitamins and mineral) needs and as a major source of household income. Mango production and marketing is constrained by several factors, among which pests and disease infestation is major. Among the insect pests, fruit flies are the most notorious. Fruit flies cause direct and indirect losses to producers and exporters. Due to economic importance of mango fruit fly International Centre of Insect Physiology and Ecology (*icipe)* in collaboration with national and international partners developed and implemented an Integrated Pest Management Fruit Fly Package (IPMFFCP) in Embu County, Kenya. The impact of this intervention, however, had not been evaluated. This study assessed the economic effect of the intervention under smallholder setting to determine the impact on marketable mango produce loss, insecticide expenditure and net income accrued from mango farming. The study also established households' perception of the effect of the intervention on human health. Data were collected using a structured questionnaire administered to 257 randomly selected IPMFFCP participants and non participants. The study employed Difference-in-difference (DD) estimation model to evaluate the economic impact of the intervention on magnitude of mango produce rejection due to fruit fly infestation, insecticide expenditure and net income. Descriptive statistics were used to assess the household perception of the effect of IPMFFCP on health. The study revealed that on average, mango IPM participants had approximately 54.5 percent reduction in magnitude of mango rejection; spent 46.3 percent less on insecticide per acre and received approximately 22.4 percent more net income than the non-participants. Seventy eight percent of households perceived the intervention improved human health. These imply high economic benefit from the application of the fruit flies IPM technology and mango farmers would profit significantly if the intervention is expanded to widely cover other mango growing areas in the county.

61. EFFECT OF PLANTING DATE, SPACING AND SEEDING METHODS ON DISEASE DEVELOPNMENT AND YIELD COMPONENTS OF RICE IN SOUTH EASTERN NIGERIA

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Abstract

Experiment was conducted in low land and upland locations. The experiment   for the upland rice was located at the eastern research farm of Michael Okpara University of Agriculture, Umudike Abia State, while the lowland variety rice farm was sited at Izzi Local Government Area of Ebonyi State. The experiment was a 4 x 3 x 2 factorial laid out in RCBD with four replications. The factors include: planting date (PD) with four levels of early June, late June, early July and late July where early June was (15TH June) late June (30th June), early July was 15th July while late July was 30th July. The second factor was planting space (sp) in three levels of 15cm, 20cm and 25cm, both inter and intra row spacing. The third factor was seeding method (SM): which was in two levels of direct seeding (seeds) and seedlings. The effective block size was 12m x 8m which gave 96m^2. Data collected from the crop include: Plant height, number of tillers, leaf area, root length, panicle length, one thousand seed weight, disease incidence and severity. The result showed that all the factors had significant effect on the parameters measured. Sowing period had the highest leaf area (LA) of 52.96cm^2 ,plant height (PH) of 62.46cm, panicle length (PL) of 19.08cm ,second largest seed weight of 24.93g,and tiller number(T) of 5.79 all in early July. Also sowing period had the highest disease severity of (4.00) in early July followed by (3.50) which occurred in late July while the least (3.42) occurred in late June. Plant spacing of 25×25cm had the highest disease incidence of (69.78%) followed by 20×20cm which had (69.71%) while the least was (69.56%) in 15×15cm space. In conclusion planting of rice in south eastern Nigeria should be done in early July as the yield components were significantly better than in other dates though with the highest disease severity.

Keywords: disease development, planting date, rice, south-eastern Nigeria, yield components.

62. EFFECTS OF DIFFERENT ORGANIC RESIDUES ON CARBON SEQUESTRATION, NUTRIENT AVAILABILITY IN SOIL AND MAIZE YIELDS AT KATUMANI, MACHAKOS COUNTY, KENYA

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Abstract

Reduced crop production in smallholder farms is the principal cause of food insecurity in semi- arid parts of Kenya. This is mainly attributed to soil fertility depletion, land degradation and climate change. The objectives of this study were: 1) to determine the effect of different organic residues on soil carbon sequestration in soil. 2) to determine the effect of organic

residues on the availability of nutrients into the soil, and 3) to determine the effect of different organic residues on maize growth and yields. Field studies were carried out in two seasons (2011/2012 short rains and 2012 long rains) at Kenya Agricultural Research Institute (KARI) – Katumani in Machakos County. Maize residues and compost manure were used, under different application methods. This constituted seven treatment combinations as follows; 1) Control, no organic residue application; 2) 10 ton/ha compost, surface application; 3) 10 ton/ha compost, incorporated application; 4) 5 ton/ha maize stover, surface application; 5) 5 ton/ha maize stover, incorporated application; 6) 5 ton/ha maize stover, 10 ton/ha compost, surface application; 7) 5ton/ha Maize stover, 10 ton/ha compost, incorporated application). The seven treatments were laid out in a randomized complete block (RCBD) design with 3 replications. Soil samples were collected from 0-20cm and 20-40cm depths before planting, at six weeks after planting and at harvest. The soil samples were analyzed for total C, total N, soil pH, available P, Mg, Ca, Na, K and CEC. Maize grain yield and total dry matter was measured. Statistical analysis of data was done using analysis of variance (ANOVA) and means separated using LSD at p=0.05. Results of this study showed that total soil organic carbon increased with application of organic residues. Treatments that had 5ton/ha maize stover and 10 ton/ha compost, incorporated recorded the highest soil carbon accumulation of 0.36 Mg C/ha and 0.39 Mg C/ha at the end of season one and two, respectively while the control decreased by 0.02 Mg C/ha in season 1 and 0.03 Mg C/ha in season two. Nutrients concentrations in the soil were found to increase with application of organic residues where by incorporated 5 ton/ha maize stover and 10 ton/ha compost treatment recorded the highest concentrations of most nutrients in the soil. Maize yields increased with the application of organic residues. Treatments that had 5 ton/ha maize stover and 10 ton/ha compost under incorporated application gave the highest maize grains which was 145% more, compared to the control in season one and 248% in season two. In conclusion combining 5 ton/ha maize stover and 10 ton/ha compost under incorporated application could be a promising soil fertility management strategy for improved carbon sequestration in soils and for increased maize yields.

Key words: Carbon sequestration, Climate change, Soil fertility depletion, Land degradation

63. PHOSPHORUS ADSORPTION ISOTHERM: A KEY ASPECT FOR SOIL PHOSPHORUS FERTILITY MANAGEMENT

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Abstract

Characterization of soils in terms of phosphorus adsorption capacity is fundamental for effective soil phosphorus fertility management and for efficient utilization of phosphorus fertilizers. Thus, this study was conducted to investigate the phosphorus adsorption characteristics of soils of two farms and to elucidate the implication of soil phosphorus

adsorption isotherm studies for soil phosphorus fertility management. The two farms, representing the major farming systems of the respective districts were selected from Adele village in Haramaya and Bala Langey village in Kersa disricts in eastern Ethiopia. Soil samples were collected from the crop fields at Adele and Bala Langey farms. Two different P-bearing sources, potassium dihydrogen phosphate (KH_2PO_4) and diammonium phosphate (DAP-$(NH_4)_2HPO_4$) were used for the adsorption isotherm studies. The adsorption data were fitted to the linear and Freundlich adsorption isotherm models. Both models revealed that soils of both farms had different P adsorption capacity from the two P sources. Amount of P adsorbed from DAP solution was higher than amount of P adsorbed from KH_2PO_4 solution by soils of both farms. Phosphorus adsorption capacity of Adele farm soils was higher than that of Bala Langey farm soils. Therefore, soils of the two farms should be managed differently for P fertility. Percentages of P adsorbed (%Pa) and P remained in the equilibrium solution (%EC) were also calculated. By plotting the two percentages i.e. % Pa and % EC against the initial concentration of P (IC), two regions were observed. The two regions were described as P intensity and quantity factor windows. Based on the intensity and quantity factor windows, at currently existing soil condition, between 200 and 500 kgha^{-1} P should be applied as fertilizer to soils of Adele farm at 0-30 cm depth for immediate benefits and soil P fertility maintenance.

