Journal of Agriculture and Agricultural Technology 6(1), 2015

# Rotation Effect of *Aeschynomene Histrix* on Soil Carbon and Nitrogen and Maize Grain Yield at Minna in the Southern Guinea Savanna of Nigeria

Lawal, B.A*, Adeboye, M.K.A., Usman, A.[1], Afolabi, S.G. and Adekanmbi, A.A.
Department of Soil Science and Land Management, School of Agriculture and Agricultural Technology, Federal University of Technology, P.M.B. 65, Minna, Niger State, Nigeria.
[1]Niger State Fadama Coordination Office, P.M.B. 182, Tunga, Minna, Niger State, Nigeria.
*Corresponding Author e-mail: lawalba63@futminna.edu.ng
GSM No. 08036207353

## ABSTRACT

*Crop rotation with natural fallow and herbaceous legume can help to improve soil properties and productivity. A study was conducted in 2011 and 2012 to determine the effects of natural and Aeschynomene histrix fallows on soil organic carbon (SOC), soil total nitrogen (STN) and grain yield of succeeding maize crop. The nitrogen fertilizer replacement value (NFRV) of A. histrix was also determined. In 2011, natural fallow and A. histrix fields were established and followed in 2012 by maize with inorganic N fertilizer rates of 0, 60, 90, and 120 kg N ha$^{-1}$. The experiment was laid out using split plot design with the two fallows as main plots and inorganic fertilizer rates as subplots. The two fallows significantly ($P < 0.05$) increased SOC. The A. histrix fallow had a smaller increase compared to natural fallow. Only A. histrix fallow significantly ($P < 0.05$) increased STN with addition of 137 kg N ha$^{-1}$ to the soil. Maize grain yield of 1085 kg ha$^{-1}$ after natural fallow was not significantly ($P > 0.05$) different from that after A. histrix with a grain yield of 1208 kg ha$^{-1}$. Inorganic N application had a highly significant ($P < 0.01$) effect on grain yield. Lowest grain yield of 547 kg ha$^{-1}$ was obtained without inorganic N application, which was significantly ($P< 0.05$) different from those fertilized with inorganic N, that had comparable grain yields. Inorganic N fertilizer rate of 60 kg ha$^{-1}$ was optimum for maize. The NFRV of A. histrix (4 kg N ha$^{-1}$) was very low. The effects of both fallows on maize grain yield were therefore due mainly to increased SOC content.*

**Key words**: *Aeschynomene histrix*, rotation effects, soil properties, southern Guinea savanna.

## INTRODUCTION

In the last two to three decades, maize (*Zea mays* L.) has become one of the most important staple crops in human diet, livestock feeds and as raw material for industries in Nigeria (Fakorede *et al.*, 2003). The increased importance of maize is such that it has evolved as a major food crop in 33 % of the villages in northern Nigeria to a major food crop in 96 % and a major cash crop in 70 % of the villages in 1989 (Smith *et al.*, 1993). It is well adapted to the savanna ecology with mono-modal rainfall distribution and 120- to 180-day growing period (Carsky and Iwuafor, 1999).

The relatively high N requirement of maize and the inherently low plant-available N in the soils of the Guinea savanna of Nigeria, make N to be one of the major constraints to maize production. Hence, external input of N is inevitable for maize production. The high cost and poor distribution of inorganic N fertilizer prevent farmers from using them to supply N. The integration of legumes into the cropping system can be an option for improving the N nutrition of maize (Carsky *et al.*, 2001).

Herbaceous legumes offer potentially high N contribution to the subsequent cereals, if seed is not harvested and if biomass is not fed to animals (Carsky and Iwuafor, 1999). Many studies have reported positive rotation effects of herbaceous legumes on subsequent cereal yields in the savanna agro ecological zone of Nigeria (Oikeh *et al.*, 1998; Adeboye *et al*, 2005a). The yield benefit had been attributed to increased soil N availability through biological N fixation by the legume (Yusuf *et al.*, 2009a), mineralization of their residues (Muyinda *et al.*, 1988), release of N from the breakdown of roots and nodules after harvest (Brophy and Heichel, 1989), higher soil organic carbon (Yusuf *et al.*, 2007) and other rotation effects (Sanginga *et al.*, 2002).

One of the commonly used method for determining the N benefit to subsequent cereal is the N fertilizer replacement value (NFRV) or N-fertilizer equivalence defined as the quantity of fertilizer N required to obtain the same yield with continuous non-legume crop as the yield obtained following a legume crop (Giller, 2001). The NFRV of herbaceous legumes is usually relatively high when they are grown for more than one year or when their residues are incorporated into the soil. Tarawali (1991) estimated the NFRV of *Stylosanthes hamata* when grown for 2 to 4 years to be approximately 45 kg N ha$^{-1}$ in the Guinea savanna of Nigeria. The NFRV of another herbaceous legume, *Centrosema pascuorum*, with the residues incorporated, was estimated to be 34 kg N ha$^{-1}$ in the northern Guinea savanna of Nigeria (Adeboye, 2008).

