

EVALUATING THE AGRONOMIC POTENTIAL OF *TITHONIA DIVERSIFOLIA* PRUNINGS IN THE ACID SOILS OF NORTHERN ZAMBIA.

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ABSTRACT

Due to the high cost of inorganic fertilizer, small-scale resource poor farmers of Northern Zambia are unable to afford it. Cheaper alternatives are being sought. Addition of P alone tends to be ineffective as some of the P is fixed. Thus, use of *Tithonia* alone or in combination with sources of P was employed as this approach has been shown elsewhere to improve crop yield and available soil P better than inorganic P sources alone. This study evaluated *Tithonia* prunings as (1) a source of nitrogen for maize, alone or when combined with P sources and (2) its effects on soil acidity and fertility in general. Prunings were cut as fresh material and incorporated into the soil based on the maize recommended rate of N of 112 kg N ha⁻¹ (McPhillips, 1987). Mixtures of *Tithonia* residue with P sources were made before incorporation (Malama, 1998). Northern Zambian *Tithonia* was found to be of high quality. *Tithonia* prunings had 2.5% N, 0.14% P, 4.20% K, 0.98% Ca, 0.32% Mg, 300 ppm Fe and 11 ppm Zn. Application of *Tithonia* improved available soil P and P uptake by maize. Thus, *Tithonia* appears to enhance P availability on these P-fixing acid soils. Exchangeable Al, acidity and Al saturation were reduced in all the *Tithonia* treatments. Both the stover and the grain yields were improved by the incorporation of *Tithonia*. *Tithonia* prunings were found to improve soil fertility and maize yield, alone or in combination with P sources (single superphosphate [SSP] or Ground Rock Phosphate [GRP]), and are a cheap and effective method of ameliorating soil acidity in Northern Zambia.

Keywords: Al-saturation, maize, P-fixation, soil acidity amelioration, *Tithonia diversifolia*, Zambia ground rock phosphate.

INTRODUCTION

Justification of this study is that due to the high cost of inorganic fertilizer, small-scale resource poor farmers of Northern Zambia are unable to afford it. Therefore, cheaper alternatives are being sought. Soils of northern Zambia are acidic and are of medium-to-high P fixing capacity (1-3 ppm Bray 1) (Soil Productivity Annual Reports, 1990, 1991, 1996). Thus addition of P alone tends to be ineffective as some of the P is fixed and therefore becomes unavailable to a crop. Use of mixtures of *Tithonia* alone, or in combination with inorganic sources of P or ground rock phosphate (GRP) has been shown in Kenya to boost crop yields and improve P availability better than inorganic P sources alone (Niang *et al.*, 1999; Questions and Answers in Agroforestry Today, 1998; Buresh and Tian, 1998; Sanchez *et al.*, 1997), in Zimbabwe (Jiri and Waddington, 1999) and Malawi (Ganuga, 1998). Past research work with Zambian GRP at Misamfu has shown that using GRP on its own, on annual crops, was not agronomically effective due to the slow rate of P release (Soil Productivity Annual Reports, 1990, 1991, 1996) and thus testing of Zambian GRP has shifted to perennial crops where it is believed that over the long-term, release of P would be beneficial to such perennial crops.

Tithonia diversifolia popularly known as the Mexican sunflower, is a common plant in the Isoka and Kasama Districts of Northern Zambia. It is mainly planted as a hedge around households in compounds as an ornamental. A few farmers plant it as a hedge around their fields in Isoka District. This plant is used as fish food (Fisheries Specialist, Dept of Fisheries Isoka District, pers comm., 2000). Fresh leaves are put into fish-ponds and within few days the leaves undergo decomposition, providing some valuable food. According to the Fisheries Specialist, the fact that *Tithonia* decomposed leaves makes the pond water green is an ideal

environment because it provides camouflage for the fish. This makes the fish to feel good as the fish is thus protected from predators. Some farmers say they use it as a medicinal plant to treat various ailments. However, when farmers were asked if they have used it for soil fertility improvement the answer was no. Even those few farmers who have planted it as a hedge around their gardens do not know that it can be used for soil fertility improvement. When asked what the prunings were used for, they responded by saying that they threw away the prunings. Apparently pruning were carried out on average 3 times during one rain season (Malama and Kapekele, 2001).