Key words: Phosphorus sources; P-fertility; P- intensity-quantity factor window

64. LOW COST MACRONUTRIENTS IN THE MICROPROPAGATION OF SELECTED SWEET POTATO [*Ipomoea Batatas* (L.) Lam] VARIETIES

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Abstract
Sweet potato is a dicotyledonous plant in the family convolvulaceae family. Although in vitro regeneration protocols have been developed for producing disease and pest free planting materials that can be produced throughout the year, micropropagation costs are high. The objective of this study was to assess in vitro regeneration response of KSP 36 and KEMB 36 varieties using low cost macronutrients source to reduce the cost of micro-propagule production. Three conventional macronutrients; ammonium nitrate, potassium nitrate and magnesium sulphate were substituted each at a time with ammonium fertilizer, potassium fertilizer and Epsom salt respectively. Nodal cuttings were used as source of explants. Results obtained from the present investigation indicated that explants cultured in low cost macronutrient Epsom substitute media, performed better in regeneration in term of leaves and nodes formed compared to the conventional media, while in other substitute significant differences (p > 0.05) were not detected in varieties tested. Use of locally available macronutrients significantly (p < 0.05) reduced the cost of micropropagation of sweet potato. KEMB 36 performed better compared to KSP 36 in regeneration response. There is therefore

a potential for using locally available low cost macronutrients source as alternative to the conventional costly laboratory macronutrients.

65. EFFECTS OF ECO-FRIENDLY NETS ON GROWTH AND SEED YIELD OF AFRICAN LEAFY VEGETABLE, *Amaranthus hybridus*

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Abstract

A field experiment was conducted at Egerton University, Kenya, in the Horticulture Research and Teaching Field, from May to September 2014. Objectives were to investigate the effects of Eco-friendly net on growth, leaf and seed yield of Africa Leafy Vegetable (ALV) *Amaranthus hybridus*. The area measured 33 m by 17 m and divided into smaller plot sizes of 3 m X 5 m. *Amaranthus* seedlings were raised in a protected seed bed under the same type of net for 4weeks before transplant into the field plots. *Amaranths* seedlings were transplanted, with spacing of 40 cm by 20 cm. DAP fertilizer was used at the rate of 10 g per hole. The treatments were two; growth under net and those on open field. The experimental design was a Randomized Complete Block Design (RCBD) and replicated five times. Growth data was collected on height, collar diameter, number of branches of spike and main spike length. Leaf and seed yield data were taken on total weight in the 10th week at termination of experiment. These were subjected to analysis of variance (ANOVA) and on the significant; means were separated using Tukeys SHD at $P \leq 0.05$. The results indicated that Eco-friendly net has significant influence on growth of *Amaranthus hybridus*. The vegetative growth rate was high by 45%, leaf yield by 20% and seed yield by 80% in the Net compared to open treatments. Leaf yield was good under net up to 7th and 8th weeks of harvesting period, but reduced on net compared to the open treatments as inflorescence started to form. In overall, net production was higher for quantitative seed yield. While for leaf yield net was better with narrow margin compared to open field. From this work, the use of eco-net can be recommended for Amaranth leaf and seed production.
Keywords: Eco-friendly nets, *Amaranthus hybridus*, Growth, leaf and seed yield

66. INFLUENCE OF ONE AND TWO NODE CUTTINGS ON RAPID VEGETATIVELY PROPAGATED INFILLING TEA (*Camellia Sinesis*) PLANTS

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Abstract

The tea industry in Kenya is rural-based and provides a livelihood to over three million people. Tea is grown in prime agricultural land and can be potentially productive for 100 years if well managed. Peak yields under optimal management are obtained at 20–40 years after planting only if gaps that arise due to factors such as lightening, pests, diseases, unfavorable climatic conditions and incorrect pruning are taken care of through an elaborate infilling program and use of appropriate infilling plants. Infilling in tea farms is however faced with a challenge of lack of suitable infilling plants since commonly used single node cuttings take very long in the nursery and is less robust to compete with established ones. The purpose of this study was therefore to investigate the suitability of vegetatively propagated (VP) tea plants raised from two nodes as opposed to single node cuttings as infilling plants. The study was conducted at tea nurseries of KTDA Kangaita and Kagochi farms in Kirinyaga and Nyeri Counties, respectively. The treatments were two types of cuttings namely single node cutting (SNC) and two node cutting (TNC) from three tea clones (TRFK 31/8, TRFK 6/8 and AHP S15/10). The experimental design was CRD with split arrangements where main plot was the node cutting (2) and subplot was constituted by three clones. The treatment comprised a set of 200 cuttings and was replicated thrice in the two different sites. The parameters measured were survival count, ability to produce two shoots, number of new leaves and size, root and shoot length, and root biomass. All data collected were subjected to analysis of variance ($p \leq 0.05$) and where significant differences among treatments were found the means were separated using Least Significant Difference (LSD). The SAS statistical package was employed in all analyses. Results revealed that TNC had superior performance in most parameters measured compared to SNC with clone TRFK 31/8 showing better performance in more parameters than other clones apart from the ability to produce two shoots from TNC. The results showed that apical dominance in tea is not absolute and therefore a good number of cuttings grown as two node cutting (TNC) were capable of producing two shoots, a characteristic desirable for an infilling plant. The outcome of the study shows that tea farm productivity can be increased through faster development of healthy and robust infilling plants using TNC than through the conventional method employing SNC. It is therefore recommended that tea growers requiring faster infilling plants can use TNC in the tea nurseries. A further research to explore suitability of cuttings with more than two nodes needs to be undertaken.

67. PEST MANAGEMENT PRACTICES AND COMPLIANCE TO MARKET STANDARDS AMONG FRENCH BEAN FARMERS

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Abstract
The EU commission increased to 10% sampling and pesticide residue analysis of French beans and peas imported from Kenya. This resulted in a 25% dip in bean sales in January 2013. This study aimed at determining pest management strategies used by small scale French bean farmers. A survey to determine farmers' pest management practices was done in Embu east and Mwea east district, where 32 and 38 farmers were from Embu east and Mwea east, respectively. The farmers considered French beans farming as an important source of income, and up to 50% of the farmers had been in French beans production for a period of three years and more. Most of farmers in the study area entirely relied on synthetic pesticides for pest and disease control. White fly was the major insect pest while rust was the major disease as identified by the majority of farmers. Less than 30% of the farmers were involved in the implementation of GLOBALGAP, with 3.1% of the farmers being certified. The findings showed that farmer's pest management practices were incompatible with good agricultural practices and export market standards. There is a need to sensitize farmers on the use of alternative pest management strategies and requirements of the export market standards.
Key words: French beans, export market requirements, maximum residue levels, Global G.A.P