The herbaceous legume, *Aeschynomene histrix* is a fast growing and decomposing green manure with high potential as a legume fallow in the humid tropics (Muhr *et al.*, 1999). It is moderately drought tolerant and adapted to neutral, well drained low fertility soils (Merkel *et al.*, 2000). *Aeschynomene histrix* has a rapid growth and ability to fix large quantities of N, thus enriching the poor tropical savanna soils (Peters and Schultz-Kraft, 2009). It grows wildly and widely in the southern Guinea savanna of Nigeria. Despite all these attributes of the plant, very few studies have been carried out to evaluate its effect on soil properties and grain yield when rotated with maize in the southern Guinea savanna. The objectives of the study were therefore to determine the rotation effect of the legume on soil organic carbon, soil total nitrogen and maize grain yield and estimate its NFRV.

## MATERIALS AND METHODS

**Table 1: Monthly rainfall during the period of study**

| Month | Rainfall (mm) | |
|---|---|---|
| | Year | |
| | 2011 | 2012 |
| January | 0.0 | 0.0 |
| February | 1.5 | 0.0 |
| March | 0.0 | 0.0 |
| April | 258.0 | 34.2 |
| May | 140.4 | 204.5 |
| June | 67.3 | 96.5 |
| July | 194.7 | 333.1 |
| August | 160.4 | 376.9 |
| September | 301.8 | 337.2 |
| October | 100.3 | 158.0 |
| November | 0.0 | 0.0 |
| December | 0.0 | 0.0 |
| **Total Rainfall** | **1,224.4** | **1,540.4** |

Table 2: Some soil physical and chemical properties of experimental site before planting in 2011

| Properties | Value |
|---|---|
| Sand (g $kg^{-1}$) | 860 |
| Silt (g $kg^{-1}$) | 47 |
| Clay (g $kg^{-1}$) | 93 |
| Textural class | Loamy sand |
| pH ($H_2O$) | 6.8 |
| Organic carbon (g $kg^{-1}$) | 2.30 |
| Total Nitrogen (g $kg^{-1}$) | 0.15 |
| Available P (mg $kg^{-1}$) | 12 |
| Exch. Acid (cmol $kg^{-1}$) | 0.04 |
| Exch. Na (cmol $kg^{-1}$) | 0.23 |
| Exch. K (cmol $kg^{-1}$) | 0.36 |
| Exch. Ca (cmol $kg^{-1}$) | 0.77 |
| Exch. Mg (cmol $kg^{-1}$) | 1.65 |
| ECEC (cmol $kg^{-1}$) | 3.05 |

**Experimental site:** The field experiments were conducted in 2011 and 2012 at the Teaching and Research Farms of Federal University of Technology, Gidan Kwanu, Minna ($9^{0}$ 31.860' N; $6^{0}$ 27.244'E; 254 m above sea level) in the southern Guinea savanna ecology. Rainfall pattern is monomodal with the rainy season starting in April or May and ending in October. Monthly rainfall during the period of study is shown in Table 1. The soil of the site was classified as Typic Plinthustalf (Lawal *et al.*, 2012) with loamy sand surface soil texture. Selected soil physical and chemical properties before land preparation in 2011 are shown in Table 2. The field was heavily infested with *Striga hermonthica* which made it to be sparingly cultivated with maize and sorghum over the years with no fertilizer application.

**Treatments and experimental design:** At the commencement of the experiment in 2011, treatments consisted of two fallows: natural fallow (NF) and *A. histrix* fallow (AF). The field was divided into two blocks and each block divided into three to give three replicates. The blocks were separated by a strip of 2 m width and the treatments were randomly assigned to each block. In the following year 2012, the treatments were four: inorganic N fertilizer levels of 0, 60, 90 and 120 kg $ha^{-1}$. The experimental design was a split plot arrangement fitted to a randomized complete block with three replicates. The main plot treatments were the two fallows, NF and AF and the subplots were the four N levels. There were 24 subplots with dimensions of 3 m by 8 m ($24 \text{ m}^2$).

