Available online at www.scholarsresearchlibrary.com

Scholars Research Library

Archives of Applied Science Research, 2014, 6 (2): 42-47
(http://scholarsresearchlibrary.com/archive.html)

Archives of Applied Science Research
Scholars Research Library
ISSN 0975-508X
CODEN (USA) AASRC9

Soil fertility improvement potentials of Mexican sunflower (*Tithonia diversifolia*) and Siam weed (*Chromolaena odorata*) using okra as test crop

Taiwo M. Agbede[a] and Lawrence A. Afolabi[b]

[a]Department of Agricultural Technology, Rufus Giwa Polytechnic, Owo, Ondo State, Nigeria
[b]Department of Crop, Soil and Pest Management Technology, Rufus Giwa Polytechnic, Owo, Ondo State, Nigeria

---

ABSTR ACT

Fallowing is considered an important management practice in maintaining soil productivity. In this study, soils fallowed to mexican sunflower (Tithonia diversifolia), siam weed (Chromolaena odorata), spear grass (Imperata cylindrica) and soil cropped to cassava for 3 years were chemically analyzed. Soil physical properties such as bulk density, total porosity, moisture content and temperature were also determined. The soils collected from the fallows were used to grow okra (Abelmoschus esculentus) in pot experiment using randomized complete block design with three replications. The results showed that soils fallowed to Tithonia and Chromolaena had significantly higher organic matter, N, P, K, Ca and Mg at 0-15 cm depth and higher organic matter, N, P and Ca at 15-30 cm depth compared with soils fallowed to spear grass and cropped to cassava. Soil fallowed to Tithonia had significantly higher organic matter, N and K than Chromolaena fallow. The growth and yield parameters like okra height, leaf area, stem circumference and fruit weight of okra were significantly higher in soil under Tithonia fallow than soils under Chromolaena, spear grass and cassava fallow. Relative to soil cropped to cassava, soils fallowed to Tithonia, Chromolaena and spear grass increased fruit weight of okra by 161, 122 and 22%, respectively. Soils under Tithonia and Chromolaena showed significant improvement in soil physical properties compared with soils under cassava and spear grass as indicated by lower bulk density and higher porosity. This can be attributed to the high fertility potentials of the Tithonia and Chromolaena weeds with sound potential for protecting the soil against erosion and leaching, proliferating surface soil with their roots, and attracting fungi, producing high biomass and building soil organic matter to adequate level that will meet nutritional needs of crops as well as improve the nutrient element status of nutrient depleted soils into which organic sources are used as fallow weeds.

Key words: *Chromolaena*, fallows, okra, soil cropped to cassava, soil properties, spear grass, *Tithonia*

INTRODUCTION

High procurement cost of chemical fertilizers in tropical agriculture necessitated dependence on biological means of maintaining soil fertility and productivity. Fallowing is considered an important management practice in maintaining soil productivity. "Fallow", the resting state of an agricultural field, is a soil conservation and soil improvement technique, which is important for maintaining and restoring soil fertility over wide areas of the world [1]. Many farmers in the tropics still use fallows as part of their farming system. Fallowing replenishes nutrients removed by crops, reduces erosion and leaching, and maintains better soil physical and biological conditions [2,3]. However, fallow periods throughout the tropics have become progressively shorter, as a result of pressure on land, arising from human population growth. The fallow system is no more efficient to maintain soil productivity due to too short or non-existent fallow period. Therefore, there is dire need to research on fast growing weed species which produce large amount of high quality biomass during a growth period of one to three years. Unused, nontraditional organic resources grow on or near small holder farms. Some have relatively high nutrient concentrations, but little is known about their potential as a nutrient source to improve soil fertility and crop yields. One of such organic resource is the green biomass of *Tithonia* (*Tithonia diversifolia* (Hemsley) A. Gray).

Tithonia, commonly known as Mexican sunflower, is a shrub belonging to the family Asteraceae. *Tithonia* originated from Mexico, and it is now widely distributed throughout the humid and sub-humid tropics in Central and South America, Asia and Africa, and it is a common in indigenous fallow systems in Southeast Asia. *Tithonia* is an aggressive weed growing to a height of about 2.5 m and adaptable to most soils [4]. *Tithonia* was probably introduced into Africa as an ornamental plant. It had been observed to be widely spread in Nigeria where it is found growing on abandoned/waste lands, along major roads and waterways and on cultivated farmlands. The reported uses of *Tithonia* include; fodder, poultry feed, fuel wood, compost, land demarcation, erosion control, building materials and shelter for poultry [4,5]. The stems and leaves of *Tithonia* had been reported to contain sesquiterpene lactones e.g. tagitinins (terpene) that prevents attack by termites [6] and possess antimicrobial properties. Hence, *Tithonia* with low lignin (6.5%), polyphenol (1.6%) and considerably high nitrogen (3.5%), phosphorus (0.37%) and potassium (4.10%) contents [7] has great potential for use as soil amendment.

