Journal of Natural Sciences Research www.iiste.org
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.4, No.17, 2014

Influence of Composted Phyto-residues and Harvesting Frequency on Growth and Forage Potentials of Grain Amaranth *(Amaranthus cruentus)* Under Oxic Paleutult Soil Conditions

Peter Akintoye Babajide* , Adebanke Omolara Olayiwola
Department of Crop Production and Soil Science, Ladoke Akintola University of Technology, PMB 4000, Ogbomoso, Nigeria.
* E-mail of the correspondence author: akinbabajide@yahoo.com

Abstract
Earlier research activities on *Amaranthus cruentus* were majorly focused on the suitability of its small edible grains for human and livestock consumptions, but other certain beneficial attributes of the crop-plant, such as relatively long succulent stem, high foliage production and rapid re-growth which make the shoot a potential forage crop (particularly under improved soil nutrition), had been enshrouded and therefore suffered adequate studies. Field studies were carried out in the year 2010, at the Teaching and Research Farms, Ladoke Akintola University of Technology, Ogbomoso, Nigeria, to evaluate the forage potentials of *Amaranthus cruentus,* under suitable agronomic practice and improved soil nutrition. The trial treatments were: four application rates (0.0, 1.5, 3.0 and 6.0 t ha^{-1}) of composted-Tithonia biomass and four harvesting frequencies (i.e. zero or no-harvesting, mono-weekly, mono-fortnightly and mono-monthly harvestings). The trials were laid out in a Randomized Complete Block Design (RCBD) and were replicated three times. At the fourth week after sowing, some growth parameters were measured prior to 1st cutting or harvesting. At every harvest, the harvested shoot dry weight and nutrient uptake of N, P and K were determined. After the final harvest, the cumulative dry weights of the above-ground biomass (followed by the below-ground biomass), were determined. Compost rate of 3.0 t ha^{-1} under mono-fortnightly cutting or harvesting gave the best values of all the growth parameters measured i.e. plant height, stem circumference, number of leaves and leaf area. Biomass yields obtained from both the no-harvesting / zero-harvesting and the mono-fortnight harvesting (cumulative), which received 3.0 tons of composted materials were statistically similar and the best, compared to the other treatment combinations. Therefore, mono- fortnight harvesting or cutting of grain amaranth with 3.0 t ha^{-1} application of composted Tithonia-residues may be beneficial to its accelerated shoot re-growth. This makes it dually suitable for human consumption as a leaf vegetable and a desirable forage / soilage for livestock management. Also, this approach may encourage maximum utilization of available soil nutrients and equally promote crop and animal production efficiency.
Keywords: Grain amaranth, Forage potentials, Composted phyto-residues, Harvesting frequency, Oxic paleutult soil.