**Crop establishment and management:** In 2011, the NF and AF fields were established. The entire field was manually cleared and the AF portion ploughed. *Aeschynomene histrix* was manually sown by broadcasting 20 kg of the seed mixed with 50 kg of soil $ha^{-1}$. The fallow blocks were not weeded, while the *A. histrix* blocks were weeded by hand-pulling when necessary during the season. In the following year 2012, existing vegetation in all the plots was incorporated by manual ploughing and ridging at 75 cm apart. Maize variety SUWAN 1 which is highly susceptible to *Striga* was manually sown at 3 seeds per hill and spaced 50 cm within rows. The seedlings were thinned to 2 plants per hill at 2 weeks after sowing (WAS) to give a plant population of about 53,333 plants $ha^{-1}$. Basal application of 30 kg P $ha^{-1}$ as single superphosphate and 30 kg K $ha^{-1}$ as muriate of potash were carried out after thinning. Urea was split-applied to plots that were to receive N fertilizer. At 2 WAS, one-third of the N was applied while the remaining two-thirds was applied 5 to 6 WAS. Fertilizers were applied by side banding at about 5 cm away from the seedlings and at about 5 cm deep along the ridge. In 2012, all the plots were hoe-weeded at 3 and 6 WAP followed by careful hand-pulling of weeds other than *Striga*.

**Sampling and analysis:** For initial characterization of the field, surface soil (0 – 15 cm) samples were collected with an auger along four diagonal transects from ten points each prior to land preparation. The samples were mixed thoroughly and bulked to give four composite samples. In 2012, surface soil samples were collected from each subplot before planting, at tasselling stage and physiological maturity of the maize. Samples were collected from three points, between two plant stands and furrow along three diagonal transects, mixed thoroughly and bulked to give one composite sample per plot. All the soil samples were air-dried, crushed gently and passed through a 2 mm sieve for analysis.

Particle size distribution was determined by Bouyoucos hydrometer method (Klute, 1986). Soil reaction was determined potentiometrically in 1:2.5 soil to water suspension with the glass electrode pH meter. Organic carbon was determined by the Walkley and Black wet oxidation method (Nelson and Sommers, 1982). Exchangeable bases were determined by extraction with neutral 1 N $NH_4OAc$. Potassium and sodium in the extract were determined with flame photometer, while calcium and magnesium were determined using atomic absorption spectrophotometer. Exchangeable acidity was determined by titrimetric method using 1 N KCl solution. Effective cation exchange capacity (ECEC) was estimated by summation of exchangeable acidity and exchangeable bases. Available phosphorous was extracted by the Bray P1 method and the P concentration in the extract was determined colorimetrically using spectrophotometer. Total N was determined by Kjeldahl digestion method (Bremner and Mulvaney, 1982).

Maize grain yield measured by harvesting maize ears in the two central rows, leaving out the border rows at both ends (net plot of 5.25 $m^2$). The ears were shelled, air-dried and weighed. Grain yield was adjusted to 12 % moisture content for each plot. The NFRV of the *A. histrix* was estimated by the method described by Carsky *et al.* (2001). The response of maize to urea N in the natural fallow plot was fitted to a linear model. The intercept is the grain yield after fallow with no N fertilizer and the slope is the response of maize to fertilizer N.

NFRV = Yield after legume with no N fertilizer — Intercept / slope

**Statistical analysis:** Statistical analysis including analysis of variance (ANOVA) and means separation where significant by Student Neuman Keuls test were computed using the General Linear Model Procedure of SAS version 9.0 (SAS, 2002). Paired t-tests were also used to compare means of the soil chemical properties.

## RESULTS AND DISCUSSION

**Soil organic carbon and total nitrogen:** Fallowing had a significant ($P < 0.05$) effect on soil organic carbon (SOC) (Table 3). Both fallows: natural fallow (NF) and *A. histrix* fallow (AF), significantly increased SOC. The NF had a higher increase of 84 % compared to 71 % increase by AF. The NF produced a biomass of 3330 kg $ha^{-1}$ which was incorporated while the AF had a significantly lower biomass yield of 2550 kg $ha^{-1}$. Changes in SOC are dependent on incorporation of crop residue (Al-Kaisi *et al.*, 2005; Karlen *et al.*, 2006). The increase in SOC is related to the amount of biomass produced by the fallows and incorporated (Huang *et al.*, 2007). The significantly lower increase by the AF may also be partly attributed to higher rate of mineralization of legume residues due to its low C/N ratio (Swift, 1987) and more contact with soil enzymes, when incorporated. Costa *et al.* (1989) has reported that incorporation of legume residues ensures more contact with soil enzymes and consequently faster rate of mineralization.