Chromolaena odorata (Siam weed) belongs to the family *Asteraceae*. It originated from North America and had since been widespread throughout the humid forest zone of West Africa. *Chromolaena* is the dominant fallow vegetation in southwest Nigeria where it grows luxuriantly and rejuvenates the soils. It has the potential of being used as nutrient source [8,9].

According to [7], *Tithonia* has aroused research interest because of the relatively high nutrient concentrations (N, P and K) that are found in its biomass and because of its ability to extract relatively high amount of nutrients from the soil. The abundance and adaptation of this weed species to various environment couples with its rapid growth rate and very high vegetative matter turn over makes it a candidate species for soil rejuvenation [4].

Tithonia has received less research attention in Nigeria compared with Siam weed as to their effect on soil properties and productivity. Despite the potential of *Tithonia* and C*hromolaena* in restoring soil fertility, comparative studies to assess their effects on soil properties and okra yield in the forest-savanna transition zone of southwest Nigeria are limited. In the guinea savanna zone of Nigeria, [10] found that soil under *Tithonia* and *Chromolaena* weed had higher pH, porosity, moisture content, nitrogen, phosphorus, potassium, sodium, calcium, mycorrhizal fungi spores and earthworm cast density and lower bulk density compared with bare soil. Hence the objectives of this work are to:

(a) assess the potential of *Tithonia* and *Chromolaena* weed in the forest-savanna transition zone of southwest Nigeria.
(b) investigate soil depth to which *Tithonia* and *Chromolaena* weed influence soil chemical properties in the forest-savanna transition zone of southwest Nigeria and relative effect of their natural fallows on soil properties and growth of okra.
(c) evaluate the effect of *Tithonia*, *Chromolaena*, spear grass and cassava fallows on soil properties and performance of okra.

MATERIALS AND METHODS

Two studies were carried out in separate phases. The first study investigated effect of *Tithonia*, *Chromolaena* weed, spear grass and cassava fallows on soil properties and okra (*Abelmoschus esculentum*). The second study investigated effect of *Tithoinia*, *Chromolaena* weed and cassava at different soil depths on soil chemical properties.

Pot experiment
In the first study, soil samples were collected from plots that were under three years fallow of *Tithonia*, *Chromolaena* weed and spear grass (i.e. a relatively uniform site was seeded/planted to *Tithonia*, *Chromolaena* and spear grass) and plots cropped to cassava for three years in the same locality and that the soil conditions at the start of the fallow phase were determined and comparable (i.e. from the Teaching and Commercial Farm of Rufus Giwa Polytechnic, Owo, Nigeria). Soil samples were randomly collected from different points with soil auger from fallow and cassava plots and later bulked into three per plot. Portions of the soil samples were kept for chemical analysis before they were weighed into pots (20 cm in diameter and 22 cm deep). Each of the pot which had been perforated at its base was filled with 10 kg soil taken from fallow and cassava plots. Sub-samples taken for chemical analysis were air-dried and sieved using 2 mm sieved. There were three pots per treatment given 36 pots on the whole. Pots were laid out in a randomized complete block design. The pots were thoroughly irrigated or wetted before planting. Three okra seeds, variety NH_{47} obtained from the National Institute for Horticultural Research and Training Ibadan, Nigeria were sown in each pot on 10 May, 2013 and 25 August, 2013 for the early season and late season, respectively. Seedlings were thinned to 1 plant per pot at 10 days after sowing (DAP). Light mulching was done and each pot was watered as needed. Cypetex, an insecticide containing 100 mg ml^{-1} of cypermethrin as active ingredient was used against leaf eating beetles (*Podagrica spp*).

