GRAIN AND BIOMASS YIELD OF COWPEA AS INFLUENCED BY NPK FERTILIZER APPLICATION IN THE SUDAN SAVANNAH ZONE OF GHANA

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ABSTRACT

Low yield of cowpea among smallholder farmers in Ghana has necessitated the need for fertilizer combination for increased yield. The yield response of cowpea to NPK application was investigated in a field study at Lawra, Upper West region of Ghana. The treatments were laid out in a randomized complete block design with 4 replications and carried out from July to September of 2013. Performance of Omondaw cowpea variety was evaluated at different combinations of Nitrogen (0, 10, 20 and 30 kg ha^{-1}), Phosphorus (0, 15, 30 and 45 kg ha^{-1}) and Potassium (0, 10, 20, 30 kg ha^{-1}) fertilizers making 10 treatments. The highest grain yield was recorded by fertilizer application rate of 20 – 30 – 20 kg N-P_2O_5- K_2O ha^{-1} which gave a yield of 1.88 tons ha^{-1} corresponding to 123.81% increase more than control. A lower application rate of fertilizer (10 – 15 – 10 kg N-P_2O_5- K_2O ha^{-1}) was capable of increasing cowpea yield to 32.14% more than the control with a yield of 1.11 tons ha^{-1}. This however was not significantly different when compared with control. Omission of phosphorus and potassium led to a yield reduction. The biomass yield did not differ significantly among the treatments. Application of 20 – 30 – 20 kg N-P_2O_5- K_2O ha^{-1} also gave the highest biomass yield. Fertilizer rate of 20 – 30 – 20 kg N-P_2O_5- K_2O ha^{-1} was therefore recommended as the most promising rate for both grain and biomass yield at Lawra.

Key words: Cowpea, fertilizer (NPK) application, growth, yield responses

INTRODUCTION

Cowpea is an important staple food in Ghana. It is beneficial in tropical farming system due to its ability to improve marginal land through nitrogen fixation and as cover crops (Sanginga *et al.,* 2003). Its production is mainly in the hands of smallholder; farmers under low input and rain fed conditions. It is mostly cultivated in the breadbasket region of Ghana which consists of the savanna and transitional agro-ecological zones (CRI, 2006). Despite being widely consumed, the yields are among the lowest in the world with an average production of 310 kgha^{-1} (Ofosu-Budu *et al.*, 2007).

Efforts towards increasing yield has concentrated more on introduction of improved variety (Addo-Quaye *et al.*, 2011) which has not achieved the desired yield due to the marginal soil and low input agriculture. However, these improved varieties require appropriate and site specific fertilizer recommendation for increased yield. Magani and Kunchinda (2009) reported a positive interaction between P fertilizer and cowpea grain yield and suggested that P fertilizer recommendation for cowpea should be location specific. Although cowpea symbiotically fixes nitrogen, plant depended on fixed nitrogen may suffer from temporary N deficiency during the seedling growth once the cotyledonary reserve have been exahausted (Abayomi *et al.,* 2008). Chiezey *et al.* (1990) also reported that in poor soils, cowpea hardly satisfies N requirements but the crop performance is improved by fertilizer application. On the other hand, cowpea as compared with other crops has received little attention from smallholder farmers in terms of fertilizer application and efforts needed to be made to promote fertilizer use for its production. This will help close the yield gap if cowpea production is to keep pace with the other crops especially cereals. In order to update fertilizer recommendation for cowpea, this study was undertaken to assess the performance of the crop in response to different levels of NPK fertilizer application. The objective of this study was to update fertilizer recommendation for cowpea in the Guinea savannah zone of Ghana. Such information will be of significance to smallholder farmers, researchers, environmentalists, agricultural extension officers and also inform Government policy.

Materials and Methods

Study Site

The study was conducted on a benchmark soil at Dondori in Lawra district of the Upper West region of Ghana. It lies geographically between latitudes 10°40' and 11°00' N and longitude 2°51' and 2°45' W. The soil belongs to Dorimon soil series which is classified as Ferric Lixisol according to IUSS World Reference Base (2006). The site experiences unimodal pattern of rainfall annually with annual range of 800 – 1100 mm.