Therefore this study was conducted in order to evaluate the *Tithonia* prunings as a source of plant nutrients on the performance of maize, when used alone or when combined with P sources and its effects on soil acidity and fertility in general.

MATERIALS AND METHODS

Prunings were cut as fresh material (small twigs and leaves). These were incorporated into the soil using a hand hoe as intact unground fresh leaf materials based on the recommended rate of N of 112 kg N ha⁻¹, which translates into 4.5 t ha⁻¹ fresh matter of *Tithonia*. Mixtures of *Tithonia* residue with either SSP or GRP were made by mixing residues with these P sources and then incorporated into the soil. The rate of P applied was the recommended rate of 60 kg P ha⁻¹ and 20 kg P ha⁻¹, respectively, at Misamfu Regional Research Center (10° 10' S 31° 12' E) and Mungwi (10° 10' S 31° 15' E) District, both in Northern Zambia. This difference in rate being due to differences in fertility status between the two sites as has been shown by previous soils data from these sites. Misamfu soil is an oxisol, a Kandiuults. Mungwi soil is classified as udandic Kandiuults.

Treatments:

1. Control (no *Tithonia*, no fertilizer)
2. NPK compound fertilizer
3. *Tithonia* alone
4. *Tithonia* + ¼ recommended rate of P as SSP
5. *Tithonia* + Full recommended rate of P as GRP
6. *Tithonia* + ¼ recommended rate of P as GRP

Design: RCBD replicated four times.

Grain yield: Grain harvest was recorded from plants in an area with borders 0.5m from the edge of each plot. Seed was allowed to dry in the sun after shelling of the cobs. A sub-sample of about 100 g was taken for moisture content determination using a Dole 400 moisture Tester (1987) in order to see whether the grain had reached 12% moisture content after which yield measurement ($t\ ha^{-1}$) were corrected for moisture content based on the entire plot harvested area rather than cropped area.

Soil nutrient analysis: Soil samples were collected from the depth of 0–15 cm in each harvested area per plot using a standard auger at the time of harvesting maize. The samples were put into polythene bags and taken to the laboratory for analysis. They were air dried and sieved to pass 1 mm sieve

Exchangeable bases Ca, Mg, K, Na and Al were extracted by 0.1 N ammonium acetate (pH 7); Ca and Mg were determined on a Perkin Elmer atomic absorption spectrophotometer and K on a flame photometer. Available P was analysed by Bray-1; total N by the regular Macro-Kjeldahl Method, Organic C by Walkley and Black, effective cation exchange capacity (ECEC) was found by adding the exchangeable bases and the exchangeable acidity (H^+ and Al^{3+}). Al and H cations were extracted in 1 M KCL solution. CEC was estimated from ECEC based on the pH. Base saturation was calculated by adding the exchangeable bases multiplying by 100 and dividing by CEC. Aluminium saturation was calculated by multiplying exchangeable acidity by 100 and dividing by ECEC (Laboratory methods, 1985).

***Tithonia* leaf analysis:** Fully matured leaf samples were sampled at random. Samples were oven-dried at 60°C for 48 hours and ground to pass a 1 mm sieve before sending them to Mount Makulu Research Station, Lusaka for nutrient analysis. The mineral nutrients were extracted from the leaf material in 1 N HNO_3 . Concentrations of N, K, Ca, Mg, Fe and Zn were determined in a similar way as described above for soil analysis. P was determined with HCl and NH_4F as extractants (Lab. Methods, 1985).

Statistical analysis: Analysis of variance was performed on all parameters using SAS Software (2000).

