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DYNAMICS OF CARBON, NITROGEN, PHOSPHORUS AND POTASSIUM UNDER DIFFERENT *Tithonia diversifolia* MANAGEMENT SYSTEMS IN A TROPICAL ALFISOL: A GREENHOUSE BIOASSAY

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ABSTRACT

The research investigated the dynamics of C, N, P and K under different Tithonia management options. Changes in soil N and P showed significant increase in these nutrients in treatment with incorporated Tithonia + NPK and Mulched Tithonia + NPK respectively. There was a reduction in the soil K at 6 WAP in all the treatments except those with NPK and mulched Tithonia. Generally, there was a sustained increase in soil organic carbon in all the treatments. There was an increase in N and P contents of maize plant with successive cycles thus indicating residual effect, most pronounced in treatment with incorporated Tithonia + NPK. However, there is the need for K supplementation at the second maize cycle. Maize biomass yield indicated the possibility of two cycles with mulched or incorporated Tithonia + NPK fertilizers as most promising option. Economic feasibility should, however, be considered.

Keywords: *Tithonia diversifolia*; nutrient dynamics

INTRODUCTION

Carbon, Nitrogen, Phosphorus and Potassium are essential plant nutrients needed in a large amount to be supplied by the soil to the plant. These nutrients' deficiency has constituted the largest constraints to food production; this has adversely affected food security in the world (Azeez *et al*., 2005). The dynamics of carbon, nitrogen, phosphorus and potassium has a very significant implication in soil due to their solution state that makes plant to absorb them easily from the soil. However, agricultural practices without adequate management to supply the nutrient back to the soil had made soil inherently poor in nutrients and inability to sustain crop productivity without external inputs of fertilizer. Hence, there is an urgent need to increase the use of external inputs to reverse the negative nutrient balance and increase food production. High prices of inorganic fertilizer and the scarcity, particularly in sub-Saharan African countries had contributed to the rapid decline in soil fertility, because farmers cannot afford the prices and this led to the over-exploitation of the soil nutrients without replenishment. Agroforestry systems are considered to be a potential alternative to mineral fertilizers that are not affordable by some farmers. Therefore, production systems based on the use of local resources which require low financial input are likely to be more suitable for managing soil fertility in small and large holdings.

Such an opportunity is offered by Tithonia (*Tithonia diversifolia* (Hemsley) A Gray). Among different plant species used as green manures, *Tithonia diversifolia* has been suggested as particularly promising (Palm *et al.,* 1999). The plant is widespread in many regions in Nigeria. Besides having typically high concentrations of N, P, K and S, *Tithonia* biomass also contains high concentrations of Ca and Mg (Buresh *et al.,* 1997; Palm *et al.,* 1999). It is a shrub that grows naturally and is ubiquitous (Ganunga *et al.,* 1998).This potential alternative could serve as green manure for soil fertility management. *Tithonia diversifolia* commonly known as "Mexican Sunflower" or "Tree marigold" is a dicotyledonous in the family Asteraceae. This shrub grows in tropical and subtropical environments of Africa. It is a readily available source of plant biomass and exists in hedges bordering farms and roadsides. The ubiquitous quality, wide broad leaves, fast decomposition and readily supply of nutrients to the soil makes it very easy for farmers to use as nutrient supplement. *Tithonia diversifolia* has been reported to have a moderate nutrient content and reasonable decomposition rate (Nagarajah and Nizar, 1982).

The use of Tithonia plant varies from its use as fodder (Roothaert and Patterson 1997), poultry feed (Odunsi *et al.*, 1996), Fuel wood (Nginja *et al.,* 1998) and compost material (Drechsel and Reck, 1998). Tithonia is potentially superior specie for soil fertility management because of the very high nutrient concentration of Tithonia leaves (Gachengo et al,1999). In Nigeria, little has been done on its use to improve soil fertility, despite the fact that it grows massively in farms and roadsides. Its use for maize production is hinged on its rich nutrient composition (Jiri and Waddington, 1998). However, detailed changes in soil fertility indicators C, N, P and K with the application of Tithonia are not well documented in literature. Detailed knowledge of the dynamics of these nutrients will elucidate the specific pattern of use of the nutrients and the appropriate supplementation of nutrients where necessary.

Accordingly, the objectives of this study were to:

1. evaluate the effect of *Tithonia diversifolia* biomass on soil fertility and maize growth.
2. investigate the dynamics of carbon, nitrogen, phosphorus and potassium under different *Tithonia diversifolia* management options.