The AF significantly ($P < 0.05$) increased soil total N (STN) by 40 % to 0.21 g $kg^{-1}$ while the NF increased it insignificantly ($P > 0.05$) by 19 % to 0.19 g $kg^{-1}$ (Table 3). The N content of biomasses of NF and AF were 0.80 and 1.40 g $kg^{-1}$ respectively. Using the bulk density of 1.52 Mg $m^{-3}$ reported for the soils of Minna area (Odofin *et al.*, 2011), and the weight of one hectare furrow slice of 2,280 t, the additional N in NF plots was 91 kg $ha^{-1}$ and AF plots, 137 kg $ha^{-1}$ when their residues were incorporated. Similar increase in STN with incorporation of residues of natural fallow and herbaceous legumes in the savanna zone had been reported by other workers (Adeboye *et al.*, 2005b; Carsky *et al.*, 1997; Yusuf *et al.*, 2009b). The significantly higher increase by AF compared to NF may be ascribed to mineralization of their residues (Muyinda *et al.*, 1988), enhancement of soil microbial activity and possibly heterotrophic $N_2$ fixation (Ladha *et al.*, 1989) and release of N from the breakdown of their roots and nodules (Brophy and Heichel. 1989).

Table 3: Effect of natural and *A. histrix* fallows on soil organic carbon and total nitrogen

| Treatment | Soil organic carbon (g $kg^{-1}$) | | | Soil total nitrogen (g $kg^{-1}$) | | |
|---|---|---|---|---|---|---|
| | Initial value in 2011 | Value at Beginning of 2012 | Percentage change | Initial value in 2011 | Value at Beginning of 2012 | Percentage change |
| | 2.30 (0.05) | | | 0.15 (0.015) | | |
| Natural Fallow | | 4.24 (0.35)$^a$ | 84 | | 0.19 (0.003)NS | 19 |
| *A.histrix* | | 3.93 (0.07)$^a$ | 71 | | 0.21 (0.003)$^a$ | 40 |

Standard error of means in parenthesis

a – By t-test between each treatment and initial value indicates significant difference at $p < 0.05$

NS – Not significantly different from initial value at $p < 0.05$

The effects of fallowing and N fertilization on SOC and STN at different growth stages of maize are shown in Tables 4 and 5. Fallowing had a significant ($P < 0.05$) effect while N fertilization had no significant ($P > 0.05$) effect on SOC at the tasselling growth stage of maize. As obtained at the beginning of the season, NF plots had significantly higher SOC of 4.69 g $kg^{-1}$ which was a slight increase from the value at the beginning of the season compared to a value of 3.58 g $kg^{-1}$ for AF which was a slight reduction from 3.93 g $kg^{-1}$ obtained at the beginning of the season. The low C/N ratio of *A. histrix* residue might have caused a rapid rate of mineralization of the residue with consequent reduction in SOC. There was no significant effect of fallowing and N fertilization on STN although there was a slight increase across almost all the treatments. Despite uptake by maize, the increase might be due to much of the STN being in organic form which was not immediately available for crop use.

Table 4: Effect of fallowing and nitrogen fertilization on soil organic and total nitrogen at tasselling stage of maize

| Treatment | Soil organic carbon (g $kg^{-1}$) | Soil total nitrogen (g $kg^{-1}$) |
|---|---|---|
| Fallow (F) | | |
| Natural | 4.69a | 0.20a |
| *A.histrix* | 3.58b | 0.32a |
| SE ± | 1.12 | 0.11 |
| Significance | ** | NS |
| Nitrogen Level (kg $ha^{-1}$) (N) | | |
| 0 | 3.85a | 0.30a |
| 60 | 3.92a | 0.19a |
| 90 | 3.88a | 0.34a |
| 120 | 4.88a | 0.22a |
| SE ± | 0.71 | 0.1 |
| Significance | NS | NS |
| Interaction | | |
| F x N | NS | NS |

Means for same column and factor followed by the same letter are not significantly different at $p < 0.05$.

At the physiological maturity of maize, fallowing and N fertilization had no significant effects on SOC but there was an increase in SOC. Dead leaves and roots added to the soil might have been responsible for the higher SOC observed at the physiological maturity of maize. There was a significant effect of fallowing on STN at the physiological maturity of maize, with NF plots having a significantly higher value of 0.91 g $kg^{-1}$ compared to 0.79 g $kg^{-1}$ in AF plots. The immobilization of N as a result of the high C/N ratio of the NF residues could be responsible for the higher STN in the NF plots. Legume residues with low C/N ratio usually have high rate of mineralization with consequent release of N in inorganic forms, $NO_3$-N and $NH_3$-N, available for plants uptake or lost from the soil by leaching. Nitrogen fertilization had no significant effect on STN. All the N levels had comparable STN values > 0.81 g $kg^{-1}$. Similar to SOC, there was a high increase over that at tasselling stage across the treatments, probably due to the same reason advanced for SOC. Fallowing and N fertilization had no interactive effect on SOC and STN at both tasselling stage and physiological maturity of maize. This suggests that both effects were at play at the same time at these growth stages of maize.