Determination of growth and yield parameters

The growth parameter determined at the early boom of flowering were; plant height (by using measuring tape), number of leaves per plant (determined by direct counting of well - developed leaves per plants), leaf area was measured by graphical method (i.e. placing the leaf on graph sheet for area determination), stem circumference (by using vernier caliper, which first gave the value of the diameter, which was later converted to circumference using a formula of πD (i.e. 3.142 multiplied by the obtained diameter (D) value). At harvest number of fresh fruit per plant was determined (by direct counting) and weighed. The cumulative fruit weight values per plant, obtained from multiple harvestings spanning 5 weeks, were later converted to fruit yield (Mg ha^{-1}).

Determination of soil physical properties

Five undisturbed steel core samples (4 cm diameter, 10 cm high) were collected at 0-10 cm depth from each plot and were used for the determination of bulk density, gravimetric moisture content and total porosity after oven drying of samples at 100^0C for 24 h. Total porosity was calculated from bulk density and particle density of 2.65 Mg m^{-3}. Soil temperature was determined at 15.00 h with a soil thermometer inserted to 10 cm depth. Five readings were made per plot and mean computed.

Determination of soil chemical properties

In the second study, soil samples were collected in duplicate from 0-15 and 15-30 cm depths in a pit dug at each plot dominated by *Tithonia*, *Chromolaena* weed and cropped to cassava to determine their chemical properties at different depths. Air-dried 2 mm sieve soil samples collected from the two studies were subjected to routine chemical analysis as described by [11]. Soil organic carbon was determined by the procedure of Walkley and Black using the dichromate wet oxidation method. Organic matter was deduced by multiplying C by 1.724. The total N was determined by micro-Kjeldahl digestion and distillation techniques, available P was extracted using Bray-1 solution and determined by molybdenum blue colorimetry. Exchangeable K, Ca and Mg were extracted using 1N ammonium acetate. Thereafter, K was determined using a flame photometer and Ca and Mg by atomic absorption spectrophotometer.

Statistical analysis

Data collected were analyzed statistically using the analysis of variance (ANOVA) and the treatment means were separated using the Duncan's multiple range test and the least significant difference test (LSD) at p = 0.05 probability level [12].

RESULTS

Effect of weed fallow on soil chemical properties (0-15 cm depth)

Effect of three year fallow of *Tithonia*, *Chromolaena* weed, spear grass and plots cropped to cassava on soil chemical properties (0-15 cm depth) are shown in Table 1. *Tithonia* and *Chromolaena* had significantly higher (p = 0.05)) values of soil organic matter, N, P, K, Ca and Mg compared with soil cropped to cassava and fallowed to spear grass. Cropped soil had the least values of the chemical properties. Compared with soil cropped to cassava, *Tithonia* and *Chromolaena* increased soil organic matter by 144 and 103%, respectively. The percentage increases for total N were 155 and 100%, respectively while the percentage increases for available P were 51 and 47%, respectively. The percentage increases for exchangeable K were 80 and 40%, respectively; for exchangeable Ca, the percentage increases were 100 and 91%, respectively while the percentage increases for exchangeable Mg were 96 and 100%, respectively. Soil Ca and Mg between soils fallowed to *Tithonia* and *Chromolaena* were not statistically different from each other, but soil fallowed to *Tithonia* was significantly higher (p = 0.05) than C*hromolaena* in organic matter, N and K by 20, 27 and 29%, respectively.

Table 1. Effect of weed fallow on soil chemical properties (0-15 cm depth)

Fallow	OM (%)	N (%)	P (%)	K (cmol kg^{-1})	Ca (cmol kg^{-1})	Mg (cmol kg^{-1})
Chromolaena	1.91b	0.22b	8.4a	0.14b	2.1a	0.90a
Tithonia	2.29a	0.28a	8.6a	0.18a	2.2a	0.88a
Spear grass	1.54c	0.17c	7.0b	0.12c	1.6b	0.66b
Cassava	0.94d	0.11d	5.7c	0.10d	1.1c	0.45c

Means followed by the same letters in the same column are not significantly different at p = 0.05 according to Duncan's multiple range test

Effect of weed fallow on soil chemical properties at different depths

Table 2 shows data on values of soil chemical properties at 0-15 and 15-30 cm depths. At 0-15 cm depth (surface layer), soils fallowed to *Tithonia* and C*hromolaena* had higher values of OM, N, P, K, Ca and Mg than soil cropped to cassava. At 15-30 cm depth (subsoil layer), soils under weed fallows also had higher OM, N, P and Ca. The organic matter and other nutrients were higher at the surface layer than at the subsoil layer and generally soil nutrients reduced with depth from 0-30 cm depth. The values of soil chemical properties reduced in the order *Tithonia*, *Chromolaena* and cassava soils. When K and Mg were considered at 15-30 cm depth, cassava soil had highest K concentration and relatively high Mg concentration.