MATERIALS AND METHODS

Nutrient exhausted surface soil sample (0-15cm) was collected from University of Agriculture, Abeokuta farm. The soil sample was air dried for 24 hours and sieved with 2 mm sieve. Initial soil analysis was carried out on the soil collected before treatment application. The samples was analysed for pH (H_2O) using a glass electrode attached to Corney pH meter (Cater, 1993). Exchangeable bases were extracted with 1N neutral NH_4OAc, while Na and K- was analysed by flame photometry. Calcium and Mg was determined by atomic absorption spectrophotometer [Photomec AAS model 210 VGP] (Cater, 1993). Exchangeable acidity (H and Al) was extracted with 1N KCl and determined by titrating with NaOH (Cater, 1993). Total nitrogen content of the soil was determined using kjeldahl method (Cater, 1993), while available P was extracted with Bray-1 solution and analyzed using a spectrophotometer (Cater, 1993). Particle size analysis of the soil was determined by hydrometer method (Bouyoucous, 1951). Total organic carbon was determined by wet dichromate oxidation method (Nelson and Sommers, 1982).

Ten kilogram of the air–dried and sieved soil samples were dispensed into plastic pots arranged in a completely randomised design in the green house with three replications. The treatments applied were: Control, *Tithonia diversifolia* (10 tons ha^{-1}) applied as mulch, *Tithonia diversifolia* (10 tons ha^{-1}) incorporated into the soil, *Tithonia diversifolia* (10 tons ha^{-1}) applied as mulch plus NPK fertilizer at 60 kg ha^{-1} of NPK 20:10:10, *Tithonia diversifolia* (10 tons ha^{-1}) incorporated into the soil plus NPK fertilizer at 60 kg ha^{-1} and NPK fertilizer applied at 120 kg ha^{-1} of NPK 20:10:10. The *Tithonia diversifolia* used for the study was harvested when they were 1.8 m tall.

The soil samples with treatments applied were watered to field capacity and three maize seeds (DMR-ESR-Y) were sowed per pot. Planting was done two weeks after *Tithonia diversifolia* mulching or incorporation into the pots, and fertilizer application. One week after germination, the seedlings were thinned to one per pot. Each crop was grown for 6 weeks.

At harvest, the aboveground materials were harvested. The plant materials were dried at 65^0C for 48 hours and weighed. They were analysed for their N, P and K content by standard procedures (Cater, 1993). At four and six weeks after planting, composite soil samples were taken from each pots and analysed for organic carbon, total nitrogen, available P and exchangeable K using methods as described above.

Data generated from the experiment were subjected to analysis of variance to determine the significance of treatments by the general linear model procedure (SAS 1990). Significant treatment effect was separated by Duncan Multiple Range Test at 5% probability.

RESULT AND DISCUSSION

Table 1 shows some characteristics of the experimental soil. The soil showed a moderately acid of nearly neutral pH value of 6.9, this is considered adequate for nutrient availability in tropical soils. (Udo and Ogunwale, 1986) hence it is favourable for crop production. The amount of the exchangeable cations showed that K had the lowest value of 0.11 $Cmol^+ kg^{-1}$ and Ca had the highest value of 6.69 $Cmol^+ kg^{-1}$ while Mg and Na are 3.00 $Cmol^+ kg^{-1}$ and 0.12 $Cmol^+ kg^{-1}$ respectively. The soil organic carbon is 0.95 g kg^{-1}, this shows that the experiment soil sample is low in organic matter (Udo and Ogunwale, 1986). The soil nitrogen content was 0.062 g kg^{-1} and available phosphorus 24.50 mg kg^{-1} .The textural analysis of the soil indicated that the soil was sand. This is perhaps due to intense rainfall because soils of humid tropic have been subjected to a process of elluviation involving downward movement of clay and other suspended colloids. Hence water and nutrient holding capacity of the soil is expected to be low.

Table 2 shows the effects of various treatments on N, P, K and organic carbon of soil analysis at 4 weeks after planting. The nitrogen content of the soil among treatments were not significantly different as presented in the Table, although the nitrogen concentration was highest in treatment with the incorporation of Tithonia and the least was recorded with mulched Tithonia. The application of NPK alone did not increase nitrogen concentration at week 4 compared to the control and also the combination of mulched Tithonia + NPK. The soil is sandy and this could have caused the leaching of the nutrients.