Table 5: Effect of fallow and nitrogen fertilization on soil organic and total nitrogen at physiological maturity of maize

| Treatment | Soil organic carbon (g kg$^{-1}$) | Soil total nitrogen (g kg$^{-1}$) |
|---|---|---|
| Fallow (F) | | |
| Natural | 5.93a | 0.91 |
| *A. histrix* | 4.85a | 0.79 |
| SE ± | 1.08 | 0.11 |
| Significance | NS | ** |
| Nitrogen fertilizer (kg ha$^{-1}$) (N) | | |
| 0 | 5.12a | 0.81 |
| 60 | 5.83a | 0.85 |
| 90 | 5.97a | 0.85 |
| 120 | 4.65a | 0.88 |
| SE ± | 0.88 | 0.04 |
| Significance | NS | NS |
| Interaction | | |
| F x N | NS | NS |

Means followed by the same letter are not significantly different at $p < 0.05$
**Significant at $p < 0.01$, NS: Not Significant.

**Maize grain yield:** The effects of fallowing and N fertilization on maize grain yield are shown in Table 6. Maize grain yield was not significantly ($P > 0.05$) affected by fallowing. Natural fallow had a yield of 1085 kg ha$^{-1}$ which though not significantly different but was lower than 1208 kg ha$^{-1}$ recorded for AF. Although the 19 % increase in STN by NF was lower compared to 40 % increase by AF, the comparable grain yield obtained could probably be due to incorporation of all fallow residues resulting in high SOC. Increase in soil organic matter level could result in increase in soil fertility, nutrient supply, porosity, permeability and thus, soil productivity (Gray and Morant, 2003). Results obtained are consistent with those of other workers in the same savanna agroecological zone of Nigeria (Yusuf *et al.*, 2009).

There was clear evidence that N nutrition was a major constraint to maize production. Grain yield without inorganic N fertilization was 547 kg ha$^{-1}$ which was significantly lower than the yields for the inorganic N levels. Similar response to inorganic N fertilizer had been reported in the same area by Adeboye *et al.* (2009). The highest grain yield of 1492 kg ha$^{-1}$ was recorded for 120 kg N ha$^{-1}$ which was however comparable with the other N levels of 60 and 90 kg ha$^{-1}$. The 90 kg N ha$^{-1}$ had a yield of 1436 kg ha$^{-1}$ which was 4 % lower than 120 kg N ha$^{-1}$, but 11 % higher than that of 60 kg N ha$^{-1}$. These results suggest that 60 to 90 kg ha$^{-1}$ of fertilizer N is the optimum range for maize in this area. Adeboye *et al.* (2009) had also reported 90 kg N ha$^{-1}$ to be optimum for maize in the area. In the West African savannas, 60 to 120 kg N ha$^{-1}$ had been recommended by Carsky and Iwuafor (1999). Series of trials conducted in savanna zone led to a recommendation of 100 to 120 kg N ha$^{-1}$ (Chude *et al.*, 1994). Carsky *et al.* (1997) had put the economic rate of N at 60 kg ha$^{-1}$. Generally, maize grain yields recorded are relatively high, thus confirming the assertion that the most suitable zone for maize are areas characterized by 120 to 180 days of growing period in a monomodal rainfall pattern which is characteristic of the study site. Yield potential is high in the zone compared to wetter and drier environments because of adequate moisture, relatively low disease pressure, high solar radiation, and low night temperature (Carsky and Iwuafor, 1999). The interactive effect of fallowing and N fertilization on grain yield was not significant. This indicates that N effect might not be solely responsible for maize grain yield obtained.

Table 6: Effect of fallowing and nitrogen fertilization on the grain yield of maize

| Treatment | Grain yield (kg ha$^{-1}$) |
|---|---|
| Fallow (F) | |
| Natural | 1085a |
| *A. histrix* | 1208a |
| SE ± | 90 |
| Significance | NS |
| Nitrogen fertilizer (kg ha$^{-1}$) (N) | |
| 0 | 547b |
| 60 | 1290a |
| 90 | 1436a |
| 120 | 1492a |
| SE ± | 592 |
| Significance | ** |
| Interaction | |
| F x N | NS |

Means followed by the same letter are not significantly different at $p < 0.05$
**Significant at $p < 0.01$, NS: Not Significant.