68. RESPONSE OF TROPICAL EARLY AND EXTRA-EARLY MAIZE HYBRIDS UNDER DROUGHT AT SEEDLING AND FLOWERING STAGE

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Abstract
Drought is a major abiotic constraint to maize productivity in sub-Saharan Africa. Critical stages of maize when drought results into maximum loss are the seedling/vegetative stage and flowering/grain-filling periods. Much research efforts had been concentrated at breeding maize for tolerance to drought stress at flowering and grain filling period without considering the response of the genotypes to drought when it occurs at seedling/vegetative stages. Therefore, the objective of this study was to evaluate the response of maize hybrids from two maturity classes to drought stress imposed at seedling and flowering stages and identify adaptive traits at this growth stage. This study was conducted in the screenhouse facility of the Faculty of Agriculture and at the Teaching and Research Farm (T&RF), Obafemi Awolowo University, Ile-Ife, Nigeria. In the screenhouse experiment, 15 varieties each from early and extra-early maturity groups were planted in eight liters pots filled with 3 kg of top

soil each and were laid out in a randomized complete block design with three replicates. Six seeds were sown per pot, which was later thinned to five and water was applied to each bucket at the rate of 0.6 litre of water per bucket/day for 7 days when watering was stopped. In this study, plants were observed for 42 days and data were recorded on emergence, growth rate and other seedling traits. In the field evaluation, the 30 varieties were evaluated using randomized incomplete block design with 3 replicates. Data were collected on grain yield and other agronomic traits. Data collected were subjected to analysis of variance and means were separated using LSD to compare performance of genotypes. Principal Component Analysis and Correlation analysis were employed to assess relationship among traits. Results showed that effects of variety and maturity were significant for seedling traits such as total leaf shed, root length, fresh shoot weight, total fresh weight and seedling aspect, indicating that the traits are efficient for selecting maize genotypes for drought tolerance at seedling stage. Principal component analysis identified these traits as the primary traits contributing to diversity among the hybrids under induced drought at seedling/vegetative stage. Traits such as emergence at 5, 7, and 9 days after planting (DAP), plant aspect, streak disease infection, husk cover, stay-green characteristics, ear height, plant height, number of ears per plot, ears harvested, ear aspect, ear rot infection, ear weight, moisture, number of kernel rows, ear length, ear diameter and yield. It was concluded that the thirty maize hybrids responded differently under induced drought stress imposed at both seedling and flowering stages. In addition, total leaf shed, root length, fresh shoot weight, total fresh weight and seedling aspect, were identified as the most important traits to select drought tolerant maize genotype at seedling and vegetative stages. It is therefore recommended that the inclusion of these seedling traits in the base index for selecting genotypes for drought tolerance with produce genotypes with tolerance to drought at all periods.

69. AFRICAN LEAFY VEGETABLE VALUE CHAIN ANALYSIS IN BUSIA COUNTY: FARMERS PERSPECTIVE

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Abstract

In Kenya, Africa leaf vegetables offer a significant opportunity for poor people in western Kenya especially Busia county to earn a living because it can be done with little capital investment. The overall objective of the study was to identify entry points for every stakeholder so as to enhance sharing of knowledge and information for effective and efficient multi-sectoral approach towards development of the African leafy vegetable industry. The study was carried out in three locations in Busia County (Mundika, Township and Bukalama Locations. A total of 101 farmers participated in the activities and exercises (checklist of questions, group discussions, plenary sessions and group exercises). African leafy vegetables were identified categorized and ranked using criterion (food, health, nutrition, income,

competitiveness in market, seed availability, soil fertility and early maturing indicators) developed by farmers and traders and ranked in order of priority as Spider plant, African night shades and Amaranths. Cowpea leaves and Crotolaria ranked 4th in Mundika, Crotolaria ranked 4th Bukalama and Pumpkin leaves (ranked 4th in Township. Farmers in Bukalama location consider spider plant to be more profitable as has higher gross margin than night shade and Amaranth. Amaranth has a negative gross margin which is a loss to the farmer. Spider plant was more profitable in Mundika location followed by night shade. About 30% of the farmers in Mundika location sell their vegetables directly from the farm, 25% take them to Mundika market and the remaining 25% take their vegetables to Busia, Korinda, Bumula and Matayos market. All actors in the value chain are from within the county except for a few traders who comes from the nearby counties. African leafy vegetables need to be prioritized in the county so as to increase farmers' income thus improving their lifestyle and reducing poverty in the county.

70. A BRIEF HISTORY OF SOYBEAN PRODUCTION IN KENYA

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Abstract
Soybean is a very important crop in the world. Its economic, nutritional and functional importance warrants due attention in Kenya where over 30% of children are malnourished, unemployment rate is over 40% and fertilizer use is low. Soybean is a legume crop with ability to fix nitrogen. Having a high protein content of up to 40% and oil content of 20% that have essential amino acids and unsaturated oils respectively, soybean has been recommended by nutrition experts to deal with increasing lifestyle diseases and already high levels of undernourishment in the country. The crop is versatile, in terms of its both utilization and agronomical attributes. It is a crop that can grow in varied agronomical areas, convertible to many products e.g. tofu, soymilk, soy beverages, soy seasonings and soy meal and be an ingredient in many products such as bread, cakes and breakfast cereals. In its complete value chain, soybean can form a huge industrial base for such a developing country as Kenya. However, Soybean production in the country has remained low and has never picked up since the British colonialists introduced it in 1909. Unlike countries in the Northern hemisphere and the Americas who have embraced the crop and enjoyed its benefits, adoption of the crop has remained low. This paper attempts to trace the historical roots to the current situation and recommends ways of ameliorating the same. Soybean development policy need to be established and the crop considered for the important crop it is by all stakeholders.

71. TROPICAL MAIZE TRANSFORMATION THROUGH CELL SUSPENSIONS AND PROTOPLAST CULTURE SYSTEMS

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Abstract

Tropical maize transformation using cell suspension and protoplast culture systems provide a convenient way of upgrading maize genome towards developing improved varieties. In this study, optimization for establishing cell suspensions and protoplast cultures for five tropical maize genotypes was done to identify: genotypes that can readily get established in liquid cultures; whose cells are transformable using *Agrobacterium tumefaciens*; genotypes whose protoplasts are transformable and can regenerate plantlets. Among 5mg/l Dicamba, 3mg/l 2, 4-D and 5mg/l Picloram used as plant growth regulators, dicamba and picloram induced immature zygotic embryos to form friable calli that readily initiated cell suspensions in liquid medium. The medium was amended with 0.1g/l asparagine and either 0.4 or 0.8g/l proline. Cell growth was determined by gain in packed cell volume (PVC %) every two days where cells of inbred lines CML 216, EO4 and CML 144 exhibited gain in PCV of 6.6%, 11.2% and 7.9% relative to the total culture volume by the second week of culture. Further determination of the growth rate of the established cells indicated an exponential increase of PCV up to the 8th day of culture. Cells maintained in liquid medium without or 0.4g/l proline in combination with 0.1g/l asparagine showed reduced doubling of PCV (increase in PCV of 30-40%) as compared to those maintained in liquid medium supplemented with 0.8g/l proline and 0.1g/l asparagine (PCV increase of 80%). The cells obtained produced protoplasts using 2% cellulase and 0.5% pectolyase in an enzyme digestion cocktail. When 3% percent cellulase was used, the cells were over digested and 1% had little activity or probably required longer time of incubation to result in any protoplasts.