Table 2. Effect of weed fallow on soil chemical properties different depth

Fallow /depth (cm)	OM (%)	N (%)	P (%)	K (cmol kg^{-1})	Ca (cmol kg^{-1})	Mg (cmol kg^{-1})
Chromolaena/0-15	1.91	0.22	8.4	0.14	2.1	0.90
Tithonia/0-15	2.29	0.28	8.6	0.18	2.2	0.88
Cassava/0-15	0.94	0.11	5.7	0.10	1.1	0.45
LSD (0.05)	0.32	0.03	2.1	0.02	0.6	0.19
Chromolaena/15-30	1.57	0.16	6.1	0.11	1.3	0.76
Tithonia/15-30	1.95	0.18	6.5	0.15	1.4	0.79
Cassava/15-30	0.68	0.09	4.3	0.23	0.7	0.83
LSD (0.05)	0.28	0.11	0.8	0.03	0.2	NS

Effect of weed fallow on soil physical properties (0-10 cm depth)

Effect of weed fallow on soil physical properties at the end of 3 years are shown in Table 3. Soils under *Tithonia* and *Chrommolaena*, respectively had better physical conditions of soils than that of soils under cassava and spear grass. Soils under *Tithonia* and *Chromolaena* had relatively lower soil bulk density, higher total porosity compared to soils fallowed to spear grass and cropped to cassava. Among the fallow systems, bulk density of soil under cassava and spear grass exceeded that of soils fallowed to *Tithonia* and *Chromolaena* by an average of 23%. Soil under spear grass had the highest moisture content which was significantly higher ($p = 0.05$) compared to soils under *Chromolaena* and Cassava, but not statistically different from soil under *Tithonia* fallow. Soil cropped to cassava had the least total porosity and highest bulk density, and it also had least moisture content. Fallowing had no significant ($p = 0.05$) effect on soil temperature.

Table 3. Effect of weed fallow on soil physical properties (0-10 cm depth)

Fallow	Bulk density (Mg m^{-3})	Total porosity (%, v/v)	Moisture content (%)	Temperature (^{0}C)
Chromolaena	1.20ab	54.7ab	33.4b	28.7a
Tithonia	1.13a	57.4a	40.9a	28.5a
Spear grass	1.44c	45.7c	42.7a	31.0a
Cassava	1.58d	40.4d	25.3d	29.3a

Means followed by the same letters in the same column are not significantly different at p = 0.05 according to Duncan's multiple range test

Effect of weed fallow on growth parameters and fruit yield of okra

The effect of weed fallow on growth parameters and fruit yield of okra are shown in Table 4. Plant height, leaf area, stem circumference and fruit yield were significantly affected by weed fallow. Soil under *Tithonia* gave the highest values of plant height, leaf area, stem circumference and okra fruit yield which were significantly higher ($p = 0.05$) compared to soils fallowed to *Chromolaena*, spear grass and cropped to cassava. Soil under *Chromolaena* fallow produced okra plant height, leaf area, stem circumference and fruit weight which were significantly higher ($p = 0.05$) than soils fallowed to spear grass and cropped to cassava. Soil cropped to cassava had the least okra plant height, leaf area, stem circumference and fruit weight which were significantly lower ($p = 0.05$) when compared to soils dominated by *Tithonia*, *Chromolaena* and spear grass. In the overall performance, okra height, leaf area, stem circumference and fruit weight increased in order: cassava < spear grass <*Chromolaena* < *Tithonia* soil. Relative to soil cropped to cassava, soils fallowed to *Tithonia*, *Chromolaena* and spear grass increased fruit weight of okra by 161, 122 and 22% respectively.