1. Introduction

Grain Amaranth (*Amaranthus cruentus L.)* is an annual dicotyledonous plant belonging to the family Amaranthaceae. It is a broadleaf pseudocereal with an upright growth habit mainly cultivated for its edible grains and leaves. Grain Amaranth is probably originated from America but now widely cultivated in the tropical and subtropical Africa, Asia, the Pacific Islands, the Caribbean and Central America (Olaniyi, 2007). Some of the most frequently cultivated species are *Amaranthus blitum; A. lividus; A. dubius; A. spinosus; A. Thunbergii; A. graecizans* (vegetables); *A cruentus and A. hypochondriacus* (grain) (Schippers, 2000). *Amaranthus cruentus L.* is a vegetable of high dietary value commonly grown and consumed in many parts of Nigeria. *Amaranthus cruentus* is best recognized by its leaves that are twice or three times as long as wide, which are often known to have pointed leaf tips and plume-like inflorescence with raceme diameter of 10mm or more (Schippers, 2000). Although all African species are used for their leaves, they can also be grown for their seeds. It contains relatively high levels of vitamin A and C, carotene, iron, calcium, potassium, protein and lysine (Akanbi and Togun, 2002). The seeds contain 1.5 – 3.0 times higher oil content than any cultivated cereal (Olaniyi, 2007). Leaves are processed into many food items, supplements and additives (Ojo and Olufolaji, 1997). Uses of amaranth include; grains used in breakfast cereals or as an ingredient in confectioneries. South Americans parch or cook it for gruel of porridge, or mill it to produce light-colored flour. The flour contains little or no glutens and must be blended with wheat flour so baked goods will rise. As a snack, the tiny grains are popped and taste like nutty-flavored popcorn, or it is mixed with honey. The leaves (which are high in protein, vitamins and minerals) are boiled and eaten as greens. They are the most commonly grown vegetable of the lowland tropics in Asia and Africa. Amaranth seeds are occasionally used in Ethiopia to brew the alcoholic beverage "tala", a kind of beer. It is especially rich in protein and lysine, an essential amino acid that is lacking in most of the cereal-based diets and could be processed into animal feed (Breene, 1991). Apart from its nutritional value, amaranthus is extensively cultivated in Nigeria for its relatively drought tolerant quality and wide range of climatic adaptability. It could be grown in areas where grains like sorghum, maize and millet can thrive well and could compete effectively with some other arable crops, under mixed cropping conditions (Denton, 1992). Green leaves of amaranth were reported to contain 2.6mg iron and 654µg vitamin A per 100g which make it suitable forage, for livestock feed management (Olaniyi, 2007).

Moreso, despite the dietary importance, versatility and popularity of this vegetable in traditional cropping system, its yield per unit area is still very low. For instance, an average yield of 8 tons ha^{-1} was recorded for it by Denton (1992) in the survey of farmers' cropping system conducted in South Western Nigeria as against between 24 – 30 tons ha^{-1} shoot yield realizable under research conditions. Amongst the causes of such undesirable yield is incorrect application of chemical fertilizers coupled with poor agronomic practices (Robert, 1998).

One of the major hindrances to achieving sustainable crop production in the tropics today is the rapidly declining soil fertility / productivity as aggravated by climatic attributes (i.e. torrential rainfall, high solar radiation, temperature, relative humidity e.t.c.) and undesirable human activities such as excessive logging, bulldozing, mining, overgrazing, bush burning, incessant application of chemical fertilizers e.t.c. (Akanni and Ojeniyi, 2007). However, the use of plant residue as fertilizer could come as an alternative to the use of mineral fertilizer and thereby reduce the risks of environmental pollution on crop yields (Babajide *et al.,* 2008). When these wastes are composted, they form a more stable material called compost (Akanbi *et al.,* 2004). Composts made from organic wastes, when applied to soil increase soil organic matter and supply plant nutrients in a slowly available form, improve soil physical, chemical and microbial properties (Hartz *et al*; 1996; Smith *et al*., 1992; Babajide *et al*., 2008). Composting is an aerobic process in which microorganisms convert mixed organic substrate into carbon dioxide, water, minerals and stabilized organic matter under controlled conditions. The key requirements are moisture and aeration levels creating temperatures that are conducive to the microorganisms involve in the composting processes (Chen *et al*., *1993*). Compost can comprise of wasted organic materials, e. g. grasses, weed, crop trimmings, kitchen waste and other residues. These are stimulated into a state of decomposition by the addition of water and manure (Akanbi *et al.,* 2004).

