Research Journal of Soil Biology

ISSN 1819-3498

Academic Journals Inc.

www.academicjournals.com

Research Journal of Soil Biology 1 (1): 20-30, 2009
ISSN 1819-3498

Soil Fertility Restoration Potentials of Tithonia Green Manure and Water Hyacinth Compost on a Nutrient Depleted Soil in South Western Nigeria Using *Zea mays* L. as Test Crop

K.S. Chukwuka and O.E. Omotayo
Department of Botany and Microbiology, University of Ibadan, Ibadan, Nigeria

Abstract: The study was conducted to investigate the influence of *Tithonia diversifolia* (Hemsley) A. Gray green manure and water hyacinth *Eichhornia crassipes* (Mart) Solms compost on a nutrient depleted soil-an Alfisol in South-Western Nigeria. The study was carried out at the Botany and Microbiology Department, University of Ibadan, Ibadan, Nigeria. The two different soil amendments in fresh green manure and compost forms respectively (apart from control) were used as treatments in the study. These were applied in sole applications as well as in varying combinations of the different treatments. The organic amendment treatments were compared to unfertilized control in a modified screen house experiment replicated 3 times in a Completely Randomized Design (CRD). The results showed that for all treatments used, *Tithonia* + Water hyacinth (T+WH) at various combination ratios of 0.5:0.5, 0.25:0.75 and 0.75:0.25 kg were most significant ($p<0.05$) for increase in status of macronutrient elements Ca, K, Na and P compared to control treatment in topsoil samples. In subsoil samples however, sole application of *Tithonia* green manure and water hyacinth compost at 1 kg each respectively showed greater significant values ($p<0.05$) for micronutrient elements Cu, Fe and Zn in amended soil samples compared to control. Of all soil parameters assayed in the study, both ECEC and pH status of amended soils were not significantly changed by treatments with regard to control. Nutrient elements uptake was also significant for maize biomass samples of T+WH treatments in amended top and subsoil samples with regard to control. These observations indicate the high fertilizing potentials of the two organic soil amendments studied; with sound potential for building soil organic matter to adequate levels that will meet nutritional needs of crops as well as improve the nutrient element status of nutrient depleted soils into which such organic resources are incorporated.

Key words: Organic soil amendments, *Tithonia diversifolia*, *Eichhornia crassipes*, nutrient elements, green manure, compost

INTRODUCTION

Organic resources acting as soil amendments are becoming increasingly utilized as soil fertility improvers over recent years in tropical agriculture. In the sub Saharan tropical Africa, soil productivity maintenance remains a knotty issue due to poor cultural practices and fragile nature of most arable soils (Lloyd and Anthony, 1999; Oyetunji *et al*., 2001). Bationo *et al*. (2006) described soil fertility depletion as the single most important constraint to food security in West Africa. Though use of organic resources such as animal manure, crop residues and farmyard compost have been in use since earliest times for improving soil fertility (Sridhar and Adeoye, 2003), and more recently use of inorganic fertilizers, varying constraints still make the use of these traditional non conventional and conventional methods of soil fertility improvement inadequate to meet the challenges of soil fertility depletion in the region. Such constraints include high procurement cost for mineral fertilizer sources

Corresponding Author: K.S. Chukwuka, Department of Botany and Microbiology, University of Ibadan, Ibadan, Nigeria

in sufficient quantities to meet farmers' needs especially in resource poor countries and relatively low nutritive contents of traditional crop residues/animal manure used for soil improvement.

The use of non traditional organic resources such as weeds for soil fertility improvement purposes has been studied by Sonke (1997), Gachengo (1996), Jama *et al*. (2000), Nziguheba *et al*. (2002) and Chukwuka and Omotayo (2008) and these studies have established the high potential of these resources in improving nutrient status and subsequent crop yield in soils amended by these resources.

The objectives of this present investigation are to:

- Assess the overall potential/impact of these two non traditional organic resources, *Tithonia diversifolia* (tree marigold) and *Eichhornia crassipes* (water hyacinth) on nutrient status of depleted experimental soil samples.
- Evaluate nutrient uptake patterns of *Zea mays* L. in a nutrient depleted soil amended with these organic residues.