Field experiment

The field experiment was carried out during the 2013 cropping season (June – October). Prior to land preparation of ploughing and harrowing, a composite soil sample of the experimental plot was collected and analyzed for its physical and chemical properties. The plot size was 24 m^2 with a planting distance of 60 cm × 20 cm, while seeds were planted at 2 seeds per hole. Omondaw cowpea variety was used at different fertilizer levels of 10 treatments NPK $kgha^{-1}$ *viz* 0–0–0; 0–45–30; 30–0–30; 30–45–0; 10–15–20; 20–45–30; 20–30–20; 20–45–20; 10–15–10 and 20–30–10 referred to as T1 to T10 respectively. The treatments were laid out in a Randomized Complete Block Design with four replications. Fertilizer application was done at planting as spot application using urea, triple superphosphate and muriate of potash. Weed control was done by the application of glyphosate followed by hand weeding with traditional hoe at the onset of flowering. Insect pests were controlled using Sunhhalothrin 2.5% EC (25 g lambda-cyhalothirn per litre). Spraying started at the commencement of flowering and continued every two weeks until pod maturity. Biomass yield was determined at 50% flowering while at pod maturity, yield components such as number of pods per plant, number of seeds per pod and 100 seed weight were measured. All data collected were subjected to analysis of variance using Genstat 9 statistical package. Means were separated using Least Significance Difference (LSD) at 5% level of probability.

RESULTS AND DISCUSSION

The physical and chemical properties of soil samples of the experimental site (Table 1) indicated that the soil was sandy loam, with total N (0.70 gkg^{-1}) and available P (1.79 $mgkg^{-1}$) values below the critical levels ($N < 1.00$ gkg^{-1} and $P < 10$ $mgkg^{-1}$). Owusu-Bennoah and Acquaye (1989) had earlier characterized some savanna soils of Ghana as sandy loam, low clay and low organic matter content resulting in low cation exchange capacity. Phosphorus deficiency is wide spread and is a major constraint to crop production (Owusu-Bennoah *et al.*, 1995) especially in soils impoverished through continuous cropping/short fallows without nutrient amendments.

Total nitrogen and the available P values were 0.07 and 1.79 mg kg^{-1} respectively. Both values are below the critical levels ($N < 0.10$ % and $P < 10$ mg kg^{-1}). The soil pH (1:1 H_2O) was 5.78 which is slightly acidic but satisfactory for most crops. Exchangeable potassium values were also below the critical value (< 0.15 $cmol_+kg^{-1}$) with 0.11 $cmol_+kg^{-1}$. The investigated soil was low in Phosphorus. Phosphorus deficiency has been reported to be wide spread and is a major constraint to crop production (Nwoke *et al.*, 2005; Kisinyo *et al.*, 2011).

Table 1: Selected initial soil physical and chemical properties of the experimental site

Soil characteristics	Value
Sand (gkg^{-1})	570.00
Silt (gkg^{-1})	380.00
Clay (gkg^{-1})	50.00
Textural class	Sandy loam
pH (H_2O)	5.78
Org. C (gkg^{-1})	4.60
Total N (gkg^{-1})	0.70
Available P ($mgkg^{-1}$)	1.79
Exch. Ca (cmol kg^{-1})	3.60
Exch. Mg (cmol kg^{-1})	1.70
Exch. K (cmol kg^{-1})	0.11
Exch. Na (cmol kg^{-1})	0.15
ECEC	7.76

Table 2. [illegible] yield of cowpea at cowpea at Lawra in 2013 cropping season

Fertilizer rates (N-P_2O_5- K_2O kg ha^{-1})	Grain yield (tons ha^{-1})	Increase over control (%)
0 - 0 – 0	0.84	-
0 – 45 – 30	1.47	73.81
30 – 0 – 30	1.10	30.95
30 – 45 – 0	0.94	11.90
10 – 15 – 20	1.37	63.09
20 – 45 – 30	1.41	67.86
20 – 30 – 20	1.88	123.81
20 – 45 – 20	1.35	59.52
10 – 15 – 10	1.11	32.14
20 – 30 – 10	1.45	72.62
F.pr	<0.001	
LSD	0.34	

It was reported to be considerably lower in the savanna than the forest soils of Ghana (Issaka *et al.*, 2008). The inability of soils to supply adequate amounts of P for plant growth is partly due to extensive losses due to long periods of intense weathering and strong fixation by Al and Fe oxides prevalent in many tropical soils (Doe, 2006). The organic matter level of the soil was below the critical value (< 1.7%) while the exchangeable calcium, sodium and magnesium levels were moderate for cowpea production (similar to that reported by Landon, 1996). Fosu and Tetteh (2008) reported soil organic matter level of 0.48% for soils of Lawra and soil nitrogen level of between 0.02 and 0.07% for savanna soils. The soil's low organic carbon and total nitrogen contents could be attributed to the high temperatures resulting in high rate of decomposition. It can also be attributed to overgrazing as the farmers release their animals to feed on crop residues soon after harvest, making residue incorporation unlikely. Soil organic matter is a major contributor to agricultural production in Africa and it influences soil properties and consequently plant growth (Fosu and Tetteh, 2008). According to the authors, it provides up to 70% of the cation exchange capacity making it important for soils with low activity clay as found in Ghana.