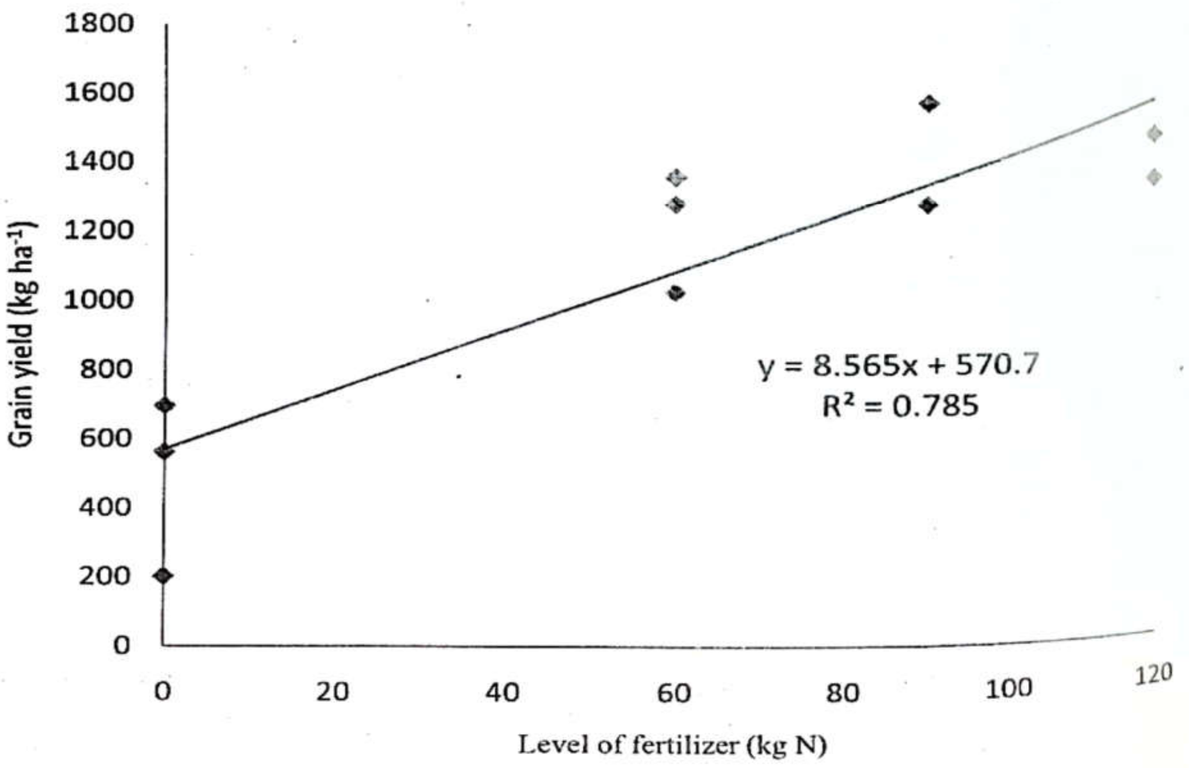

Fig.1 Response of maize grain yield to inorganic nitrogen fertilizer

### Nitrogen fertilizer replacement value

The response of maize succeeding natural fallow to inorganic N fertilization is shown in Fig. 1. The estimated N fertilizer replacement value (NFRV) of the *A. histrix* was 4 kg N ha$^{-1}$. This value is lower than 34 kg N ha$^{-1}$ recorded for similar herbaceous legume, *Centrosema pascuorum* in the same savanna agroecological zone by Adeboye (2008). Tarawali (1991) estimated the NFRV to be approximately 45 kg N ha$^{-1}$ after 2 – to 4 – year fodder banks, composed of *Stylosanthes hamata* that had phosphorous application in four sites in the Guinea savanna of northern Nigeria. The

NFRV obtained appears to be an underestimation of the N contribution of *A. histrix*. This is because the N content in the soil was increased by 137 kg ha$^{-1}$. However, most of the N could have been leached beyond the maize roots zone due to rapid mineralization of the *A. histrix* residue that would have resulted in lack of synchrony between N availability and maize uptake. Other non-nitrogen benefits, especially reduction in *Striga hermonthica* parasitism, might have played a role in the grain yield of maize. The low NFRV may be partly attributed to the use of fallow as control. The use of fallow as control, is likely to give lower estimate of NFRV compared to continuous cereal monoculture because of N export by the cereal and because of pests and diseases problem (Carsky *et al*., 2001). The significant increase in SOC by natural fallow which not only improved the soil nutrient content but soil physical properties as well resulting in good growth and yield of maize might have contributed to the low NFRV.

## CONCLUSION

From the results of this study, both natural and *A. histrix* fallows improved soil organic matter and hence physical, chemical and biological properties of the soil for good crop growth. Incorporation of the *A. histrix* residue substantially increased soil N content. Maize rotation with natural fallow was as equally good as rotation with *A. histrix* with respect to maize grain yield. There was response to inorganic N fertilizer application, suggesting the need for N application to maize for optimum grain yield. Nitrogen rate of 60 kg ha$^{-1}$ was optimum for maize grain yield. A very low amount of N was contributed to the succeeding maize crop by *A. histrix*.