Key words: *Agrobacterium tumefaciens*, Asparagine, Cell suspension, cellulase, Dicamba, Pectolyase, protoplasts

72. REGIONAL ORGANISATIONS AND FOOD SECURITY POLICY GOVERNANCE: A CASE STUDY OF THE INTER-GOVERNMENTAL AUTHORITY ON DEVELOPMENT FOOD SECURITY PROGRAMMES IN THE HORN OF AFRICA

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Abstract

This paper seeks to examine the role of regional bodies in advancing a common food security policy framework among the member states. The aim of this analytical process is to find out if the governments and states in the Horn of Africa sub-region have made corrective policy

amendments to address internal food shortages and gradually eradicate the level of hunger and starvation for their populations. It has been advanced that the Horn of Africa sub-Region has a perennial shortage of food and that the communities across borders are always in conflict as they scramble for transnational environmental resources for socio-economic livelihoods. The IGAD was established to mitigate on the transnational pacification on natural resource sharing and management. To deal with this problem the sub-regional body has sought to come up with various environmental conservation and management programmes to empower people to achieve sustainable food production. The research will therefore interrogate the IGAD food security programme on the social, structural, and gender components to advance the purpose of food security in the sub-region. Secondly it will investigate into the capacity and challenges of IGAD to implement the proposed food security in all the member states. Thirdly there will be a comparative analysis of the implementation of the IGAD food security programmes in the sub-region. Finally the paper will synthesise the diverse experiences of the IGAD member states for the purpose generating a regional food security policy whose intent is to mainstream environmental and socio-economic resources for sustainable development.

Key words: Policy, governance, gender, food security.

73. ADAPTATION TO CLIMATE CHANGE AND MULTIPLE USE OF LOWLAND IN DASSARI CATCHMENT, BENIN WEST AFRICA

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Abstract

Arid and semi-arid regions of West Africa are part of the most vulnerable regions of the world to climate change and with high probability to face acute water scarcity problem in the coming years. This paper provides an analysis of adaptation to climate change using lowlands in a semi-arid region in West Africa. Unlike other studies of adaptation, this paper examines the differences use of lowlands based on around 360 farm surveys collected across Dassari catchment North West Benin. In the first stage, the characteristics of used lowlands and the criteria of choice by farmers were analysed. In the second stage, the different uses regarding the spatial distribution of stored water were assessed and, finally the economic value of lowlands based on incomes obtained by selling the different products harvested. The results indicate that Dassari farmers increase the use of lowlands in response to a warmer climate. On the other hand, has been observed that the different crops cultivated in a given lowlands are based first on the crop characteristics and the spatial distribution of water. Moreover,

people harvest shallow water in lowland as a response to water scarcity for human consumption. Lowlands have an important economic value for semi-arid region population.
Keywords: Climate change, Adaptation, Semi-arid, lowland.

74. SOIL N, P AND K BALANCES AFTER APPLICATION OF DIFFERENT P SOURCES IN LEGUME-MAIZE CROPPING SYSTEMS IN KABETE, KIAMBU COUNTY: A NUTMON APPROACH

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Abstract

Calculation of nutrient balance is necessary for assessment of impact of agricultural technologies on soil fertility. The objective of the study was to assess N, P and K balances under legume-maize cropping systems with application of *Minjingu* phosphate rock (MPR) or triple superphosphate (TSP) fertilizer. A field experiment was conducted in the short (SRS) and long (LRS) rain seasons of 2012. The set up was a randomized complete block design (RCBD) with a split plot arrangement. The main plots comprised three cropping systems; (i) monocropping (sole maize [*Zea mays* L.]), (ii) intercropping (white lupin [*Lupinus albus* L.]/ Maize; chickpea [*Cicer arietinum* L.]/ Maize) and (iii) crop rotation (white lupin -maize; chickpea - maize). The split plots were two phosphorous (P) sources; MPR and TSP applied, at 60 kg P ha^{-1}, and a control. Soil N, P and K balances were determined at plot level using NUTrient MONitoring (NUTMON) tool box. The overall farm balances were negative with losses of 282.7 kg ha^{-1} yr^{-1} N, 131 kg ha^{-1} yr^{-1} P and 84.7 kg ha^{-1} yr^{-1} K recorded. With a maize/lupin intercrop, the soil N balances are found to be less negative (-137) as compared to the other cropping systems. However, for higher P balances, rotation of chickpea with maize (-99.9) and application of either P source is recommended. Soil K balances are higher when crop rotation is done with either of the legumes. To ensure cumulatively higher nutrient balances in farms, the use of lupin as an intercrop is recommended.

75. EFFECT OF FEED RESTRICTION ON GROWTH PERFORMANCE CHARACTERISTICS OF BROILER CHICKENS

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Abstract

This study was carried out to examine the effect of feed restriction on growth performance characteristics of broiler chickens. A total of sixty (60) Anak broiler chicks were used. The birds were allotted into four dietary treatments in a Complete Randomized Design (CRD).

Each treatment was replicated three times with five birds per replicate. The dietary treatments were identified as T_1, T_2, T_3, and T_4. Birds on T_1 were on ad libitum feeding throughout the experimental period, T_2 were on 70% ad libitum for first 21 days followed by ad libitum feeding for the last 21 days, T_3 were on 70% ad libitum throughout the experimental period and T_4 were on 70% of commercial diet + 30% sun-dried maize sievette throughout the experimental period. Analysis of data obtained revealed that the means of the final body weight showed significant difference between T_1 and T_4 but differences existed between T_2 and T_3 and the other treatments (P<0.05). Feed intake value of T_1 and T_4 was significantly (P<0.05) higher than T_2 and T_3. Feed efficiency did not differ between treatments. Result on carcass quality revealed that there was significant difference between the live weight of T_1 and other treatments. But similarities existed between T_2 and T_4. No significant difference were found between T_1, T_2 and T_4 for the breast, drum stick/thigh, wing and gizzard weight but T_3 remain the lowest among the treatments.

76. EFFECT OF ORGANIC AND INORGANIC SOURCES OF FERTILIZER ON GROWTH, YIELD AND FRUIT QUALITY OF EGGPLANT (*Solanum Melongena* L)

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Abstract

Eggplant (*Solanum melongena* L) is one of the important Asian Vegetables grown in Kenya for export market. As might be expected with crop of such promising potentials, effort to improve its productivity and quality should be emphasized. Declining soil fertility resulting from continuous cultivation of small holder farms and escalating cost of imported fertilizers and the need to conserve and build natural resource capital and biodiversity, has led to renewed interest in the use of local nutrient resources for soil fertility management in Kenya. The study was conducted at Bukura Agricultural College farm during the short (SRS) and long rain seasons (LRS) of the year 2009 and 2010 respectively. The LRS occurs between March and July and SRS from September/October to December with peaks in April and November, respectively. The experiment aimed at evaluating the effect of combination between two levels of the recommended mineral fertilizers(50% and 100% of research recommended rates) with three types of organic manures on growth, fruit yield and quality of egg plant (*Solanum melongena* L) var. *Black beauty*. The experimental design was split plot with three replications, where two levels of mineral fertilizers treatments (50% and 100%) were randomized in main plots while three types of organic manures(FYM, Compost and Tithonia) and control treatments were randomized in the subplots. Topsoil (0-20cm depth) were sampled before transplanting seedlings and analyzed for soil physical properties, PH, N, P, K, OC and CEC. The organic manures were also analyzed for their chemical properties i.e. PH, N, P, K, OC and CEC. Results showed significant differences in eggplant growth, fruit

yield and quality (p<0.05) between the two main treatments (50%RRR and 100%RRR), the three organic manures and their control. Similarly, there was significant difference between and the interactions between the two inorganic fertilizer levels and the organic manures. Increasing NPK from 50% to 100% of the research recommended rates encouraged the vegetative growth of eggplants as expressed as plant height and fresh weight. Besides increasing the total yield it enhanced the fruit quality. The plants in the organic manure treated plots were characterized with vigorous vegetative growth, which in turn led to increase in total fruit yields as well as improving fruit quality. The farm yard manure was considered the superior source of manure to obtaining the highest value of the parameters under study as compared to compost and *Tithonia diversifolia* (tithonia). Soil fertilized with 100% recommended NPK combined with organic manures produced the superior growth of plants and the highest amount of total fruit yields. The best response was produced by 100% of recommended NPK combined with farm yard manure.