Grain yield of cowpea

The application of fertilizer significantly ($p < 0.05$) increased the grain yield of cowpea (Table 2). Fertilizer application rate of 20 – 30 – 10 kg N-P_2O_5- K_2O ha^{-1} increased grain yield of cowpea by 72.62% relative to the control. However, there was a sharp increase in grain yield with the increase of K from 10 to 20 kg ha^{-1} (20 – 30 – 20 kg N - P_2O_5 - K_2O ha^{-1}). The yield obtained was 123.81% over control. The grain yield obtained following fertilizer application rate of 20 – 45 – 20 kg N-P_2O_5- K_2O ha^{-1} (1.34 tons ha^{-1}) was not significantly difference to the yield obtained from 10-15-20 kg N-P_2O_5- K_2O ha^{-1} (1.37 tons ha^{-1}). Omitting nitrogen (0-45-30 kg N-P_2O_5- K_2O ha^{-1}) gave a yield of 1.46 tons ha^{-1} amounting to an increase of 73.81% more than the control. Treatment 30 – 0 – 30 kg N-P_2O_5- K_2O ha^{-1} on the other hand gave a yield of (1.10 tons ha^{-1}), an increase of about 40% above control. The omission of K (30 - 45 - 0) gave a yield of 0.94 tons ha^{-1} which corresponds to 11.90% increase above control. The highest grain yield (1.88 tons ha^{-1}) was obtained from the application of 20 – 30 – 20 kg N -P_2O_5 - K

Cowpea obtains its nitrogen requirement through symbiotic fixation of atmospheric nitrogen but the importance of externally applied N especially in deficient soils is important for growth and grain yield (Abayomi *et al.*, 2008). Osunde *et al.* (2007) and Yakubu *et al.* (2010) reported that addition of 40 kg P_2O_5 produced the highest cowpea grain yield in southern Guinea savanna and Sudano-sahelian zones of Nigeria respectively. It was noteworthy

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Grain yield of cowpea

The application of fertilizer significantly ($p < 0.05$) increased the grain yield of cowpea (Table 2). Fertilizer application rate of 20 – 30 – 10 kg $N-P_2O_5-K_2O$ ha^{-1} increased grain yield of cowpea by 72.62% relative to the control. However, there was a sharp increase in grain yield with the increase of K from 10 to 20 kg ha^{-1} (20 – 30 – 20 kg $N-P_2O_5-K_2O$ ha^{-1}). The yield obtained was 123.81% over control. The grain yield obtained following fertilizer application rate of 20 – 45 – 20 kg $N-P_2O_5-K_2O$ ha^{-1} (1.34 tons ha^{-1}) was not significantly difference to the yield obtained from 10-15-20 kg $N-P_2O_5-K_2O$ ha^{-1} (1.37 tons ha^{-1}). Omitting nitrogen (0-45-30 kg $N-P_2O_5-K_2O$ ha^{-1}) gave a yield of 1.46 tons ha^{-1} amounting to an increase of 73.81% more than the control. Treatment 30 – 0 – 30 kg $N-P_2O_5-K_2O$ ha^{-1} on the other hand gave a yield of (1.10 tons ha^{-1}), an increase of about 40% above control. The omission of K (30 - 45 - 0) gave a yield of 0.94 tons ha^{-1} which corresponds to 11.90% increase above control. The highest grain yield (1.88 tons ha^{-1}) was obtained from the application of 20 – 30 – 20 kg $N-P_2O_5-K_2$

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Biomass yield of cowpea

Biomass yield of cowpea is presented in Table 3. Biomass is important to the poor farmers in the investigated area because they depend on it to feed their livestock. A quick glance at Table 3 showed that the application of fertilizer increased biomass yield significantly ($P < 0.05$), except for treatments 0 – 45 – 30 and 30 – 0 – 30 kg N - P_2O_5 - K_2O ha^{-1} that recorded marginal increase (4.55 and 3.94% increase respectively above control). But for the two treatments that gave marginal increase over control, biomass yields obtained from all other treatments were not significantly different from each other ($P > 0.05$). Application rate of 20 – 30 – 20 kg N - P_2O_5-K_2O ha^{-1} gave the highest yield though not significantly different from the yield obtained from other treatments, with the exception of 0 – 45 – 30 and 30 – 0 – 30 kg N - P_2O_5 - K_2O ha^{-1}. Also there was no significant difference between the yields obtained from the control, 0 – 45 – 30 and 30 – 0 – 30 kg N - P_2O_5 - K_2O ha^{-1}.