Tithonia diversifolia (Hemsl.) A. Gray, which is also known as Wild flower or Mexican sunflower or simply as Tithonia, is a shrub belonging to the family Asteraceae. Tithonia is a common weed, which is relatively high in nutrient concentrations, particularly nitrogen, but little is known about its potentials as a dependable nutrient source for improved soil fertility and crop yields. It is one of the numerous indigenous wild plant species which are commonly found growing naturally on or near small holder farmlands. It is an annual and highly aggressive weed which grows usually to a height of about 2.5m and adaptable to most soils (Olabode *et al.,* 2007). It is believed to have originated from Mexico and now widely distributed all over the humid and sub-humid tropics of the central and South America, Asia and Africa (Sonke, 1997). Tithonia was probably introduced into Africa as an ornamental plant. It is now widely spread in Nigeria on abandoned waste-lands, beside highways, waterways and cultivated farmlands (Olabode *et al*., 2007). The reported uses of tithonia include; fodder (Anette, 1996; Roothaert and Paterson, 1997), poultry feed (Odunsi *et al*., 1996), fuel-wood (Ng'inja *et al.,* 1998), building materials and shelter for poultry (Otuma, *et al*., 1998). In addition, plant extracts protect crops from termites (Adoyo *et al.,* 1997) and contain plant growth inhibitory chemicals (Baruah *et al.,* 1994; Tongma *et al.,* 1997), and control insects (Babajide *et al.,* 2008). Extracts cure hepatitis (Lin *et al.*, 1993; Kuo and Chen, 1997) and control amoebic dysentery (Tona *et al.,* 1998).

Amaranth cruentus, like other leaf vegetables can be harvested either by uprooting (NIHORT, 1986) or repeated cutting back of the shoots until when inflorescences appear (i.e. seed production) on the main trunks. Repeated cutting in corchorus production (when done at the right height and interval), was reported to produce higher shoot yield per unit of land This harvesting technique induced relatively high returns and was found to be more economical, when compared with insitu-uprooting technique which is usually done at once (NIHORT, 1986). Spreading of harvests over a period of time may also help in awaiting more favourable future market price and hence higher returns.

However, where the soil nutrients are low (all other things being equal), the yield as well as the nutritional value of the harvest will be poor. Hence, consideration of adequate soil nutrition alongside with cutting frequency may be beneficial to the efficiency of production and the quality of the harvestable herbage. There is scanty information on the effect of integrating organic fertilizer with a suitable agronomic practice such as cutting or harvesting frequency on growth and foliage yield of *Amaranth cruentus*. Hence, this study was carried out to assess the response of *Amaranthus cruentus* to composted phyto-residues and harvesting or cutting frequency.

2. Materials and methods

Field experiment was conducted at the Teaching and Research Farms, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria, which falls within the guinea savannah agro-ecological zone of

Nigeria. Ogbomoso lies between Longitude 4^0 10'E and Latitude 8^0 10'N. This location is found to be cold and dry from November to March and then warm and moist from April to October. It is characterized by bimodal rainfall distribution whereby the early rainy season starts in late March and ends in late July/early August, followed by a short dry spell in August and finally the late rainy season from August to November. The annual mean rainfall is between 1150 mm and 1250 mm. The soil was a low fertile Oxic paleutult, Egbeda series (Bridges, 1997; Smyth and Montgomery, 1962). The experimental site had been under cultivation of arable crops for several years, before the experiment was set up. After land clearing, pre–cropping soil sample collection was done for laboratory analyses of the soil physical and chemical properties. The results of the laboratory analyses showed that the soil was mildly-acidic (pH; 6.08) and texturally sandy-loam (sand; 80.20, silt; 14.40 and clay; 5.40). Also, the soil was grossly low in essential nutrients (total N; 0.06 %, available P; 4.60mg kg^{-1} and 2.30, 0.41, 6.43, and 0.10mg kg^{-1} for exchangeable Ca, Mg, Na, and K, respectively).

The compost used was prepared from *Tithonia diversifolia (Hemsl.) A. Gray* plant materials and well-cured poultry manure. The Tithonia-biomass was harvested (by cutting each plant from 5cm above the soil level), at exactly 8 weeks after emergence (i.e. before flowering), from an adjacent fallowing experimental plot, specially reserved for this research. The tithonia-plant materials were cut into pieces (3-5cm long), carefully spread and air-dried for seven (7) days. The manure was equally air-dried, followed by removal of foreign non-biodegradable materials like stones, iron e. t. c. The organic materials were then carefully mixed together at weight ratio of 3:1 (i.e. tithonia-biomass : poultry manure), and were composted in a concreted pit for eight (8) weeks. The materials were properly watered and carefully turned once weekly for the first two (2) consecutive weeks, followed by fortnight turnings until proper maturation occurred at the 8^{th} week of composting. After maturation of the compost, the matured compost was evacuated from the pit and air-dried for seven days before the required plots were amended with the composted Tithonia-biomass at three weeks before sowing, using hand- fork for proper mixing.