## ACKNOWLEDGEMENTS

This research was funded by the Agricultural Research Council of Nigeria (ARCN) through CARGS Project 4/25. The authors express gratitude to the council for the funding and permission to publish the paper. We also acknowledge the technical assistance provided by Mallam Alhassan Aliyu on the field.

## REFERENCES

Adeboye, M.K.A., Iwuafor, E.N.O. and Agbenin, J.O. (2005a). Effects of legumes on soil nitrogen, yield and nitrogen use efficiency of succeeding maize in Guinea savanna Alfisol, Nigeria. *Nigerian Journal of Soil Research*, 6: 9-21

Adeboye, M.K.A., Iwuafor, E.N.O. and Agbenin, J.O. (2005b). Rotation effects of grain and herbaceous legumes on maize yield and chemical properties of an Alfisol in the northern Guinea savanna, Nigeria. *Nigerian Journal of Soil Research*, 6: 22-31.

Adeboye, M.K.A. (2008). Nitrogen fertilizer replacement value of legumes with residues incorporated in the Guinea savanna zone of Nigeria. *Journal of Soil and Environmental Research*, 8: 50-61.

Adeboye, M.K.A., Osunde, A.O., Tsado, P.A., Odofin, J.A., Bala, A. and Adeyemi, R.A. (2009). Response of maize grain yields to rates and split application of nitrogen and NPK combinations in the southern Guinea savanna of Nigeria. *Journal of Agriculture and Agricultural Technology*, 2(1): 108-118.

Al-Kaisi. M.M., Yin, X.H. and Lichit, M.A. (2005). Soil carbon and nitrogen changes as influenced by tillage and cropping systems in some Iowa soils. *Agriculture Ecosystem and Environment*, 105: 635-647.

Bremner, J.M. and Mulvaney, C.S. (1982). Nitrogen-total. In, Page, A.L., Miller, R.S., Keeney, D.R. (eds.). Methods of Soil Analysis. Part II. Chemical and Microbiological Properties. Am.Soc.Agron, Madison, Wisconsin. Pp. 643-698.

Brophy, L.S. and Heichel, G.H. (1989). Nitrogen release from roots of alfalfa and soybean grown in sand culture. *Plant and Soil*, 116: 77-84.

Carsky, R.J., Abaidoo, R., Dashiell, K. and Sanginga, N (1997). Effect of soybean on subsequent maize grain yield in the Guinea savanna zone of West Africa. *African Crop Science Journal*, 5: 31-38.

Carsky, R.J. and Iwuafor, E.N.O. (1999). Contribution of soil fertility research and maintenance to improved maize production and productivity in sub-Saharan Africa. Pp. 3-20. In, Badu-Apraku, B., M.A.B. Fakorede, M. Ouedraogo and P.M. Quin (eds). *Strategy for Sustainable Maize Production in West and Central Africa*. Proceedings of a Regional Maize Workshop, IITA-Cotonou, Benin Republic, 21-25 April, 1997. WECAMAN/IITA.

Carsky, R.J., Singh, B.B. and Oyewole, B. (2001). Contribution of early season cowpea to late season maize in the savanna zone of West Africa. *Biological Agriculture and Horticulture*, 18: 308-315.

Chude, V.O., Iwuafor, E.N.O. and Lombin, O. (1994). Field evaluation of Nigeria made granular urea on maize production in the semi-arid zone of Nigeria. In, J.M. Menyonga, T. Bezuneh, J.Y. Yayock and I. Soumana (eds). *Progress in Food Grain Research and Production in Semi-arid Africa*. Proceedings of a Conference in Niamey, Niger, 7-14 March, 1991. OAU/STRC-SAFGRAD, Ouagadougou, Burkina Faso.

Costa, F.J.S.A., Bouldin, D.R. and Subet, A.R. (1989). Evaluation of N recovery from mucuna placed on the surface or incorporated in a Brazilian Oxisol. *Plant and Soil*, 124:91-96.

Fakorede, M.A.B., Badu-Apraku, B. Kamara, A.Y., Menkir, A. and Ajala, S.O. (2003). Maize revolution in West and Central Africa: An overview. Pp. 3-15. In, B. Badu-Apraku, M.A.B. Fakorede, M. Ouedraogo, R.J.Carsky and A. Menkir (eds.). *Maize Revolution in West and Central Africa*. Proceedings of a Regional Maize Workshop, IITA-Cotonou, Republic of Benin, 14-18 May, 2001. WECAMAN/IITA, Ibadan, Nigeria.

Giller, K.E. (2001). Nitrogen Fixation in Tropical Cropping Systems. 2nd Edition. C.A.B. International, Wallingford, UK.

Gray, L.C. and Morant, P. (2003). Reconciling indigenous knowledge with scientific assessment of soil fertility changes in south western Burkina Faso. *Geoderma*, 111:425-437.