... report of Bationo *et al.* (2002) that application of fertilizers can triple cowpea biomass production. Azarpour *et al.* (2011) also emphasized the contribution of applied N to cowpea biomass growth even though it has the ability to fix N.

Table 3 Effect of fertilizer rates on biomass yield of cowpea at Lawra in 2013 cropping season

Fertilizer rates (N-P_2O_5- K_2O kg ha^{-1})	Biomass yield (tons ha^{-1})	Increase over control (%)
0 - 0 – 0	2.86	-
0 – 45 – 30	2.99	4.55
30 – 0 – 30	2.96	3.49
30 – 45 – 0	3.83	33.92
10 – 15 – 20	3.63	26.92
20 – 45 – 30	4.05	41.60
20 – 30 – 20	4.17	45.80
20 – 45 – 20	4.10	43.36
10 – 15 – 10	3.78	32.17
20 – 30 – 10	3.77	31.82
F.pr	0.21	
LSD	1.19	

Bationo and Ntare (2000) also reported increase in cowpea biomass with N application up to 45 kg ha^{-1}. Application of N fertilizer may be required for increased cowpea biomass production in the study location. However, application of N must be at the recommended rate to avoid high biomass production at the expense of grain yield which is of more interest to farmers. Our results also agreed with the results of Gweyi-Onyango *et al.* (2011) whose report indicated that P application did not significantly increase cowpea biomass.

Conclusion and recommendation

Findings from this research work indicated that the application rate of 20-30-20 NPK kg ha^{-1} increased the yield of cowpea by 112.35% more than the control, thus making it the most promising fertilizer rate for cowpea production in the Guinea savanna zone of Ghana. The rate also resulted in biomass yield of 4.17 tons ha^{-1}

production above control. ... application rate of 20-30-20 NPK kgha^{-1} is a promising fertilizer rate for optimum production of cowpea in Lawra, Upper West region of Ghana.

REFERENCES

Abayomi, Y.A., Ajibade, T.V., Samuel, O.F. and Sa'adudeen, B.F. 2008. Growth and yield responses of cowpea (*Vigna unguiculata* [L.] Walp) genotypes to nitrogen fertilizer (N.P.K.) application in the Southern Guinea Savanna zone of Nigeria. *Asian Journal of Plant Sciences*. 7(2): 170-176.

Addo-Quaye, A.A., Darkwa, A.A., and Ampian, M.K.P. 2011. Performance of three cowpea (*Vigna unguiculata* [L.] Walp) varieties in two agro-ecological zones of the Central Region of Ghana II: Grain yields and its components. *ARPN Journal of Agricultural and Biological Science 6 (2): 1-9.*

Ahamefule E.H., and Chinedu, P. P. 2014. Cowpea (*Vigna unguiculata* [L.] Walp) response to phosphorus fertilizer under two tillage and mulch treatments. *Soil and Tillage Research* 136: 70–75.

Bationo, A. and Ntare, B.R. 2000. Rotation and nitrogen fertilizer effects on pearl millet, cowpea, and groundnut yield and soil chemical properties in a sandy soil in the semi arid tropics, West Africa. *Journal of Agricultural Science* 134: 277–284.

Bationo, A., Ntare, B. A., Tarawali, S. A. and Tabo, R. 2002. Soil fertility management and cowpea production in the semiarid tropics, pp. 301-318. *In* Challenges and opportunities for enhancing sustainable cowpea production. Proceedings of the World cowpea conference III held at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. 4-8 September 2000, IITA, Ibadan, Nigeria.

Chiezey, U. F, Katung, P. D and Yayock, J. Y. 1990. Response of cowpea (*V. unguiculata*

... *Journal of Agricultural Education* 4(1): 161-168.

Crop Research Institute (CRI) of Ghana Annual Report. 2006.

Doe, R. 2006. Future challenges in P fertilizer and the environment. 18th World Congress of Soil Science July 9-15, 2006-Philadelphia, Pennsylvania, USA.

Fosu, M. and Tetteh, F.M. 2008. Soil Organic Matter and Nitrogen in Ghanaian Soils: A review, *pp. 67-81. In* Bationo, A., Tabo, R., Waswa, B., Okeyo. J., Kihara, J., Fosu, M. and Kabore, S. (eds.). Synthesis of soil, water and nutrient management research in the Volta Basin. *CIAT-TSBF Publ.* Nairobi, Kenya.