Table 1: The physical and chemical properties of the soil

Parameter	Value
Initial Soil pH (H_2O)	6.9
Organic carbon (g kg^{-1})	0.95
N (g kg^{-1})	0.062
Available P (mg kg^{-1})	24.50
Exchangeable cations (cmol kg^{-1})	
K	0.11
Ca	6.69
Mg	3.00
Na	0.12
Al + H	0.07
ECEC	9.99
% base saturation	99.30
Particle size (%)	
Sand	92.4
Silt	3.4
Clay	4.2
Micro nutrient (mg kg^{-1})	
Cu	0.73
Zn	3.73
Fe	8.90
Mn	6.20

The concentration of phosphorus in the treatments recorded the highest value at incorporated Tithonia; this is significantly higher than the soil P content in treatment with mulched Tithonia. This value is however, comparable to that observed in most other treatments. The soil available potassium concentrations recorded the highest level at mulched Tithonia plus NPK fertilizer with the value of 0.15 cmol kg^{-1}. The application of these treatments such as Tithonia mulching plus NPK and Tithonia mulching only did not increase potassium concentration at 4 weeks after planting compared to the control with 0.13 cmol kg^{-1} and slightly increase in NPK alone and Tithonia incorporated plus NPK with 0.14 cmol kg^{-1}. The organic carbon recorded the lowest value for mulched Tithonia with 1.59 % and highest value at incorporated Tithonia with 2.18 % which shows that carbon was significantly different among the treatments. These results indicated that with applications of the higher quantity Tithonia incorporated into the soil and Tithonia mulching alone illustrate faster release patterns of carbon, nitrogen, phosphorus and potassium as compared to other treatments into the soil at 4 weeks after planting (WAP). The results also showed that incorporated Tithonia favourably compared with incorporated Tithonia plus NPK fertilizer at least for soil nitrogen, carbon and phosphorus content at 4 weeks after planting maize. The low soil content of nitrogen, phosphorus and carbon in the mulched treatment as compared to other

Table 2: Effect of different Tithonia management options on soil N, P, K and organic carbon at 4 and 6 weeks after planting maize

Treatment	4WAP N	P	K	Organic carbon	6WAP N	P	K	Organic carbon
	%	mg kg-1	cmol kg-1	%	%	mg kg-1	cmol kg-1	%
Control	0.17 a	32.62 ab	0.13 a	2.17 a	0.19 a	35.54 ab	0.17 a	2.20 a
Incorporated	0.18 a	35.53 a	0.13 a	2.18 a	0.16 a	27.38 bc	0.11 a	1.97 a
NPK	0.17 a	29.84 ab	0.14 a	1.95 ab	0.17 a	28.71 c	0.10a	2.91 a
Mulched + NPK	0.17 a	28.51 ab	0.15 a	1.94 ab	0.18 a	30.62 b	0.16 a	2.17 a
Incorporated + NPK	0.15 a	31.13 ab	0.13 a	1.85 ab	0.17 a	37.21 a	0.10 a	2.24 a
Mulched	0.13 a	28.44 b	0.14 a	1.59 b	0.17 a	22.96 c	0.10 a	1.83 a

treatments is perhaps due to the limited time available for mineralization before sampling; 4 WAP is probably not enough for the mulched materials to mineralise and release its nutrients. The mobility of these nutrients by these treatments agree with an extensive review by Gachengo *et al.,* 1996 that biomass of Tithonia incorporated and mulching only act as an effective source of releasing nutrients faster into the soil. It was also reported that incorporation of Tithonia biomass equivalent to 5 tons dry matter ha^{-1} in western Kenya increased nitrogen, phosphorus and carbon in soil microbial biomass and reduced phosphorus sorption by soil (Nziguheba *et al*., 1998). Increased nitrogen, carbon and phosphorus in soil at two weeks after Tithonia incorporation presumably indicates enhanced biological cycling and turnover of phosphorus in labile pool of phosphorus (Iyamuremye and Dick, 1996). However, the addition of NPK to the incorporated Tithonia did not significantly improve the soil nutrients at 4 WAP.