Keywords: inorganic fertilizers, organic manures, eggplant growth, yield and quality.

77. EFFECT OF APPLYING ORGANIC FERTILIZERS ON SOIL AVAILABLE NITROGEN, PHOSPHORUS AND ORGANIC CARBON UNDER MAIZE AND TOMATO IN CENTRAL KENYA

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Abstract

A study was carried out to determine the effect of applying farm yard manure (FYM) and Minjingu rock phosphate (MRP) on soil available nitrogen, phosphorus and organic carbon at Kiserian and field station, Kabete Campus University of Nairobi, Kenya. The experimental design was a randomized complete block (RCBD) with four replications in a split plot arrangement where the main plots were the three cropping systems; monocropping, intercropping and crop rotation and the split plots were FYM and MRP and sampling done at crop physiological maturity. Soil pH, N, P K and C increased in the different treatments in the following order control<MRP<FYM in the three cropping systems across the four growing seasons at both sites. In maize under rotation with chickpea, control had; 0.281% N, 2.82% C and 10.68 ppm P. FYM; 0.554% N, 4.41% C and18.24 ppm P. MRP; 0.45% N, 3.6% C and 41.08 ppm P. Maize chickpea intercrop control; 0.389% N, 3.192% C and 13.4 ppm P. FYM; 0.531% N, 4.98% C and 41.02 ppm P. MRP; 0.49% N, 4.08% C and 50.9 ppm P. Soil under maize monocrop exhibited; control; 0.2% N, 2.59% C and 11.26 ppm P. FYM; 0.416% N, 3.83% C and 18.01 ppm P. MRP; 0.28% N, 3.13% C and 26.1 ppm P. Almost a similar trend was observed in maize and tomato plots at both sites in all the growing seasons. Thus it can be deduced that, FYM and MRP application and legume integration in cropping systems improves soil fertility.

Keys words; organic cropping systems, organic inputs, soil nutrient dynamics

78. FARMERS LED AFRICAN NIGHT SHADES SEED PRODUCTION, PROCESSING AND PACKAGING: RESTORATION OF GERMPLASM FOR SUSTAINABLE UTILIZATION

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Abstract

African Nightshades are some of the most widely consumed traditional leafy vegetables in Africa where they are important sources of daily nutrition and income for small scale farmers. Despite these enormous benefits, their production remains low which is attributed to several challenges including; inappropriate fertilizer application, poor cultural practices and poor seed quality and un-availability to small scale farmers during periods of planting. Quality seed production, processing and packaging is essential for guaranteed quality attributes including higher germination rates. To address these issues, an onfarm participatory African nightshades seed production, processing and packaging was initiated in Western Kenya. One acre of land was planted with *solanum scabrum* and fully managed participatorily with the farmers until seed production stage. Participating farmers have the capacity to produce clean night shade seeds, package and distribute to other farmers who are not involved in seed production. Seed production along the nightshade value chain is important in maintaining the species in existence and continual utilization without depletion. Seed production is a commercial venture that can improve household economic security.
Key words: African night shades, seed production, small scale farmers, community participation.

79. BARLEY BASED FARMING COMMUNITY SEED PRODUCTION AND BUSINESS (LSB) TO IMPROVE SEED ACCESS TO FARMERS IN ARSI AND WEST ARSI, ETHIOPIA

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Abstract

To improve the existing improved seeds scarcity of major crops in particular to malt barley, faba bean, field pea and linseed among farmers in Arsi and West Arsi zones, two Community Seed Production and Business (LSB) were established in Chole and Lemu-bilbilo districts in 2011by the support of malt barley project. Based on success story of these pioneer LSBs, currently their number is increased to14. In addition to enhancing improved seeds access and availability, LSB is aimed to break the prevailing wheat and barley mono-cropping system that attributes to different grass weeds and diseases development in the zones. To attain the intended targets multidisciplinary team composing different researchers worked collaboratively with respective district agricultural experts and farmers in a participatory approach. More than 360qt of basic and pre-basic seeds were delivered to 571 farmers in

LSB group and more than 1000 individuals including farmers agricultural experts has trained on techniques of quality seed production and business since 2011. Accordingly, the access and availability of improved seeds of focused crops and income of LSB participant farmers has been improved in target areas. Farmers involved in LSB group produced noticeable improved seeds of malt barley, faba bean and field pea which is supplied to local farmers and even to farmers in other areas. Further, LSB shortens time of technology transfer and speeds up technology uptake of farmers in the areas. Hence, strengthening the existing LSBs and extending it through the country as per the prevailing problems is crucial to advance availability of improved seeds.

80. ANALYSIS OF MARKETING EFFICENCY AND MARKETING PARTICIPATION AMONG INDIGENOUS CHICKEN PRODUCERS IN MAKUENI COUNTY, KENYA

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Abstract
The objectives of this study were to analyze the marketing efficiency of the indigenous chicken marketing channels in Makueni, determine the profitability of indigenous chicken to producers in Makueni and to determine the factors that have an effect on participation of producers in the high value markets. A purposive random sampling was used to sample 130 households from Makueni County and 66 traders from indigenous chicken markets in Makueni County. The results showed that there was an overall concentration ratio (CR4) of 41% and a Herfindahl Hirschman index (HHI) of 1087.There were 8 marketing channels, with an average marketing efficiency of 2.29. The main constraints included: price fluctuations, inadequate access to credit and information, inconsistent supply, theft and lack of storage facilities. The producers got a gross margin of Ksh.8455 per year. Apart from the age of the household head, which had a negative effect on the producer decision to participate in indigenous chicken high value markets, processing skills, education level of household head, the farmer group membership status, the flock size and region all had a positive and significant effect decision to participate in indigenous chicken high value markets. On the other hand, the family size, the type of indigenous chicken, experience in selling indigenous chicken and the flock size all had a significant and positive effect on the number of indigenous chicken sold. However the age of the household head had a negative effect on the number of indigenous chicken sold. Therefore it is recommended that contract models should be used to improve the marketing efficiency. Secondly, the producers should use collective marketing to enhance their profits. Finally to increase the participation of the producers in the high value markets, the Government policy framework must focus on improving indigenous production and marketing in Makueni County.
Key words: Marketing, concentration, fluctuations, efficiency

81. EFFECT OF WATER HYACINTH COMPOST, DAP, AND COMMERCIAL RHIZOBIA INOCULUM ON COMMON BEAN INDIGENOUS RHIZOBIA POPULATIONS IN LAKE VICTORIA BASIN

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Abstract

Common bean is an economically important grain legume with more than 200 million people in sub-Saharan Africa depending on it as primary staple. It has a major role in sustainable agriculture due to its ability to fix atmospheric nitrogen in symbiosis with rhizobia. Common bean production in sub-Saharan Africa has been reducing owing to declining soil fertility and reduced N_2-fixation. Widespread use of chemical fertilizers in agriculture has raised environmental concern and fear for consumers' health. Biofertilization such as use of rhizobia is a sustainable agricultural technique that can reduce the need for chemical fertilizers and help in alleviating environmental pollution. The aim of this study was to assess the effect of Water Hyacinth compost, DAP, and commercial rhizobia inoculum on common bean indigenous rhizobia populations in water hyacinth compost testing fields in Lake Victoria Basin. Rhizobia populations were estimated using the most probable number technique (MPN) using *P. vulgaris* as the trap host. The inoculant sources included composite soil samples representing the following soil treatments: Soils amended with; DAP, water hyacinth compost prepared using manure, water hyacinth compost prepared using EM (Effective micro organisms), commercial rhizobia inoculum and unamended soil from four farms in Korando B sub location in Kisumu and a control with no inoculation. Soils treated with water hyacinth compost prepared using EM, water hyacinth compost prepared using manure and inoculation with commercial rhizobia strain (*Rhizobium leguminosarum,* strain 446) had higher indigenous rhizobia populations in all the farms. Soils amended with DAP had the lowest rhizobia populations. The rhizobia populations in unamended soil varied from farm to farm depending on the soil characteristics. Soils treated with water hyacinth compost prepared using EM and manure had the highest rhizobia populations and therefore water hyacinth compost can be used to enhance rhizobia populations and improve common bean production.