Table 4. Effect of weed fallow on plant height, leaf area, stem circumference and fruit weight of okra

Fallow	Plant height (cm)			Leaf area (cm^{2})			Stem circumference (cm)			Fruit weight (Mg ha^{-1})		
	E	L	Mean	E	L	Mean	E	L	Mean	E	L	Mean
Chromolaena	47.3b	42.9b	45.1b	4460b	3455b	3958b	3.5b	3.1b	3.3b	4.2b	3.7b	4.0b
Tithonia	57.9a	53.5a	55.7a	5632a	4627a	5130a	4.3a	3.9a	4.1a	4.9a	4.4b	4.7a
Spear grass	40.2c	35.8c	38.0c	2540c	1535c	2038c	2.9c	2.5c	2.7c	2.5c	1.9c	2.2c
Cassava	32.6d	28.4d	30.5d	1860d	1002d	1431d	1.8d	1.4d	1.6d	2.0d	1.5d	1.8d

Means followed by the same letters in the same column are not significantly different at p = 0.05 according to Duncan's multiple range test
**E = Early crop; L = Late crop*

DISCUSSION

The increase in soil nutrients due to *Tithonia* and *Chromolaena* fallow can be adduced to increased soil organic matter which might be due to enhanced microbial activity. The organic matter is a natural source of nutrients and cation exchange. Tithonia and *Chromolaena* due to their compositions were able to release macro nutrient thereby increasing soil fertility and crop nutrient uptake. Analysis of *Tithonia* and *Chromolaena* as given by [9] were 31.7; 33.5% OC, 3.30; 2.41% N, 0.53; 0.44% P, 3.89; 1.03% K, 3.41; 2.30% Ca, 0.04; 0.04% Mg and 9.6; 13.9 C/N ratio, respectively. Hence because of their nutrient concentrations were able to give higher soil OM, N, P, K, Ca and Mg at the surface (0-15 cm depth).

The influence of *Tithonia* and *Chromolaena* for improving soil fertility in crop production had been widely reported [8,13,14,15]. This was attributed to the conversion of biomass to organic matter, which increased the levels of these nutrient elements, indicating that fallow improved soil properties. [16] found that fallows restored soil fertility and organic matter content of nutrient depleted soil for the long term and also improved subsequent crop performance.

The finding that soils under weed fallows had higher values of organic matter, N, P and Ca at the surface (0-15 cm depth) than at subsoil layer (15-30 cm depth) could be attributed to higher concentration of organic matter in the upper layer than in the subsoil layer. This was due to the fact that more organic matter decomposition occurred in the upper layer of soil profile because more organic matter was added through litter fall due to the fallowing of soils. The decrease in soil organic matter, N, P and Ca at the subsoil (15-30 cm depth) could also be attributed to soil compaction which hampers circulation of air and water and hinders microbial activity down the soil profile. The findings that cassava soil had the highest K and relatively high Mg concentration at the subsoil (15-30 cm) than soils fallowed to *Tithonia* and *Chromolaena* could be due to leaching of the cations in the more exposed cassava soil.

The reduction of the soil bulk density and higher total porosity observed in soils under *Tithonia* and *Chromolaena*, respectively compared with soils under spear grass and cassava could be attributed to increase in soil organic matter resulted from the degraded organic residues by soil organisms. The quick growing weeds should have returned biomass and enhanced organic matter which is known to enhance soil physical and chemical properties. Organic matter is known to improve soil structure, aeration, reduce bulk density and enhance water infiltration [9]. The presence of weed fallow should have increased activities of beneficial soil fauna in organic matter decomposition which led to enhancement of porosity and reduction of soil bulk density. Also by protecting the soil, the weed fallow should have stabilized the soil structure against raindrop impact and thereby preventing soil erosion, soil compaction and crusting.

Better growth and yield of okra observed under *Tithonia* and *Chromolaena* fallows over spear grass and cassava soils could be attributed to their more improved soil physical and chemical properties. Fallowing soil to weeds improved soil physical and chemical properties and okra performance as opposed to cropping. The finding that *Tithonia* fallow produced significantly higher growth and yield of okra compared with other organic sources could be adduced to its higher nutrient status and low C/N ratio which should have increased decomposition and nutrient release for okra uptake. This was in agreement with the findings of [17] and [5] that *Tithonia* is a high - quality organic source in terms of nutrient release and supplying capacity. Lower C/N ratio of *Tithonia* (7.8) compared to moderate C/N ratio of *Chromolaena* (12.1) [4] and relatively high C/N ratio of spear grass (20:1) indicates a faster decomposition. [18] and [7] also listed high N and P contents and high soluble fraction and moderate lignin content resulting in high biodegradation as the strong point of *Tithonia* as source of organic matter.