Table 2 also shows the effects of various treatments at 6 weeks after planting. The nitrogen contents of the soil for all the treatments were not significantly different as presented. Also, the application of these treatments did not increase nitrogen concentration at 6 weeks after planting. The concentration of potassium in the treatments was, however, statistically similar to that of Nitrogen. There were no significant differences among the treatments for potassium concentration. Treatment applications did not increase potassium concentration. It was also shown that the phosphorus values were high in all the treatments. There were significant treatment differences in phosphorus concentration among treatments. Incorporated Tithonia plus NPK gave the highest value of phosphorus concentration with 37.21 mg kg^{-1} followed by control with 35.54 mg kg^{-1} which revealed that only Tithonia incorporated plus NPK released more phosphorus than the other treatments at 6 WAP. The high recovery might also be an effect of the organic additions on phosphorus availability on this moderately phosphorus fixing soil (Nziguheba *et al*., 1998). The increase in phosphorus availability was related to a decrease in the phosphorus adsorption capacity of the soil with additions of Tithonia. Buresh and Tian (1997) showed enhanced microbial biomass phosphorus following integration of Tithonia with triple super phosphate and not with sole application of triple super phosphate supports the hypothesis that Tithonia increases phosphorus concentrations and also labile pools of soil phosphorus. Cong and Merckx (2005) have also reported that the concentrations of soluble P were frequently higher where *Tithonia* had been added to soils in Vietnam. The concentration of carbon also showed that Tithonia incorporated plus NPK and NPK treatments were the most effective among the treatments with the highest value of 2.24 % and 2.91 % respectively while the other treatments did not increase carbon concentration. Carbon concentrations among the treatments were not significantly different. The increased level of soil nitrogen, phosphorus potassium and carbon at 6 WAP in the control treatment relative to some treatments are indicative of the mineralization of the nutrients from the soil native nutrients.

The dynamics of the release of the nutrients between the two periods (4 and 6 WAP) showed that the release of the nutrients was fast at 4WAP particularly for the incorporated Tithonia treatments. The changes observed revealed that there is about 31 % increase in N released with the mulched

Tithonia treatment while the Incorporated Tithonia plus NPK only resulted in 13 % increase in N content of the soil at 6 WAP relative to the value at 4 WAP. The increase in soil N content was recorded in the control and mulched Tithonia plus NPK fertilizer treatments. Application of NPK alone did not change the soil N content at the two periods. The dynamics of soil phosphorus and potassium was different from that observed for soil nitrogen. The increment in the soil P showed that the highest increase in the nutrients was observed in the incorporated Tithonia and followed by the mulched Tithonia plus NPK for soil phosphorus. Mulched Tithonia plus NPK had the highest increase in soil K with 6.7 % compared to other treatments except the control that had 30.8 % increases in soil K. About 49 % increase in soil organic carbon was recorded in the NPK alone treatment while this is closely followed by the incorporated Tithonia plus NPK treatment. There were increases in the soil organic carbon in all the treatments except the treatment with Tithonia incorporated alone.

Table 3 shows the effects of various treatments on plant N, P and K contents. There were no significant differences among the treatments on maize nitrogen content. The nitrogen concentration was highest in NPK treatment the value 0.78 % while that of the control had the least value (0.34 %). Similar trend was observed for potassium concentration with the highest in Tithonia incorporated (2.98 %) and least in control (2.20 %). The application of Tithonia incorporated plus NPK gave the highest value of 855.0 mg kg^{-1} phosphorus concentration while that of the control and Tithonia mulching were least with the value of 577.7 mg kg^{-1}. Phosphorus content of maize at first harvest was significantly different among treatments. However, this trend contradicts that observed by Gachengo *et al*, 1999, who reported that the phosphorus recovery values from the treatments with organic inputs are high compared to recovery levels of 10 % for the first plant and 20-30% after several plants for inorganic fertilizers. This high phosphorus recovery is most likely related to the release of P from labile pools in the soil accentuated by the added treatments. It was, however, statistically shown that the application of these treatments increased Nitrogen, phosphorus and potassium concentrations in maize growth.

The N, P and K content of the maize plant at the second harvest is also shown on Table 3. It was observed that there was significant difference in nitrogen concentration of the plant. Incorporated Tithonia plus NPK had the highest maize N content (1.14 %), this is significantly higher than the control N content (0.48 %). There was no significant difference among majority of the other treatments. Tithonia incorporated plus NPK had the highest concentration of phosphorus value 1507.3 mg kg^{-1} and least recorded in Tithonia mulching with the value 1029.0 mg kg^{-1}. There were no significant differences among treatments for phosphorus concentrations. Potassium concentration in the maize plant at the second harvest was lowest at the control treatment (1.49 %). Tithonia mulching plus NPK had the highest K value (2.19 %). Potassium concentration was similar among the treatments but higher than the control. It also shows that all the treatments were significantly higher and effective in action than the control. However, Gachengo *et al.* (1996) reported that maize growth was significantly enhanced with Tithonia plus NPK fertilizer with an equivalent rate of N, P and K as mineral fertilizers. However, this contradicts results from previous experiment which reveal that maize growth can be much greater with combined use of Tithonia and phosphorus fertilizer than with solely NP mineral fertilizers. Maize growth with Tithonia as compared to an equivalent amount of NPK mineral fertilizer can be large, but it is often small or inconsistent (Palm *et al*, 1997).