RESULTS

***Tithonia* residue characterization:** *Tithonia* prunings had 2.5% N, 0.14% P, 4.20% K, 0.98% Ca, 0.32% Mg, 300 ppm Fe and 11 ppm Zn (Table 1).

Lignin and polyphenols were not determined as neither the laboratory at Misamfu or Mt. Makulu have ever carried out such specialized techniques but these parameters shown in Table 1 are extrapolated from TSBF organic database (Mutuo *et al.*, 2000).

Table 1. Chemical characterization of *Tithonia* from Northern Zambia

N	Lignin	Poly-phenols	P	K	Ca	Mg	Fe	Zn
-----		-----		-----		-----		(ppm)
2.7	13.16	3.83	0.14	4.2	0.98	0.32	300	11

Note: Lignin and Polyphenol values are averages from TSBF Organic database, (Mutuo, *et al.*, 2000).

Available soil P: At Misamfu the available soil P (Bray 1) was significantly different ($P < 0.05$) between the NPK fertilizer treatment and the rest of the treatments. All the treatments, except NPK fertilizer were around and below 0.1% available P. The control was significantly different ($P < 0.05$) from *Tithonia* alone, *Tithonia* combined with ¼ rate P as SSP or as GRP (Table 2). At Mungwi, available soil P was higher than at Misamfu, except in the treatment where NPK fertilizer was added. The highest was NPK fertilizer. There were no significant differences at Mungwi.

Exchangeable acidity: At Misamfu all treatments with *Tithonia* were not significantly different ($P < 0.05$) from one another, but all were significantly different from the control and NPK fertilizer treatment. The latter produced the highest exchangeable acidity (Table 2). At Mungwi there were no significant differences between the treatments which was caused by high CV due to some plots recording zero exchangeable acidity.

Exchangeable acidity was relatively lower than at Misamfu by comparing the control treatments only at these two sites.

Exchangeable aluminium: At Misamfu, exchangeable Al was significantly different ($P < 0.05$) between control and all the treatments receiving *Tithonia* and between NPK fertilizer and all treatments receiving *Tithonia*, with NPK fertilizer being the highest (Table 2).

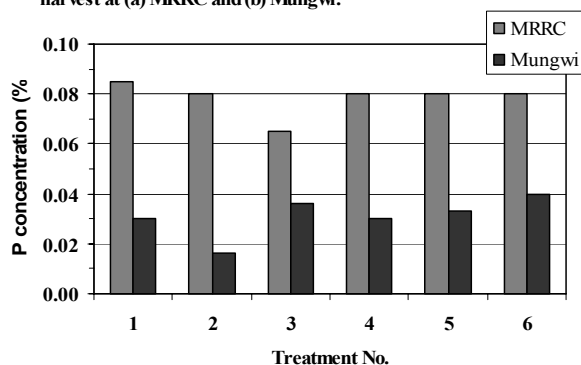
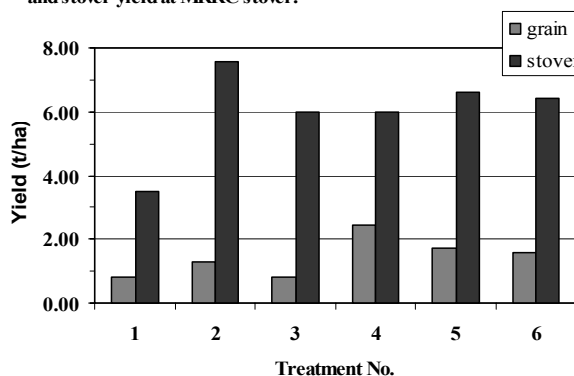
At Mungwi, there were no significant differences between treatments due to high CV as a result of some plots recording zero exchangeable Al.