Four different rates of compost application (0.0, 1.5, 3.0 and 6.0 tons ha^{-1}) were introduced in combination with four harvesting or cutting frequencies (Zero or No-harvesting, Mono-weekly (harvesting / cutting once every week), Mono-fortnightly (harvesting / cutting once every fortnight) and Mono-monthly (cutting / harvesting once in a month). All the cuttings were carried out at 20 cm plant height (as established in the earlier unpublished research data). These treatment combinations were replicated three (3) times and the trial was laid out in a Randomized Complete Block Design (RCBD). Grain Amaranth seeds (variety NH84/493-1) were used for propagation. Each plot size was 1.2m × 1.0m at spacing of 0.5m × 0.5m. Weeding was manually done using hoe as at 2, 4 and 6 weeks after sowing (WAS). Prior to the 1^{st} cutting or harvesting, after the fourth week after sowing (4 WAS), some growth parameters were first measured, these were: plant height (by using measuring tape), stem circumference (by using calipers which first gave the value of the diameter, which was later converted to circumference using a fomular of πD (i.e. 3.142 multiplied by the obtained diameter (D) value), number of branches (determined by direct counting of all well-developed branches per plant and leaf area by graph method as described by Akanni and Ojeniyi, (2007). At every harvest, all the harvested *Amaranth cruentus* herbages were carefully packed into their corresponding well-labelled giant-brown envelopes (65cm by 30cm), for oven-drying at 80^0C for 72 hours. The harvested shoot dry weights were determined using electronic weighing balance Citizen MP600H and recorded cumulatively. After the final harvest, the cumulative dry weights of the above-ground biomass were then determined per treatment combination (followed by the dry weights of below-ground biomass). The oven dried plant samples were analyzed in the laboratory to determine the N, P and K in plants (as described by Akanbi *et al*., 2005). Nutrient uptake was also determined using a formula proposed by Ombo, (1994); Nutrient uptake = Dry matter yield multiply by the nutrient content of plant (%). All data collected were analyzed following the procedures of analysis of variance (ANOVA). Where differences were observed, Duncan's Multiple Range Test (DMRT), at 95% level of probability, was used to compare differences between the treatment means using Statistical Analysis System (SAS, 2010).

3. Results and Discussion

3.1 Properties of Soil and Manure Used

The results of the laboratory analyses of the soil sample showed that the soil was mildly-acidic (pH; 6.08) and texturally sandy-loam (sand; 80.20, silt; 14.40 and clay; 5.40). Also, the soil was grossly low in essential nutrients such as Total N; 0.06 %, available P; 4.60 ppm and 2.30, 0.41, 6.43, and 0.10 $cmolkg^{-1}$ for exchangeable Ca, Mg, Na, and K, respectively (Table 1). The chemical analyses of the organic fertilizer used indicated that the compost was mildly acidic with a pH value of 6.2. The nitrogen level was relatively high (4.00 %) compared to P (0.51 %) and K (2.19 %). Other nutrient concentrations determined were Ca, Mg, Fe, Zn, Cu and organic C (9.26 gkg^{-1}, 4.60 gkg^{-1}, 12.80 gkg^{-1}, 146.50 $mgkg^{-1}$, 31.00 $mgkg^{-1}$ and 3 8.40 gkg^{-1} respectively).