Giller, K. E., Cadisch, G., Ehaliotis, C., Adams, E., Sakala, W. D. and Mafongoya, P. L. 1997. Building Soil Nitrogen Capital in Africa, pp. 151 – 192. *In* Buresh, R. J., Sanchez, P.A. and Calhoun, F. (eds.) Replenishing Soil Fertility in Africa. SSSA Special Publ. 51. SSSA, Madison, WI.

Gweyi-Onyango, J.P., Akwee, P., Onyango, C. and Tesfamariam, T. 2011. Genotypic response of cowpea (vigna unguiculata) to sub-optimal phosphorus supply in Alfisols of Western Kenya: A comparative analysis of legumes. *J. Agri Sci.* 2(1): 1-8.

Issaka, R. N., Buri, M. M., Tetteh, F. M. and Boadi, S. 2008. Review of Work on Soil Phosphorus in Ghana, pp. 189 - 203.

In Bationo, A., Tabo, R., Waswa, B., Okeyo. J. Kihara, J., Fosu, M. and Kabore, S., (eds.) Synthesis of soil, water and nutrient management research in the Volta Basin *CIAT-TSBF Publ.* Nairobi, Kenya.

IUSS Working Group World Reference Base 2006. World reference base for soil resources 2006. 2nd edition. International soil classification system for naming soils and creating legends for maps. World Soil Resources Reports No. 103. FAO, Rome.

Kisinyo, P.O., Ng'etich, W.K., Othieno, C.O

Okalebo J.R., and Opile, W.R. 2011. Phosphorus depletion – should the ACP countries be concerned? What are the current issues for future research and policy?. *Accessed June 2013.*

Landon, J.R. (1996). Booker Tropical soil Manual. A handbook for soil survey and agricultural land evaluation in the tropics and sub-tropics. Longma, New York, London. 431, pp.

Magani, I.E.1. and Kuchinda, C. 2009. Effect of phosphorus fertilizer on growth, yield and crude protein content of cowpea (*Vigna unguiculata*[L.] Walp) in Nigeria. *J. Appl. Biosci* 23: 1387 - 1393.

Nwoke, O.C., Diel, J., Abaidoo, R. and Sanginga, N. 2005. Low phosphorus availability in West African moist savanna soils: Effects of sparing soluble P sources on the growth of soybean, cowpea and maize. *African Crop Science Conference Proceedings 7: 1157-1161.*

Ofosu-Budu K.G., Obeng-Ofori, D., Afreh-Nuamah, K. and Annobil, R. 2007. Effect of phosphorus-compost on growth and yield of cowpea (*Vigna unguiculata*). Ghana J. Agric. Sci. 40: 169-176.

Oliveira, A. P., Silva, J. A., Lopes, E. B., Silva, E. E., Araújo, L. E. A. and Ribeiro, V. V. 2009. Productive and economic yield of cowpea as affected by rates of potassium. *Science Agrotechnology 33*: 629-634.

Osunde, A.O., Bala, A. and Uzoma, A. 2007. Differential response of Cowpea ((*Vigna unguiculata* [L.] Walp) lines to phosphorus fertilizer in a low phosphorus soil in the Southern Guinea Savanna of Nigeria. *Nigerian Journal of Soil Science* 17: 52-64.

Owusu-Bennoah, E. and Acquaye, D. K. 1989. Phosphate sorption characteristics of selected major Ghanaiansoils. *Soil Sci.* 148,114

Owusu-Bennoah, E. Ampofo, J.G. and Acquaye, D. K. 1995 Phosphorus status of some semi-arid agricultural soils of northern Ghana.I *Ghana Jnl Agric. Sci.* 28-29, 29-35.

Sanginga, N., Dashiell, K., Diels, J., Vanlauwe, B., Lyasse, O., Carsky, R.J., Tarawali, S., Asafo-Adjei, B., Menkir, A., Schulz, S., Singh, B.B., Chikoye D., Keatinge, D. and Rodomiro, O. 2003. Sustainable resource management coupled to resilient germplasm to provide new intensive cereal-grain legume livestock systems in the dry savanna. *Agriculture, Ecosystems and Environment* 100: 305–314.

Yakubu, H., Kwari, J. D. and Sandabe M.K. 2010. Effect of Phosphorus Fertilizer on Nitrogen Fixation by Some Grain Legume Varieties in Sudano – Sahelian Zone of North Eastern Nigeria. *Nigerian Journal of Basic and Applied Science* 18(1): 19-26.