Aluminium saturation: At Misamfu Al saturation was highest in the control treatment. The latter was significantly different ($P < 0.05$) to the rest of the treatments. NPK fertilizer treatment was the second highest and was significantly different ($P < 0.05$) to all treatments receiving *Tithonia*. The lowest were *Tithonia* alone and *Tithonia* combined with ¼ P as GRP. These latter two treatments were not significantly different from each other. At Mungwi Al saturation was highest in the NPK fertilizer treatment. *Tithonia* alone was the lowest. At this site Al saturation levels were lower than at Misamfu (Table 2). There were no significant differences between treatments due to high variations as a result of some plots recording zero Al saturation.

P uptake: At Misamfu, the P uptake by maize was significantly different ($P < 0.05$) between the NPK fertilizer treatment and the rest. All the *Tithonia* treatments were not significantly different from each other. The control was not significantly different from all *Tithonia* treatments (Fig. 2). At Mungwi, there were no significant differences between all the treatments due to the fact that P seems not to be limiting, which also confirms the available soil P results above.

Table 2. Effect of treatments on available P (Bray-1 P) and exchangeable acidity at the time of harvesting maize at (a) MRRC, Kasama, and (b) Mungwi District, Northern Zambia.

Treatment	Bray P		Exch AI+H		Exch AI		Exch AI Satn	
	MRRC	Mungwi	MRRC	Mungwi	MRRC	Mungwi	MRRC	Mungwi
	---- (ppm) ----		----- (cmol kg ⁻¹) -----				----- (%) -----	
1. Control (no <i>Tithonia</i> , no fertilizer)	0.06	0.22	0.45	0.25	0.35	0.12	20	3.6
2. NPK compound fertilizer	0.61	0.38	0.58	0.50	0.45	0.28	15	9.0
3. <i>Tithonia</i> alone	0.10	0.28	0.33	0.22	0.25	0.05	8	1.0
4. <i>Tithonia</i> + ¼ recommended rate of P as SSP	0.11	0.32	0.35	0.25	0.25	0.08	10	2.4
5. <i>Tithonia</i> + Full recommended rate of P as GRP	0.09	0.26	0.40	0.30	0.22	0.20	10	6.0
6. <i>Tithonia</i> + ¼ recommended rate of P as GRP	0.11	0.20	0.35	0.15	0.20	0.12	6	3.0

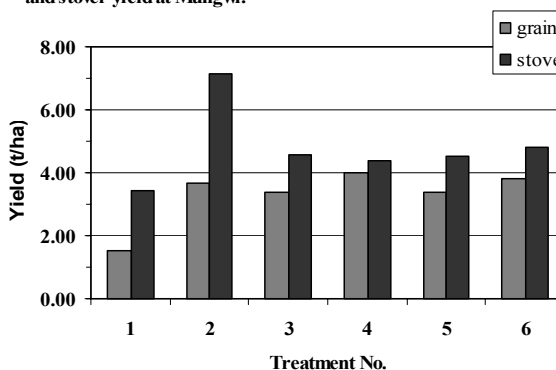
Figure 1. Effect of treatments on P concentration in maize at harvest at (a) MRRC and (b) Mungwi.**Figure 2. Effect of incorporating *Tithonia* prunings on maize grain and stover yield at MRRC stover.**

Grain yield: At Misamfu, the stover yield showed that the control treatment was significantly different ($P = 0.05$) from the rest of the treatments. There was no significant difference ($P = 0.05$) between the NPK fertilizer treatment and treatments receiving *Tithonia* either alone or in combination with SSP or GRP on stover yield. There were no significant differences between the control and NPK fertilizer on grain yield, as well as among treatments receiving *Tithonia* combined with P sources (SSP and GRP). The treatment receiving *Tithonia* combined with ¼ rate P as SSP, produced the highest grain yield at Misamfu (Fig. 3) while *Tithonia* alone produced the lowest grain yield.

These results also showed that at Mungwi stover yield was significantly different ($P = 0.05$) between the control and the rest of the treatments. There was no significant difference ($P = 0.05$) in terms of stover yield between the NPK fertilizer treatment and the treatments receiving *Tithonia* alone or in combination with either SSP or GRP. The grain yield also showed that there was a highly significant difference ($P = 0.05$) between the control and the NPK fertilizer treatments (Table 2). Among the treatments receiving *Tithonia*, there were no significant differences ($P = 0.05$) on grain yield (Fig. 3).