3.2. Growth and Yield Parameters of Amaranth

Before harvesting or cutting (i.e. at 4 WAS), application of 3.0 tons ha^{-1} of the composted Tithonia-biomass produced the best of all the growth parameters measured compared to the other levels of compost application. The control had the least values across the growth parameters of amaranth determined at 4WAS (Table 2). Plant height, stem circumference, number of leaves and leaf area were increasing with increasing rate of compost application. This supports the inferences from earlier researches that amaranth responds to improved soil nutrition (Elbehri, *et al,* 1993; Robert, 1998; Olaniyi, 2006). At four weeks after sowing (4WAS), there were no significant differences in the number of branches produced across all the treatments introduced (Table 2). This may be due to the fact that the plant was still young and yet to be at the active stage of branch formation. The best above-ground foliage production was obtained from amaranth which received 3.0 tons ha^{-1} of the composted Tithonia-biomass and harvested mono-fortnightly. Similar trend of production was observed for the below-ground biomass. Compost improves the yield and performance of a crop and it is most appropriate in vegetable production as reported by many researchers. For example, Smith *et al*; (1992) reported significantly higher yield of field-grown cabbage and onion when the soil was fertilized with 25% compost. Similarly, Manios and Kapetanios (1992) reported a yield increase of more than 50% during the peak harvest of tomatoes when grown on soil fertilized with municipal solid waste compost. In another study Akanbi *et al.,* (2001) reported high yielding effect of compost application on celosia. Generally, application of 3.0 tons ha^{-1} of Tithonia-compost combined with mono-fortnight harvesting produced the best of the growth and yield parameters. Plant height, stem circumference, leaf area, above-ground and below-ground biomass production increased by 280.7 %, 143.9 %, 271.5 %, 369.5 % and 437.8 % respectively.

3.3. Nutrient Uptake of Amaranth

Uptake of N, P and K increased with increasing rate of compost application, particularly up to application of 3.0 tons ha^{-1} of the composted Tithonia-biomass after which reduction in nutrient uptakes was observed (Table 3). This is in line with the reports of Robert (1998) and Akanbi *et al* (2001) who reported possibility of reduction in available nutrients whenever large quantity of manure is applied to the soil, as a result of high tendency to increase the carbon content of the soil. This increases the C : N ratio which causes immobilization of N and slows down the rate of decomposition and mineralization.

4. Conclusion

A rapid shoot re-growth and improved production of good quality herbage from grain amaranth could be enhanced via improved soil nutrition and reasonable frequency or interval of cuttings / harvestings. Also, Tithonia is a potential fertilizer material (which is relatively high in nutrient concentrations), and could be adequately utilized for improved soil fertility, crop yields and nutritional composition. *Amaranth cruentus*, like other leaf vegetables responds well to improved soil nutrition and its good quality herbage could be harvested either by uprooting or repeated cutting back of the shoots until when inflorescences appear (i.e. before seed production) on the main trunks (Akanbi *et al*., 2001; NIHORT, 1986). Repeated cutting (when done at the right height and interval), was observed to produce higher shoot yield when compared to a situation in which the plants were uprooted insitu only.

Consideration of adequate soil nutrition alongside with suitable agronomic practices is required in efficient crop production and livestock management. Thus, careful integration of organic manure (like Tithonia-compost) and suitable cultural practices such as cutting or harvesting frequency, may be beneficial to improved foliage production, rapid shoot re-growth and nutrient uptakes of *Amaranth cruentus,* under low fertile tropical soil conditions. Therefore, a low input technology established in this research could ensure maximum utilization of soil resources and unlocking of the hidden forage-producing potentials of some Amaranthus species in the tropics, where agricultural soils are mostly marginal.

Table 1: Pre-cropping Chemical and Physical Properties of the Soil Sample Used For the Experiment

Properties	Values
pH (H_20)	6.08
Organic C (%)	4.62
Total N (%)	0.06
Available P (ppm)	4.60
Fe (mg kg^{-1})	9.50
Cu (mg kg^{-1})	2.76
Zn (mg kg^{-1})	2.85
Exchangeable K (cmolKg^{-1})	0.10
Exchangeable Na (cmolKg^{-1})	4.43
Exchangeable Ca (cmolkg^{-1})	2.30
Exchangeable Mg (cmolkg^{-1})	0.41
Sand (%)	80.20
Silt (%)	14.40
Clay (%)	5.40
Textural class	Sandy loam