82. EVALUATION OF CEREAL–LEGUME CROPPING ON STRIGA CONTROL AND MAIZE YIELD

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Abstract

Striga hermonthica (Del.) Benth is ranked as the number one constraint to maize productivity in Eastern Uganda. The use of trap crops is one of the control measures suggested for farmers with limited resources in striga infested areas. In this study the main focus was on the effectiveness of intercropping in reducing striga infestation and hence overall land productivity. The major objective was to identify suitable legumes in the control of striga. In order to achieve this, on farm experiments were conducted in Tororo and Busia districts of Eastern Uganda where the effect of the legumes on the striga prevalence was evaluated. Maize (*Zea mays*) was intercropped with common beans (*Phaseolus vulgaris*), soybean (*Glycine max*) and silverleaf Desmodium (*Desmodium uncinatum*) with sole maize (*Zea mays*) as the control. There was a significant (p<0.05) difference in the number of emerged striga and maize yield between desmodium and the rest of the legumes. Desmodium was found to be the most effective of the legumes in the control of striga.
Key words: *Striga hermonthica* (Del. Benth), *Zea mays*, legumes, intercropping, Uganda

83. NUTRITIONAL QUALITY OF CROP RESIDUES AND AGRO-INDUSTRIAL BY-PRODUCTS IN ERITREA

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Abstract

Chemical characteristics and nutritional values of alternative animal feed resources are essential in development of optimal and economical utilisation strategies. This study was carried out to determine the chemical composition and *in situ* rumen dry matter degradability of crop residues and agro-industrial by-products in Eritrea. The chemical composition and nutritional value of 9 cereal and 7 legume crop residue samples were determined. In all, the dry matter (DM) content was highest for the sorghum stover (SS) and least in the barley straw (BS). The millet threshed head (MTH) had the highest organic matter (OM) content while the the ground nut hull (GNH) had the highest crude protein (CP) and crude fibre (CF) contents. The calcium content differed amongst the feedstuff with the highest value of 0.54% being obtained from the millet stover (MS) and the least (0.12%) being recorded for the SS and MTH. The metabolizable energy (ME) value of the crop residues ranged from 4.70 (GNH) to 9.19 (ground nut straw; GNS) MJ/kg DM. . The 48 h DMD of the crop residues ranged from

22.63% in the GNH to 64.48% in GNS. The GNH resulted in the lowest rumen DM degradation for all the incubation test times. The implications of the results obtained in this study are discussed in details in this publication.

84. EFFECTS OF *Rhizobial* INOCULATION AND PHOSPHATIC FERTILIZER ON SOIL CHEMICAL PROPERTIES, GROWTH AND YIELD OF SORGHUM-COWPEA INTERCROP IN EASTERN KENYA

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Abstract

Agriculture is the dominant source of livelihood in rural areas of sub-Saharan Africa. However, in semi-arid eastern Kenya, smallholder farm productivity is diminishing due to declining soil fertility particularly, nitrogen and phosphorus deficiencies, and drought. A one-season study was carried out in 2 sites during the short rain season of 2012 to determine the effects of *Rhizobial* inoculation and inorganic phosphorus on soil chemical properties, growth and yield of sorghum-cowpea intercrop in Kitui and Makueni Counties, Kenya. The treatments were inoculation with *Rhizobium* (with and without inoculation), two rates of inorganic phosphorus fertilizer (0 and 30 kilogramme P ha^{-1}) and three cropping systems (sorghum-cowpea intercrop, sorghum sole crop and cowpea sole crop). The treatments were laid out in a randomized complete block design with three replications. Inoculation and inorganic phosphorus markedly enhanced residual soil nitrogen and phosphorus after harvest. The combined use of *Rhizobial* inoculant and inorganic phosphorus significantly ($P < 0.05$) improved nodule production, nitrogen and phosphorus uptake, growth and yield. Intercropping significantly ($P < 0.05$) enhanced grain yield potential of sorghum while cowpea grain yield reduced significantly ($P < 0.05$) in both sites. The Land Equivalent Ratio values were > 1, indicating that intercropping was more beneficial than sole cropping in the study areas. The use of *Rhizobial* inoculants and inorganic phosphorus was recommended to enhance sorghum-cowpea productivity in eastern Kenya. Intercropping of cereals with legume crops is also recommended to improve the productivity of smallholder farm lands in the region. Further work should investigate the persistence of the introduced commercial *Rhizobial* strain in the soil, the possibility of enhancing yields with other rates of phosphorus application and economic viability of the system under smallholder farming systems' situation.

Key words: Sorghum, cowpea, *Rhizobia*, fertilizer.

85. SPATIAL DIFFERENCES IN SOLITARY BEE NEST DISTRIBUTION ACROSS FOREST-FARM LANDSCAPE GRADIENT IN KENYA

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Abstract

Increasing solitary bee abundance in the small-scale farmlands is essential for assuring sufficient pollination of crops. Native bees supplement pollination services provided by managed honey bees, and in some instances, they are the better suited to pollinate certain crops. East African countries are highly depended on agriculture for their GDP and people livelihood. As such, factors that can increase crop productivity are in high demand. This study was carried out in Mt Kenya to document bee nests in the farmlands neighboring the forests. Mt Kenya farmland has a gradient from highland (near forest) to semi-arid (furthest from forest). Nest presence is an indicator of current suitability of farmland as habitat for various bees. The study adopted a gradient from forest edge into the cultivated areas ≥ 20km away. At the site, four sectors were identified from where data was collected in 5 plots separated by a distance of about 200m (plot to plot). Results show that farms closer to the forests have slightly higher number of bee nests (Mean 0.86) compared to the farms farthest from the forest (Mean 0.11). Among the nests observed, 90% were cavity nesters found either in house rafters or in hollow, dry twigs of hedgerows trees and shrubs. Most of the carpenter bee (Xylocopa spp.) and Hypotrigona gribodoi nests were in house rafters and very few on old dead trees. The nests were commonly found on *Cupressus lusitanica*, *Mangifera indica*, *Persia americana* and Croton megalocarpus trees. Nests of small-sized bees such as Halictus spp, Braunsapis spp, Lasioglossum spp and Meliponula ferruginea were found in smaller shrubs and herbs typically within the soft pithy cores of twigs. Nests were commonly found on Lantana camara, Ocimum kilimandsharicum, Sesbania sesban, Plectranthus barbatus, Conyza floribunda and Bidens pilosa. Soil nests were found on sloping grounds or banks shielded from direct entry of water or predators. About 67% of the nests were found on black cotton soil the rest on red soil. The study showed that only 418 nests and only 7 different bee species were found nesting in all the four sectors. Lack of large carpenter bee nests outside houses is a threat to these bees as the house owners kill them with all means to reduce wood damage. The findings demonstrate that Kenyan farmlands may not be providing sufficient nesting sites for the solitary bees, which is demonstrated by the choice of the large bees and also reduced numbers in the farmland. Reduced nest presence indicates that there could be possible pollination deficit for crops. As such, we suggest area-wide management of solitary bees through improved nesting provision, among other activities.