DISCUSSION

Tithonia residue contained adequate concentration of N, very low concentration of P, higher concentration of K,

Figure 3. Effect of incorporating *Tithonia* prunings on maize grain and stover yield at Mungwi.

very high concentration of Ca and some adequate amount of Mg, as well as high quantities of Fe and some Zn (Table 1). At Misamfu grain yield data showed that P was the most limiting nutrient element (this is confirmed by previous soils data, where available P (Bray 1) = 1 ppm, (data not shown), because despite providing recommended N rate in form of *Tithonia*-N (*Tithonia* tissue-P was 0.14%), the grain yield was not significantly different to the control (Table 2).

According to Buresh (1999) upon decomposition, *Tithonia* residue would be expected to release its tissue-P readily if the latter concentration was equal or more than 0.25% P. The evidence from the data from this experiment suggests that this assertion does not perhaps hold for the acid

soils of Northern Zambia since it is clear that there was a response to grain yield at Mungwi where *Tithonia* alone was not significantly different from *Tithonia* combined with ¼ rate P as SSP (Table 2). When recommended NPK fertilizer was applied at Misamfu without *Tithonia*, it appears the applied P was fixed, thus the grain yield was significantly different to that of *Tithonia* combined with quarter rate P as SSP (Fig. 3). This implies that *Tithonia* perhaps helped to make the applied P available to the maize only in the presence of inorganic source of P as SSP, and that even with P concentration of 0.14%, some solubilization or desorption appeared to have occurred. The presence of *Tithonia* appears to also make available P from rock phosphate as can be seen from the two treatments with *Tithonia* combined with GRP which were significantly different to *Tithonia* alone (Fig. 3). The high SED obtained at Misamfu was due to poor germination (caused by drought) which occurred at the time of planting. The biggest improvement in terms of grain yield was with *Tithonia* combined with ¼ rate of P as SSP. This is desired because it involves using a cheap material – *Tithonia*, with the addition of a small quantity of expensive inorganic P fertilizer.

The maize grain yields are higher at Mungwi than has previously been found (by Soil Productivity Research Programme (1990, 1991, 1996) which was based at Misamfu) when GRP was used on its own on maize. SPRP yields were around 2 t ha⁻¹ while in this study the yield was around 4 t ha⁻¹ indicating that perhaps *Tithonia* helped to solubilize the added rock P to some extent, may be not to a degree as with inorganic P source on the Mungwi site where the acidity was lower than at Misamfu. However, both treatments with GRP had relatively low grain yield compared to *Tithonia* combined with quarter rate P as SSP, due probably to the relatively low solubility of the GRP compared to inorganic SSP (Fig. 3).

These results are in agreement to those of Ganunga (1998) who also showed that at three sites in Malawi, *Tithonia* combined with inorganic P source was able to produce comparable grain yield with inorganic fertilizers alone or produced even better yields (Table 2). In this study the NPK treatment produced comparable grain yield with *Tithonia* combined with GRP (Fig. 3). These results are similar to those obtained in studies in Kenya (Niang *et al.*, 1999; Question and Answers) where yield of maize was shown to be boosted by applying *Tithonia* combined with rock phosphate.

The Misamfu soil (an oxisol) was relatively poor in fertility terms compared to the udandic Kandiusults soil at Mungwi. The latter had all soil parameters, except for exchangeable Al and Al saturation, higher than the former site (Table 3). The soils at Mungwi are more fertile than those at Misamfu as indicated by high pH, available P (Bray 1), organic matter and CEC (from previous data not shown). These differences in soil fertility status explain why at Mungwi both stover and grain yield were higher than at Misamfu. This is why a lower rate of P was applied at this site.