Table 2: Effect of Composted Organic Phyto-residues and Harvesting Frequency on Growth Attributes of *Amaranthus cruentus*

Treatments	Plant height (cm)	Stem Circumference (cm)	No. of leaves	No. of branches	Leaf area per plant (cm^2)
C_oHo	20.20d	0.82d	15.00c	4.00 NS	110.00d
C_oH_1	20.80d	0.78d	13.80c	4.00 NS	100.60d
C_oH_2	21.20d	0.90d	14.00c	4.00 NS	96.20d
C_oH_3	23.40d	0.88d	13.60c	3.00 NS	112.10d
C_1H_o	28.80c	1.30c	21.20b	4.00 NS	237.80c
C_1H_1	34.20c	1.40bc	24.22b	4.00 NS	241.80c
C_1H_2	33.80c	1.32c	24.20b	5.00 NS	228.20c
C_1H_3	30.30c	1.38c	25.10b	6.00 NS	252.40c
$C_2\,H_o$	48.80b	1.62b	34.60a	4.00 NS	411.00ab
C_2H_1	52.30b	1.60b	34.20a	5.00 NS	408.20ab
C_2H_2	58.60b	1.80b	35.40a	5.00 NS	404.60ab
C_2H_3	73.10a	2.80a	36.20a	4.00 NS	408.60ab
C_3H_o	74.20a	2.60a	36.20a	6.00 NS	422.60a
C_3H_1	72.40a	2.76a	34.81a	6.00 NS	440.40a
C_3H_2	74.10a	2.80a	35.22a	6.00 NS	418.20a
C_3H_3	71.50a	2.72a	36.20a	5.00 NS	402.20ab

NS: Not Significant. Means followed by same letters are not significantly different at p= 0.05, using DMRT. C_o= zero compost application, C_1= 1.5 tons ha^{-1} compost application, C_2= 3 tons ha^{-1} compost application, C_3= 6 tons $ha^{-}1$ compost application, H1= mono-monthly harvesting, H_2 = mono-weekly harvesting, H_3= mono-fortnightly harvesting

Table 3: Effect of Composted Organic Phyto-residues and Harvesting Frequency on Nutrient Uptakes and Biomass Yields of *Amaranthus cruentus*.

Treatments	N (g $plant^{-1}$)	P (g $plant^{-1}$)	K (g $plant^{-1}$)	Above ground biomass production (Dry Wt. t ha^{-1})	Below ground biomass production (Dry Wt. t ha^{-1})
C_oHo	3.6c	1.9c	2.0c	8.20d	2.30d
C_oH_1	4.1c	2.0bc	2.1c	7.10d	2.15d
C_oH_2	3.2c	2.1bc	2.2c	5.14d	2.20d
C_oH_3	3.4c	2.1b	2.0c	9.16d	2.00d
C_1H_o	5.8bc	2.4b	2.4bc	18.30c	4.60c
C_1H_1	5.8bc	2.6b	2.5bc	20.40c	4.82c
C_1H_2	6.1bc	2.5b	2.6bc	22.20c	4.10c
C_1H_3	6.0bc	2.8b	2.6bc	23.00c	4.90c
$C_2\,H_o$	8.8ab	3.2ab	3.0ab	25.20b	8.25b
C_2H_1	9.2a	3.6a	3.2ab	24.40b	7.89b
C_2H_2	9.8a	3.8a	3.4a	25.20b	8.10b
C_2H_3	11.2a	4.8a	4.6a	38.50a	12.37a
C_3H_o	10.8a	4.6a	4.0a	37.2a	11.31a
C_3H_1	11.2a	2.4a	3.8a	30.2ab	12.20a
C_3H_2	11.0a	3.8a	3.6a	28.4b	12.00a
C_3H_3	10.5a	3.6a	3.8a	37.4a	12.42a

Means followed by same letters are not significantly different at p= 0.05, using DMRT. C_o= zero compost application, C_1= 1.5 tons ha^{-1} compost application, C_2= 3 tons ha^{-1} compost application, C_3= 6 tons $ha^{-}1$ compost application, H1= mono-monthly harvesting, H_2 = mono-weekly harvesting, H_3= mono-fortnightly harvesting.