Keywords: Pollination, nesting, bees, crop productivity, farmlands

86. GENETIC VARIATION FOR WATER UPTAKE, COOKING TIME AND FLATULENCE CAUSING FACTORS IN COMMON BEAN

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Abstract

Genotypic variation is a pre-requisite for developing fast cooking, low flatulence bean varieties for domestic consumption and canning. However, little has been done to determine variation for these traits in bean cultivars grown in eastern Africa. The objectives of this study were to determine water uptake, cooking time and concentration of oligosaccharides associated with flatulence in commercial bean varieties and new breeding lines. Study materials were 10 commercial varieties, seven recently developed biofortified cultivars and 17 advanced lines representing the Andean and Mesoamerican gene pools and the major market classes grown in east, central and southern Africa. Water uptake was determined 6, 12, 18 and 24 h after soaking beans in distilled water. Cooking time was determined using a Matson cooker placed in a stainless steel pan containing 1.4 l of tap water maintained at 94 ± 0.5ºC. Verbascose, stachyose and raffinose were extracted twice from ground raw and cooked bean milks using a 3:7 v/v methanol-water mixture and quantified on a high pressure chromatography system using analytical grade standard reagents. Data was analyzed using Genstat statistical software (v15). Results showed there were highly significant genotypic and duration of soaking effects on water absorption ($P<0.001$). Water absorption after 12h of soaking varied from 53.7% (*Kenya Afya*) to 154.9% (KCB13-10). Seventeen genotypes had higher water absorption than Mex 142. Among commercial varieties only KAT B1 and KAT B9 had higher water absorption than Mex 142. There were significant differences in cooking time among the test lines and market classes. Duration of cooking varied from 26 minutes (KCB 13-10 and *Kenya Cheupe*) to 105.9 minutes (KAT56). Mex 142 cooked in 47.3 minutes. Correlation between soakability and cooking time varied from r=0.03 for speckled sugar, to r=-0.82** for red kidney. There were significant differences in total oligosaccharide, raffinose and stachyose concentration among the genotypes. However, differences in verbascose concentration were not significant. Cooking significantly influenced concentration of total oligosaccharides, raffinose and stachyose. Total oligosaccharide concentration varied from 4.1 % (*Kenya Almasi*) to 5.89% (*Kenya Madini*) with a mean of 4.96%. Raffinose concentration varied from 0.40% (KCB13-08) to 0.05% (GLP 2). Stachyose concentration varied from 2.3% (*Kenya Almasi*) to 4.2% (*Kenya Madini*). Most genotypes showed only traces of verbascose except KCB13-05 (0.028%), KCB 13-06 (0.47%), *Kenya Majano* (0.049%) and GLP 1004 (0.15%). This implied that flatulence in the study genotypes was largely due raffinose and stachyose. The results indicated that there is adequate variation for water uptake, cooking time and oligosaccharide concentration to facilitate selection for fast cooking, low flatulence beans of diverse market classes, which can promote consumption of dry beans.

Key words: Flatulence, cooking time, oligosaccharides, bean genotypes, water absorption

87. MORPHOLOGICAL DESCRIPTION OF THREE NEW IMPROVED POTATO VARIETIES IN KENYA

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Abstract
Morphological characterization is commonly recommended by the International Union for Protection (UPOV) in describing of new plant varieties. Kenya is a signatory to UPOV and uses such guidelines as the primary means of variety identification and registration. This work was intended to generate morphological descriptors of three potato varieties (Kenya Mpya, Sherekea and Purple Gold) for their identification. Forty eight characters were visually observed and/or physically measured recorded during and after the growing period and on tubers after harvest. Among the distinguishing characteristics of Sherekea; very small size of the sprout tip, closed sprout tip and few numbers of numbers of root tips of sprouts and weak to strong extension of anthocyanin coloration of the stem and midrib of leaves and round shape tubers. Kenya Mpya had weak to strong pubescence of the base of the light sprouts and absence or very weak extension of anthocyanin coloration in the stem, light intensity of green colour of the leaf and short oval tuber shape. Strong intensity of anthocyanin coloration of base of light sprout, erect growth habit, strong to very strong extension of anthocyanin coloration of stem, small to large leaf size and purple tuber skin colour distinguished Purple Gold from the other genotypes. The three varieties were morphologically distinct and were declared new types of varieties compared other existing varieties of common knowledge. The new varieties were subsequently released officially by the Plant Heath Inspectorate Service (KEPHIS) and are currently in production by farmers and the seed producers. The notes generated in this study can be used in development of morphological database for cataloguing, routine seed purity inspection and in breeding research.
Key words: UPOV, descriptors, varieties, potato, release

88. EXAMINING BENEFICIAL INORGANIC AND ORGANIC FERTILIZER INTERACTION IN SOYBEAN CULTIVATION IN THE NORTHERN REGION OF GHANA

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Abstract
The need for fertilizer in soybean cultivation is inevitable, especially in Northern region of Ghana where soils are inherently low in soil fertility status. Field experiment was conducted

to investigate the response of soybean to fertisoil and inorganic fertilizer. Two levels of the fertisoil (0 and 3 ton ha^{-1}) and two levels of inorganic fertilizer (0 and 30 kg P_2O_5 ha^{-1}) were applied as sole and combined treatments. The experimental design was a randomized complete block design with split plot arrangement and was replicated four times. Parameters determined were the number of nodules, nodule dry weight, biomass and yield components. The nodule number was not significantly (P=0.05) influenced, but the dry weight accumulation was influenced significantly leading to 30, 17 and 14% increase by FS, 30P and FS*30P over the control respectively. Also 10, 15 and 30% increase in grain yield was produced over the control (30P, FS, and FS*30P) respectively. The uptake of nitrogen and phosphorus at flowering were also significantly influenced. This study indicates that the need for the use of fertilizer is paramount in increasing soybean potential and sustaining the soil for future use in the study area.

89. THE DISSIPATION OF HEXAZINONE IN TROPICAL SOILS UNDER CONTROLLED LABORATORY CONDITIONS

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Abstract

The dissipation of hexazinone in one loam tropical soil was studied under controlled laboratory conditions for a period of 28 days. The results showed dissipation to be very rapid, which can be attributed to leaching, biodegradation, volatilization, high room temperature and microbial metabolism. The DT_{50} value of dissipation was 4.6 days based on the first-order kinetics. The results obtained in this study would be useful for modelling and prediction of the impact of hexazinone in soils and nearby aquatic senvironments.

Keywords: Hexazinone; laboratory dissipation; half-life; tropical soil.