The uptake of the nutrients by the two crops differs in content and the trend. The uptake of N and P by the two maize plants showed that the soil had enough nutrients that could sustain the second crop for at least 6 weeks. Among the Tithonia treatments, the incorporated Tithonia plus NPK treatment led to more than 130 % increase in the uptake of N by maize crop in the second harvest. This is followed by the mulched Tithonia treatment alone with 30 % increase and least with incorporated Tithonia treatment alone with 15 %. The changes observed in the amount of P uptake by the maize plants indicated that the highest increase in the amount of P taken by the maize plant was recorded in the treatment with mulched Tithonia plus NPK treatment and closely followed by the mulched alone treatment. The uptake of K in the second maize was depressed in all the treatments; the magnitude was highest in the incorporated Tithonia treatment. This shows that there is the need for K supplementation for the second maize crop to optimally perform.

Table 4 shows the dry matter yield of the two maize harvests after 6 weeks each of growth period. At the first harvest, there were significant effects of the treatments on the maize dry matter yield. The application of Tithonia irrespective of the methods had significantly higher maize dry matter yield compared to the control. The highest maize yield was however recorded in the incorporated Tithonia and the PNK alone treatments. There was, however, no significant difference in the integrated use of NPK fertilizer and any of the Tithonia treatments. The maize dry matter yield was, however, higher at the second harvest in all the treatments. There were no significant differences in all the Tithonia treatments. They were higher than the control treatment. The higher maize yield suggests that the soil is still rich enough to support maize growth. This is also shown in the higher plant amount of N and P at the second harvest. The magnitude of the increase in maize dry matter yield varies among the treatments. Mulched Tithonia and incorporated Tithonia plus NPK had 109 % and 39 % increase respectively.

Table 3: Effect of different Tithonia management options on N, P and K concentrations in maize plant at two consecutive harvests

	1st Harvest			2nd Harvest		
Treatment	N	P	K	N	P	K
	%	mg kg-1	%	%	mg kg-1	%
Control	0.34 a	577.7 b	2.20 a	0.48 b	1061 a	1.49 b
Incorporated	0.59 a	845.5 a	2.98 a	0.68 ab	1099.3 a	1.88 a
NPK	0.78 a	691.7 ab	2.76 a	0.91 a	1113.7 a	2.04 a
Mulched + NPK	0.67 a	587.7 b	2.59 a	0.86 ab	1094 a	2.19 a
Incorporated + NPK	0.49 a	855 a	2.92 a	1.14 a	1507.3 a	2.04 a
Mulched	0.70 a	577.7 b	2.77 a	0.91 a	1029 a	2.04 a

Table 4: Effect of different Tithonia management options on maize dry matter yield at two consecutive harvests

Treatment	Maize dry matter (g)	
	1st Harvest	2nd Harvest
Control	1.08 b	1.71 b
Incorporated	2.59 a	2.66 a
NPK	2.42 a	2.62 a
Mulched + NPK	1.20 b	2.51 a
Incorporated + NPK	1.98 ab	2.76 a
Mulched	1.94 ab	2.30 a

CONCLUSION

The study revealed that changes in soil N and P were significantly increased with incorporated Tithonia + NPK and Mulched Tithonia + NPK. There was an increase in soil organic carbon and N and P content of maize plant with successive cycles thus indicating residual effect. This was most pronounced in treatment with incorporated Tithonia + NPK. There is the need for K supplementation at the second maize cycle. Maize biomass yield indicated the possibility of two cycles with mulched or incorporated Tithonia + NPK fertilizers as most promising option.

REFERENCE

Azeez, J.O., Chikoye, D., Kamara, A.Y., Menkir, A., Adetunji, M.T. 2005. Effect of drought and weed management on maize genotypes and the tensiometric soil water content of an eutric nitisol in south western Nigeria. *Plant and Soil,* 276: 61-68**.**

Bouyoucos G. H. 1951. A calibration of the hydrometer method for testing mechanical analysis of soils, *Agron. J.* 43: 434-438.