References

Adoyo, F., Mukalama , J. B., and Enyola, M. (1997). Using Tithonia Concoctions for Termite Control in Busia District, Kenya. ILEIA Newsletter 13:24-25.

Akanbi W. B., Olabode O. S., Olaniyi J. O., Ojo A. O. (2004) Introduction to tropical crops. Rafilink computers, Eleyele, Ibadan, Nigeria. Pp. 17-52.

Akanbi W. B.; Akande M. O. and Adediran J. A. (2005).Suitability of Composted Maize Straw and Mineral Nitrogen Fertilizer for Tomato Production. Journal of Vegetable Science,Vol.11 (1),p.57-65.

Akanbi, W.B. and A.O. Togun (2002). Productivity and Influence of Maize stover compost on growth, yield and

nutrient uptake of amaranth. Scientia Horticulture (93):1-8.
Akanbi, W.B: Adediran, J.A: and A.O. Togun (2001). Effect of organic based fertilizer and age at transplanting on shoot yield and protein contents of *Solanum macrocapron* (L). Bioscience Research Communications 13(1): 1-6.
Akanni, D.I and Ojeniyi, S.O (2007). Effect of different levels of poultry manure on soil physical properties, Nutrients status, growth and yield of tomato(Lycopersicon esculentum) (medwell journals research) Journal of Agronomy.1 P. 1-4.
Anette, M. (1996). Evaluation of Indigenous Fodder Trees and Shrubs in Different Agro-ecological Zones of Western Kenya . Diplomarbeit . Institut fur Pflanzenbau and Pflanzenzuchtung. Universitat fur Bodenkultur, Vienna, Austria.
Babajide, P.A., Olabode, O.S., Akanbi, W.B., Olatunji, O.O and Ewetola, E.A. (2008). Influence of composted Tithonia-biomass and N-mineral fertilizer on soil physico-chemical properties and performance of tomato (*Lycopersicon lycopersicum*). Research Journal of Agronomy 2 (4): 101-106.
Baruah, N.C., Sarma, J.C., Barua, N.C. , Sarma, S., and Sharma R.P. (1994). Germination and Growth Inhibitory Sesquiterpene Lactones and a Flavone from *Tithonia diversifolia* . Phyto-chemistry 36:29-36.
Breene,W.M., (1991). Food uses of grain amaranth. Cereal Food World, 36:426-430.
Bridges, E. M. (1997). World Soils (3rd Edition). International Soil Reference and Information centre, Wageningen printed in the United Kingdome of the University Press, Cambridge. ISBN. 0521497779, pp. 10-160.
Chen, Y. Ahmed, O., Inbar, U., (1993). Chemical and Spectroscopial analysis of organic matter transformation during composting in relation to compost maturity. In HAJ Hotitink and HM Keener (Eds.) Science and Engineering of composing, Pp 550-600.
Denton, L. (1992). Tomato cultivation and its potential in Nigeria. Acta Horticulture 123: 257 – 265.
Elbehri, A.D.H.,Putnam and Schmitt (1993). Nitrogen fertilizer and cultivar effects on yield and N-use efficiency of grain amaranth. Agronomy Journal 85:120-128.
Hartz,T K., F.J Costa, and W.L Schrader (1996). Suitability of composted green waste for horticultural uses. Hortscience. 31:961-964
IITA, (1982). Selected Methods for Soil and Plant Analysis. International Institute of Tropical Agriculture, Ibadan Nigeria. IITA Manual Series, No. 7.
Kuo YH nad Chen CH (1997) Diversifolol, a novel rearranged eduesmane sesquiterpene from the leaves of *Tithonia diversifolia.* Chemical and Pharmaceutical Bulletin 45:1223-1224.
Lin CC, Lin ML and Lin JM (1993) .The anti-inflammatory and liver protective effect of *Tithonia diversifolia* (Hemsl). Gray and *Dicliptera Chinensis* Juss. Extracts in rats. *Physiotherapy* Research 7:305-309.
Manios, V.I. and Kapetanios, E. (1992). Effects of town refuse compost as soil amendment on green tomato crop. Acta Hort. 302: 193-201.
National Horticultural Research Institute (NIHORT) (1986). Advances in Fruit and Vegetable Research at NIHORT, Ibadan, Nigeria pp. 18-40.
Ng'inja JO, Niang A. Palm C and 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.
Odunsi A.A, Farinu G.O and Akinola J.O .(1996) .Influence of dietary wild sunflower (*Tithonia diversifolia* Hemsl. A. Gray) leaf meal on layers performance and egg quality. Nigerian Journal of Animal Production 23:28-32.
Ojo, D.O. and Olufolaji, A.O.(1997). Effect of NPK fertilizer on the performance of *Solanum macrocarpon.* Crop Research 24: 23-29.
Olabode, O.S. Ogunyemi Sola, W.B. Akanbi, G.O. Adesina and Babajide, P.A. (2007). Evaluation of *Tithonia diversifolia* (Hemsl). A Gray for soil improvement. World Journal of Agricultural Sciences 3 (4), 503-507.
Olaniyi, J.O. (2006). Influence of Nitrogen and Phosphorus fertilizers on seed yield and quality of Egusi melon (Citrullus lanatus (Thumb) Mansf) in Ogbomoso, southwestern Nigeria. Ph.D. Thesis, University of Ibadan, Ibadan, Nigeria, pp.7-10.
Olaniyi, J.O. (2007). Evaluation of yield and quality performance of grain amaranth varieties in the southwestern Nigeria. Research Journal of Agronomy 1 (2): 42-45.
Ombo, F. 1994. Self-sufficiency in local fertilizer production for Nigeria. Proceeding 3rd African soil science conference. December 18-24, 1994, Ibadan, Nigeria.
Otuma P, Burudi C, Khabeleli A, Wasia E, Shikanga M, Mulogoli C and Carter SE (1998) participatory research on soil fertility management in Kabras, Western Kenya: Report of activities, 1996-1997. Tropical Soil Biology and Fertility Programme (TSBF), Nairobi, Kenya.
Robert L. Myers (1998). Nitrogen Fertilizer Effect on Grain Amaranth. Agronomy Journal, Vol. 90:597-602.
Roothaert R and Paterson R.T (1997). Recent work on the production and utilization of tree fodder in East