90. CHEAPER AND EFFICIENT ALTERNATIVE FOR TRUE POTATO SEED (TPS) DORMANCY BREAKING IN POTATO (*Solanum tuberosum L.)* BREEDING AND (TPS) SEED PRODUCTION

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 Abstract

In developing countries (like Kenya) where resources for conducting research can often scarce, a cheap alternative method of breaking true potato seed (TPS) dormancy can significantly cut the cost of TPS seed germination in potato (*Solanum tuberosum L.)* breeding and TPS seed production. Soaking of TPS in 1500 parts per million of gibberellic acid (GA_3) for 48 hours has been the method most widely used in breaking TPS dormancy. This study was to compare cost and efficiency of using GA_3 and fermentation (soaking of broken TPS berries in water for 48 hours) as methods of breaking TPS dormancy. Mature freshly harvested berries of open pollinated TPS of 11 potato varieties were planted in randomized complete block design (RCBD) in the glasshouse and percentage germination was assessed. There was no significant (P=0.05) difference between GA_3 and fermentation with germination of 78 % and 81% respectively. Germination percentage was lowest (32 %) at 7 days after planting (DAP) followed by 14 DAP (54 %) and highest at 21 and 28 DAP both with 80%. Significant (P=0.05) differences in percentage germination were detected between the varieties. The highest germination percentage were found in varieties Kenya Karibu (89 %), Meru Mugaruro (86 %) while the lowest were in Dutch Robyjn (32 %), Desiree (39 %). Additional cost of approximately US$ 56.8-90.9 (KSh. 5000-8000.00) would be incurred when GA_3 is used compared instead fermentation at the smallest batch of TPS dormancy breaking. Germination percentages of different varieties obtained would be useful in decision-making in selection of parental materials in breeding and TPS seed production. The use of fermentation was recommended as an efficient and cost effective way of inducing germination of TPS especially in developing countries.
Key words: True potato seeds, germination, potato, fermentation, Giberrelic acid

91. ENCLOSURE MANAGEMENT REGIMES AND THE DETERMINANTS OF THEIR USE AMONG AGROPASTORAL HOUSEHOLDS IN CHEPARERIA, WEST POKOT COUNTY, KENYA

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Abstract

The proliferation of enclosures as an emerging form of land rehabilitation in Chepareria, West Pokot Kenya has proven that local approaches have the capacity to rehabilitate degraded rangelands, enhance ecosystem integrity, and improve livelihoods. However, the variability of rehabilitation success within individual enclosures in Chepareria has necessitated the need to understand enclosure management regimes. Characterizing them not only helps prospect on the consequences of enclosure operations and management, enable the interpretation of past, present and future ecological data collected from enclosures but is also vital in coming up with a cost effective enclosure management strategy. Based on a survey of 120 semi-structured interviews, 8 Focus Group Discussion and 5 Key informant Interviews, results indicate that there are five (5) key enclosure management regimes namely: Grazing_farming; Farming_grazing; Grazing_farming_contractual grazing; Farming only and Farming_grazing_fodder/grass seeds. These regimes represent possible enterprise combinations as enclosure rights holders seek to maximize individual benefits derived from enclosures. Using the likelihood Ratio Test ($P<0.05$), agro ecological zone (AEZ), age of the household head, distance to all weather road, number of enclosures owned, acreage and household income were identified as the determinants of enclosure management regimes. Overall, enclosure management regimes seek to maximize on land use, ensure flexibility and provide fall-back options in Chepareria rangelands. Enclosure owners will therefore continue to increase the number of individual enterprises in a bid to increase their income streams as land; a factor of production continues to gain interest in Chepareria. However, the determinants of enclosure management regimes mainly zonation, size of enclosure and income will continue to play key role in influencing how enclosures are used. Therefore, it is expected that the cost of hiring land for farming or contractual grazing will rise significantly in future.

Keywords: Enclosure, Management regimes, Triple L, Chepareria, Land rehabilitation

92. VITAMIN A, IRON AND ZINC CONCENTRATION IN BEAN LEAVES

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Abstract

The potential of bean leaves as a cheap source of micronutrients is not well known. The objectives of this study was to determine the concentration of vitamin A, iron and zinc in young bean leaves of recently released bean varieties and advanced breeding lines. Vitamin A was analyzed as beta carotene. The carotenoids were extracted from 12 bean genotypes using acetone. Acetone was evaporated and the residue mixed with petroleum ether to dissolve beta carotene. This was then passed through an activated silica gel column to separate the beta carotene from the other carotenoids. The absorbance was determined using atomic absorption spectrometer and then vitamin A content calculated using a constant from the standard curve. Iron and zinc were determined by digesting ash from dry samples of bean

leaves with 20% hydrochloric acid. Results showed that there were significant differences (P<0.001) in vitamin A and zinc concentration among bean genotypes. Vitamin A concentration varied from 21, 781.685±2399.23 (BCB11-204) to 114,906.185±1343.34 IU/100 g dry matter (*Kenya Almasi*) with a mean of 61,148.2. Iron concentration varied from 89.1 (BCB11-204) to 466.9 ppm (KCB 13-04) with a mean of 212.6. Zinc concentration varied from 6.5 (BCB11-204) to 50.1 ppm (BCB11-132) with a mean of 16.8. Biofortified bean varieties had significantly more vitamin A (69,277 IU) compared with other advanced lines (54915 to 59253 IU) which were not previously selected for mineral concentration. Cooking had no significant effect on vitamin A, iron and zinc concentration, indicating a high micronutrient retention in these genotypes. Results showed that the bean leaves had 22 to 28 times more vitamin A than the recommended daily allowance of 2500 IU, suggesting that bean leaves can be a cheap source of vitamin A. About 100 g of bean leaves contained enough amounts of iron to meet the daily requirements of adult males (8mg), adult females (18mg) and pregnant and lactating mothers (27mg). Bean leaves also met the recommended daily zinc allowance of 12 mg for pregnant and lactating mothers, 11 for male adults, 8 mg for females, and 3-5 mg for children of 1 to 8 years.

93. RISK AND BENEFIT ANALYSIS OF INVESTMENTS IN CONSERVATION TECHNOLOGIES UNDER VARYING CLIMATE IN EASTERN KENYA

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Abstract

Investments in conservation technologies by the risk-averse farmers can only be undertaken when sufficient returns are guaranteed and the risks thereof are known. This study assessed soil and water conservation (SWC) technology investment by farmers, examined factors that influence investment into the conservation technologies, quantified the costs and the benefits of short term investments in the conservation technologies and finally, identified the potential opportunities to reduce risks of investments in the conservation technologies under variable climatic conditions. The study was carried out in Mwania and Kalii watersheds in Machakos and Makueni Counties. A sample size of 120 farmers was used for the household surveys. Descriptive statistics were conducted using SPSS Software. The crop simulation model (APSIM) was used to generate yield data under irrigation, tied ridges and terraces which were subjected to analysis of variance using R-statistical software. Results indicated that terraces were the most used SWC technology in both sites while tied ridges and mulching the least invested technologies. High cost and input unavailability locally were key factors constraining investments in SWC technologies while benefits accrued after the investments was the significant factor influencing investments. Benefit-cost analysis (BCA) during 2010/2011 SR season indicated that irrigation and tied ridges had the highest benefit-cost ratio (BCR) of 1.3 and 2.5 in Mwania and Kalii respectively under maize production. Terraces gave the highest BCR (1.5) in Kalii under bean production. ANOVA results

indicated that the technology used, fertilizer rate applied and the season type were significant in both maize and bean production. Modeling results indicated that investing during above normal seasons was risky in all technologies but beneficial during normal seasons. Model simulations further indicated that fertilizer application led to up to 73% and 61% yield gains in maize and beans production when up to 30kg N/ha fertilizer was applied. The study recommends development of strategies that will ensure reduction of prices of farm inputs and their availability in the study areas, farmers' economic empowerment to enhance investment in irrigation and tied ridges to ensure food their security.

ANNEXURES

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