Buresh, R.J., Smithson, P. C., Hellums, D. T. 1997. Building soil phosphorus capital in Africa. *In* Replenish Soil Fertility in Africa. Eds. R J Buresh, P A Sanchez and F Calhoun. pp. 111-149. SSSA Spec. Publ. 51. SSSA and ASA, Madison, WI.

Buresh, R.J., Tian, G. 1997 Soil improvement by trees in sub-Saharan Africa. *Agro forestry Sys*., 38: 51-76.

Cater, M.R. 1993. Soil sampling and methods of analysis. Canadian Soc. Soil Sci., Ontario Canada.

Cong, P.T., Merckx , R. 2005. Improving phosphorus availability in two upland soils of Vietnam using *Tithonia diversifolia* H. *Plant and Soil,* 269: 11–23.

Drechsel, P., Reck, B. 1998. Composted shrub-pruning and other manures for smallholder farming systems in southern Rwanda. *Agroforestry sys.,* 39: 1-12.

Gachengo, E., Rao, M.R., Jama, B.A., Niang, A.I. 1996. Phosphorus release and availability addition of organic materials to phosphorus fixing soils. MSc Thesis. Moi University, Eldoret, Kenya.

Gachengo, C.N., Palm, C.A., Jama, B., Othien, O. 1999. The potential of agro forestry to control striga and increase maize yield in sub-Saharan Africa. Proceedings of Sixth Regional Maize Conference for Eastern and Southern Africa, 21-25 September 1998 in Addis Ababa, Ethiopia, pp 180184.CIMMYT, Harare, Zimbabwe.

Ganunga, R., Yerokun, O., Kumwenda, J.D.Y. 1998. Tithonia diversifolia; an organic source of nitrogen and phosphorus for maize in Malawi. In; Waddington SR *et al*. (eds.)Soil fertility Research for Maize-Based Farming Systems in Malawi and Zimbabwe, pp 191-194.

Iyamuremye, F., Dick, R.P. 1996 Organic amendments and phosphorus sorption by soils. *Adv. Agron*., 56: 139-185

Jiri, O., Waddington, S.R. 1998. Leaf pruning from two species of Tithonia raise maize grain yield in Zimbabwe, but take a lot of labour! Newsletter of soil Fert Net, Harare, Zimbabwe. *Target,* 16: 4-5.

Nagarajah, S., Nizar, B.M. 1982. Wild sunflower as a green manure for rice in the mid-country west zone. *Trop. Agric.,* 138:69-78.

Nelson, D.W., Sommers, L.E. 1982. Total carbon, organic carbon and organic matter. In: Page AL, editor. Methods of soil analysis, part 2. 2nd ed. Agron. Monogr., vol 9. Madison, WI: ASA and SSSA., pp. 539-79.

Nginja, J.O., Niang, A., Palm, C., Lauriks, P. 1998. Traditional hedges in Western Kenya: typology, composition, distribution, uses, productivity and tenure. Pilot Project Report No. 8.Regional Agroforestry Research Centre, Maseno, Kenya.

Nzigueba, G., Palm, C.A., Buresh, R. J., Smithson, P.C. 1998. Soil phosphorus fractions and adsorption as affected by organic and inorganic sources. *Plant & Soil,* 198: 159-168.

Odunsi, A.A, Farimu, G.O., Akinola, J. O. 1996. Influence of dietary wild sunflower (Tithonia diversifolia Hemsl. A. Gray) leaf meal on layers performance and egg quality. *Nig. J. Anim. Prod*., 23: 28-32.

Palm, C.A., Mukalama, J., Agunda, J., Nekesa, P., Ajanga, S. 1997. From hedge survey: composition, management, use and potential for soil fertility management .Summary report for African Highlands Initiative. Tropical Soil Biology and Fertility Programme (TSBF), Nairobi, Kenya.

Palm, C. Nziguheba, G., Gachengo, C., Gacheru, E., Rao, M.R. 1999. Organic materials as sources of phosphorus. *Agroforestry Forum*, 9: 30–33.

Roothaert, R., Patterson, R.T. 1997. Recent work on the production and utilization of tree fodder in East Africa. *Anim. Feed Sci. & Tech.,* 69: 39-51.

SAS Institute 1990. SAS/STAT user's guide, release 6, 4th ed. SAS Institute: Cary, N.C.

Udo, E.J., Ogunwale, J.A. 1986. Laboratory manual for the analysis of soil, plant and water samples, Second edition, p.164

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