Africa. Animal Feed Science and Technology 69:39-51.
SAS (2010). Statistical Analytical System users Guide. SAS Institute INC., Cary, North Carolina, USA.
Schippers, R. R., (2000). African indigenous vegetables. An overview of the cultivated species. Chartham, U. K. Natural Recourses Institute/ACP-EU Technical Centres for Agricultural and Rural Cooperation, pp: 9-15.
Smith, S.R., J.E Hall and P.Hadley. (1992). Composting sewage sludge waste in relation to their suitability for the use as fertilizer materials for vegetable crop production. Acta Hortcult. 302:215-219.
Smyth, A.J. and Montgomery, R.F. (1962). Soils and Land use in Central Western Nigeria. Government Printer, Ibadan, Western, Nigeria 85 pp.
Sonke D. (1997) Tithonia weed ;– a potential green manure crop. Echo Development Notes 57: 5-6. South Pacific Foods (1995). Green leaves. In: South pacific foods leaflets. South pacific commission, Community Health Services 6 leaflet.
Tona L, Kambu K, Ngimbi N, Cimanga K and Vlietinck AJ (1998) Antiamoebic and phytochemical screening of some Congolese medicinal plants. Journal of Ethnopharmacology 61:57-65.
Tongma S. Kobayashi K and Usui K (1997). Effect of water extract from Mexican sunflower (*Tithonia diversifolia* (Hemsl). A.Gray) on germination and growth of tested plants. Journal of Weed science and Technology 42:373-378.