Mungwi soils seem not to represent the major soil types of Northern Zambia, so the challenge to attain food security at household or the village level lies with options such as use of *Tithonia* combined with judicious amounts of inorganic P or with GRP on these acid soils typically represented by Misamfu soil.

These results show that a resource-poor farmer of Northern Zambia can grow and produce adequate maize

Table 3. Initial chemical soil properties (0-15 cm depth) of the experimental sites

Soil characteristics	Misamfu	Mungwi
pH (CaCl ₂)	4.5	4.7
CEC (cmol (+) kg ⁻¹)	3.72	6.8
Org. C (%)	0.60	1.31
Total N (%)	0.05	0.11
Bray-1 P (mg kg ⁻¹)	1.07	2.65
Exch. K (cmol (+) kg ⁻¹)	0.47	0.97
Exch. Ca (cmol (+) kg ⁻¹)	0.28	0.84
Exch. Mg (cmol (+) kg ⁻¹)	0.03	0.08
Exch. Al ³⁺ (cmol (+) kg ⁻¹)	0.36	0.13
Al ³⁺ Saturation (%)	20	3.5
Base Saturation (%)	41	48

grain yield to attain household food security merely by using either *Tithonia* combined with judicious quantities of inorganic fertilizer (which is desirable because inorganic fertilizer is costly) or some full to quarter rate P as GRP and this practice is even more desirable as *Tithonia* is cheap and readily available locally and GRP is a cheaper source of P if only the deposits found in Northern Zambia can be exploited as this is readily available in this province. This is more applicable on the less fertile Misamfu soil, which is one of the dominant soil types in Northern Zambia. On the more fertile Mungwi soil, a resource-poor farmer would easily attain household food security by applying *Tithonia* alone or combined with cheap and locally available GRP, or if he/she can afford a little amount of inorganic P. The control shows a somewhat high grain yield at Mungwi (Fig. 3), perhaps this could be attributed to some residual P effect.

Al saturation

The pattern of Al saturation results is a mirror image of the pattern of the grain yield produced at Misamfu, implying that clearly Al saturation was the most limiting parameter to increased maize grain yield at this site (Table 2). The other soil parameters (Exchangeable acidity and Al, available P and P uptake) consistently showed that Mungwi soil was relatively more fertile than Misamfu soil. Yield data confirmed this quite accurately. Hence the discussion has dealt mostly with yield data and the soil available P, the latter being a crucial element in these soils due to its unavailability, which is directly influenced by the soil acidity. Exchangeable acidity and Al, as well Al saturation merely help to show the degree of acidity.

In general pH was lowest in fertilizer treated plots at both sites (4.4 at Misamfu and 4.5 at Mungwi), confirming the soil degradation which seems to be caused by the application of fertilizers on these soil as has been shown by other workers (e.g. Dalland *et al.*, 1993; Singh and Goma, 1995; Stocking, 1988), as also shown by the exchangeable acidity, exchangeable Al and Al saturation.

CONCLUSIONS

(1) Maize stover and grain yield obtained from the application of *Tithonia* leaves alone or in combination with both P sources, were comparable with yields obtained with inorganic NPK fertilizer treatment at Mungwi site; at Misamfu, the NPK fertilizer was able to give grain yield comparable to *Tithonia* combined with GRP. (2) Soil acidity

was reduced and there was an overall improvement in soil fertility as a result of applying *Tithonia*. (3) GRP appears to be agronomically effective on the performance of some annual (short-duration) crops such as maize if it is incorporated together with *Tithonia* prunings (contrary to the sole application of GRP) before application on the acid soils of Northern Zambia. This work has not only verified that *Tithonia* does work in improving maize yield, which has been shown elsewhere in Kenya, Malawi and Zimbabwe, but the most significant added piece of knowledge is the acid ameliorating effect. This latter aspect is particularly pertinent to Northern Zambia where acid soils are widespread and will no doubt go along way in solving the acidity problem and the associated crop production constraints.