Huang, B., Sun, W., Zhao, Y., Zhu, Z., Yang, R., Zou, Z., Ding, F. and Su, J. (2007). Temporal and spatial variability of soil organic matter and total nitrogen in an agricultural ecosystem as affected by farming practices. *Geoderma*, 139: 336-345.

Karlen, D.L., Hurley, E.G., Andrews, S.S., Cambardella, C.A., Meek, D.W., Duffy, M.D. and Mallarino, A.P. (2006). Crop rotation effects on soil quality at three northern corn/soybean belt locations. *Agronomy Journal*, 98: 484-495.

Klute, A. (1986). Methods of Soil Analysis. N 9. Part 2. Physical and Mineralogica Properties. Am. Soc. Agron., Madiso Wisconsin.

Lawal, B.A., Adeboye, M.K.A., Tsado, P.A Elebiyo, M.G. and Nwajoku, C.R. (2012 Properties, classification and agricultura potential of lateritic soils of Minna in sub humid agroecological zone, Nigeria *International Journal of Development an Sustainability*, 1(3): 903-911.

Merkel, U., Peter, M., Tarawali, G., Schultze Kraft, R. and Berner, D.K. (2000) Characterization of a collection o *Aeschynomene histrix* in sub-humid Nigeria *Journal of Agricultural Science* (Cambridge) 134:293-304.

Muhr, L., Tarawali, G., Peters, M. and Schultze Kraft, R. (1999). Forage legumes fo improved fallows in agropastoral systems o sub-humid West Africa II. Green manure production and decomposition afte incorporation into the soil. *Tropica Grassland*, 33: 234-244.

Muyinda, K., Karamanos, R.E. and Haloron, I.P.O. (1988).Yields of wheat in rotation with maize and soybean in Zambia. *Canadian Journal of Soil Science*, 6: 747-753.

Nelson, D.W. and Sommers, L.E. (1982). Total carbon, organic carbon and organic matter. In, A.L. Page, R.H. Miller, D.R. Keeney (eds.). Methods of Soil Analysis. No. 9, Part 2. Chemical and Microbiological Properties. Am. Soc. Agron., Madison, Wisconsin.

Odofin, A.J., Egharevba, N.A., Babakutigi, A.N. and Eze, P.C. (2011). Drainage beyond maize root zone in relation to tillage and mulch on an Alfisol at Minna. *Nigerian Journal of Soil and Environmental Research*, 9: 12-19.

Oikeh, S.O., Chude, V.O., Carsky, R.J., Weber, G.K. and Horst, W.J. (1998). Legume rotation in the moist tropical savanna. Managing soil nitrogen dynamics and cereal yields in farmer's field. *Experimental Agriculture*, 34: 73-83.

Page, A.L. (1986). Methods of Soil Analysis. No.9. Part 2. Chemical and Microbiological

Properties. Am. Soc. Agron., Madison, Wisconsin.

Peters, M. and Schultze-Kraft, R. (2009). *Aeschynomene histrix*. Poiret. www.fao.org/ag/AGP/AGPC/doc/

Sanginga, N., Okogun, J., Vanlauwe, B. and Dashiell, K. (2002). The contribution of nitrogen by promiscuous soybeans to maize-based cropping in the moist savanna of Nigeria. *Plant and Soil*, 251: 1-9.

Smith, J., Barau, A.D., Goldman, A. and Mareck, J.H. (1993). The role of technology in agricultural intensification. The evolution of maize production in the northern Guinea savanna of Nigeria. Pp. 144-166. In, K.A. Dvorak (ed). *Soil Science Research for Agricultural Technology Development: Spatial and Temporal Dimensions*. C.A.B. International, Wallingford, UK.

Swift, M.J. (Ed). (1987). Tropical Soil Biology and Fertility: Inter-regional Research Planning Workshop. Special Issue 13. IUBS Biology Int., Paris.

Tarawali, G. (1991). The residual effect of *Stylosanthes* fodder banks on maize yield at several locations in Nigeria. *Tropical Grasslands*, 25: 26-31.

Yusuf, A.A., Abaidoo, R.C., Iwuafor, E.N.O., Olufajo, O.O. and Sanginga, N (2009a). Rotation effects of grain legumes and fallow on maize yield, microbial biomass and chemical properties of an Alfisol in the Nigerian savanna. *Agriculture Ecosystem and Environment*, 129: 325-331.

Yusuf, A.A., Iwuafor, E.N.O. Abaidoo, R.C., Olufajo, O.O. and Sanginga, N (2009b). Grain legume rotation benefits to maize in the northern Guinea savanna of Nigeria: Fixed-nitrogen versus other rotation effects. *Nutrient Cycling in Agroecosystem*, 84: 129-139.