Tithonia and *Chromolaena* serve as protective cover against erosion and are agents of nutrient cycling and supply. [10] found that soils under *Tithonia* and *Chromolaena* contained arbuscular mycorrhizal fungi spore which enhance absorption of nutrients from soil in N, P and Ca [19,20]. Because of the ability of the weeds to protect the soil, proliferate surface soil with their roots, attract fungi, increase biomass and organic matter; the fallows improve soil structure and porosity, reduced bulk density and temperature, and increase soil fertility, okra growth and yield.

CONCLUSION

Tithonia and *Chromolaena* weed respectively reduced soil bulk and temperature and increased total porosity and soil moisture content. They also increased soil organic matter content and soil nutrient levels and subsequently produced high growth and yield of okra. This study has shown that *Tithonia* and *Chromolaena* have high fertilizing and sound potentials for building soil organic matter to adequate levels that will meet nutritional needs of crops as well as improve the nutrient element status of arable fields when bush fallows are dominated by such organic resources than when such fields are taken over by grasses like spear grass. *Tithonia* and *Chromolaena* are potential soil improvers and are therefore recommended for use as fallow plants in the forest-savanna transition zone of southwest Nigeria for enhanced productivity.

REFERENCES

[1] U. Buttner and S. Hauser, *Agric. Ecosys. Environ.*, **2003,** 100: 103-110.
[2] E. Barrios and J.G. Cobo, *Agric. Sys.* **2004,** 60: 255-265.
[3] G. Tian, B.T. Kang, G.O. Kolawole, P. Idineba and F.K. Salako, *Nutr. Cycl. Agroecosys.*, **2005,** 71: 139-150.
[4] O.S. Olabode, O. Sola, W.B. Akanbi, G.O. Adesina and P.A. Babajide, *World J. Agric. Sci.*, **2007,** 3(4): 503-507.
[5] S.O. Ojeniyi, S.A. Odedina and T.M. Agbede, *Emirates J Food Agric.*, **2012,** 24(3): 243-247.
[6] F. Adoyo, J.B. Mukalam and M. Enyola, *ILEIA Newsletter*, **1999,** 13: 24-25.
[7] B. Jama, C.A. Palm, R.J. Buresh, A. Niang, C. Gachengo, G. Nziguheba and B. Amadalo, *Agroforest. Sys.*, **2000,** 49: 201-221.
[8] O.S. Akanbi and S.O. Ojeniyi, *Nigerian J. Soil Sci*., **2007**, 17: 120-125.
[9] T.M. Agbede, A.O. Adekiya and J.S. Ogeh, *Archives Agron. and Soil Sci*., **2014,** 60 (2): 209-224.
[10] M.O. Atayese and M.O. Liasu, *Moor J. Agric. Res*., **2001,** 3: 104-109.
[11] J.R. Okalebo, K.W. Gathua and P.L. Woomer, Laboratory methods of soil and plant analysis. A working manual. Second edition. TSBF-CIAT, SACRED Africa, KARI, Soil Science East Africa, Nairobi, Kenya, **2002,** 128.
[12] R.G.D. Steel, J.H. Torrie and D.A. Dickey, Principles and procedures of statistics. A biometrical approach. Third edition. New York, Mc Graw-Hill, **1997,** 666.
[13] C.R. Obatolu and A.A. Agboola, In: Mulongoy K. and R. Merckx (Eds.) Soil organic matter dynamic and sustainability in tropical agriculture. IITA/K.U. (Leuven,John Willey and Sons, New York, **1993**) 89-99.
[14] B.O. Ademiluyi and S.O. Omotoso, *Res. J. Agron*., **2008,** 2(1): 8-11.
[15] K.S. Chukwuka and O.E. Omotayo, *Res. J. Soil Bio.*, **2009,** 1(1): 20-30.
[16] B. Thor Smestad, H. Tiessen and R.J. Buresh, *Agroforest. Sys*., **2002,** 55(3): 181-194.
[17] G. Nziguheba, C.A. Palm, R.J. Buresh and P.C. Smithson, *Plant and Soil*, **1998,** 198: 159-168.
[18] C.A. Palm and A.P. Rowland, In: Cadisch G. and K.E. Giller (Eds.) Driven by nature: Plant litter quality and decomposition, CAB International, (Wallingford, UK, **1997**) 379-392.
[19] I.B. Taiwo and J.O. Makinde, *African J Biotech.*, **2005,** 4: 355-360.
[20] M.O. Liasu and A.K. Achakzai, *American-Eurasian J. Agric. and Environ.*, **2007,** 2: 335-340.