REFERENCES

- Buresh, R. J. and Tian, G. 1998. Soil improvement by trees in Sub-Saharan Africa. In *Agroforestry Systems* 38:51-76. Kluwer Academic .
- Buresh, R.J. 1999. Combined Inorganic-Organic Nutrient Sources: Experimental Protocols for TSBF-AfNet, SoilFertNet and SWNM, Nairobi, Kenya. 25pp.
- Dalland, A., Vaje, P.I., Mathews, R.B. and Singh, B. R. (1993). The potential of alley cropping in improvement of cultivation systems in the high rainfall areas of Zambia. III Effects on soil chemical and physical properties. *Agroforestry Systems*, 21, 117 – 132.
- Dole 400 Moisture Tester (1987) Eaton Corporation, Controls Division, Carol Stream, Illinois 60188, USA.
- Ganunga, R. 1998. Potential of *Tithonia diversifolia* (Hemsley) A. Gray, as an organic source of nitrogen and phosphorus for maize (*Zea mays*) in Malawi. M.Sc. thesis, University of Zambia, Lusaka.
- Jiri, O. and Waddington, S. 1998. Leaf prunings from two species of *Tithonia* raise maize grain yield in Zimbabwe, but take a lot of labour! Target (Soil Fert Net Newsletter) 16:4-5.
- Questions and Answers In *Agroforestry Today*. July-September, 1998. Volume 10, No.3. 25p.
- Laboratory Methods. (1985). Dept. of Agriculture, Mt. Makulu Central Research Station, Chilanga, Zambia. 300pp.
- Malama, C.N. and Kapekele, E. 2001. Informal survey on the utilization of *Tithonia Diversifolia* in the farming systems of the Isoka District of Northern Zambia. (in press).
- Malama, N. C. 1998. Manipulating Nitrogen Release from Tropical Tree Prunings through Interactions Mediated by their Resource Qualities. PhD Thesis, Wye College, University of London, Wye, Ashford, Kent. UK.
- McPhillips, J. K. (ed). 1987. Commercial Crop Production Recommendations. Department of Agriculture, Zambia. 57pp.
- Mutuo, P., Marandu, A. E., Rabeson, R., Mwale, M. Snapp, S. Delve, R. and Palm, C. 2000. Nitrogen fertilizer equivalency values of organic materials of differing quality: Network trials results from East and Southern Africa. Paper presented at the symposium entitled "Balanced Nutrient Management Systems for the Moist Savanna and Humid Forest Zones of Africa," held from 9 – 12 October, 2000, Cotonou, Benin Republic.
- Niang, A., Recke, H., Place, F., Kiome, R., Nandwa, S and Nyamai, D. 1999. Soil fertility replenishment in Western Kenya. In *Agroforestry Today*. January-June, 1999, Volume 11 Nos.1-2, 19- 21p. Questions and Answers In *Agroforestry Today*. July-September, 1998. Volume 10, No.3. 25p.
- Sanchez, P. A.; Izac, A. M.; Valencia, I and Pieri, C. 1997. Soil fertility replenishment in Africa: A concept note.
- SAS Institute Inc. (2000). SAS/STAT™ Guide for Personal computers. SAS Institute, North Carolina, USA.
- Singh, B. R. and Goma, H. C. (1995). Long-term Soil Fertility Management Experiments in Eastern Africa, 347-382pp. In: *Advances in Soil Sciences: Soil Management Experimental Basis for sustainability and Environment Quality*. R. Lal and B. A. Stewart (Eds). CRC Press, Inc. Lewis Publishers.
- Soil Productivity Research Programme Annual Reports. 1990, 1991, 1996. Misamfu Regional Research Centre, P.O. Box 410055, Kasama, Zambia.
- Stocking, M. 1988. Tropical red soils: Fertility management and degradation. In K. Nyamapfene, K. Hussein and K. Asunadu (eds.) *Proceedings of an International Symposium*, Harare, Zimbabwe.