MATERIALS AND METHODS

Collection of Soil Samples

The study was conducted in the year 2007 commencing February up to October of the same year. Two different soil profiles of an Alfisol [Arenic Kandiudalf] (Soil Survey Staff, 2003) of top and sub soil samples were collected from the Teaching and Research Farm, University of Ibadan, Ibadan-Nigeria. Top soil samples were collected from a depth of 0-30 cm, while subsoil samples were taken from depths of 45-60 cm, respectively.

Experimental Design and Treatments

The experimental design was a Complete Randomized Design (CRD) with three replications for all treatments applied in both top and subsoil samples. Equal weights (8 kg) of soil samples were measured in designated labeled pots (10 L plastic buckets) which had been perforated at their bases. Pots were labeled A-F. Fresh green leaves and tender stems of freshly collected *Tithonia* biomass and also Chinese heap method prepared water hyacinth compost (Basak, 1948) were applied to "designated" soils in labeled buckets in sole and varying combinations applied as follows:

A = *Tithonia* green manure alone (1 kg)
B = Water hyacinth compost alone (1 kg)
C = *Tithonia* green manure + Water hyacinth compost (0.5: 0.5 kg)
D = *Tithonia* green manure + Water hyacinth compost (0.25: 0.75 kg)
E = *Tithonia* green manure + Water hyacinth compost (0.75:0.25 kg)
F = Control (no fertilizer application)

The organic soil amendments were incorporated into soils in labeled pots for all designated treatments and allowed to mineralize in soil for a period of 7 weeks. Early Yellow maize seeds (var. TZE COMP. 5-Y) obtained from the International Institute of Tropical Agriculture (IITA), Ibadan-Nigeria were used in the study. Three seeds were sown per pot representing experimental units. Seeds germinated 3-4 days after planting and were thinned to one plant per pot seven days after emergence (7 DAE). Normal atmospheric precipitation served as water source to the growing seedlings since the experiment was performed during the rainy season.

Weather Conditions, Measurement of Plant Parameters and Harvest

The maize seeds were grown from July to October 2007 under atmospheric conditions with maximum and minimum temperature values of 32 and 23°C respectively with relative humidity value of 73% within the study period. Annual rainfall range was between 1,300 and 1,500 mm (NIMET, 2007). Throughout the growing season of about 12 weeks, growth responses and nutrient accumulation of early yellow maize variety was assessed by measuring plant growth parameters. These parameters include leaf length, leaf width, stem girth and plant height were recorded from seven days after emergence (7 DAE) and was measured and noted on weekly basis.

The maize cobs and residues (stover) were harvested after the growing period of 12 weeks (12 WAP) and weighed individually to determine their fresh weight for each plant sample. Cobs were then oven dried at 50°C for a period of seventy-two hours and their dried weights were also recorded. Total biomass weights of individual maize plants stover, that is, above and below ground parts (shoot and root portions respectively) were initially measured to obtain fresh weight values of their respective shoot and root biomasses, after which the plant samples were also oven dried at 50°C for a period of 72 h and their dried weights were also recorded.

Plant samples were milled, ground and passed through a 0.5 mm sieve and then analyzed chemically. This was done to determine nutrient recovery from amended soils and also nutrient accumulation within plants tissue biomasses during the growing season up to harvest time.

Statistical Data Analyses

All data generated during the course of the experiment were analyzed using the One Way Analysis of Variance (ANOVA) via the Graph InStat statistical analytical package software. Significant means were detected using the Dunnett's Multiple Comparisons Test at 0.05 level of significance ($p<0.05$) and 0.01 level of significance ($p<0.01$).

RESULTS

Initial soil analyses for nutrients before addition of amendments are shown in Table 1 for top and subsoil samples respectively. pH values for top soil sample indicate a slightly alkaline medium, while that for sub soil indicates a more acidic medium. The high C/N ratios in both soil levels represent low contents of N in the respective soil samples. Textural classification of the soil indicates a sandy loam class for both levels of the soil being investigated.

The use of organic amendments significantly affected soil chemical properties at both soil levels investigated. Statistical analysis of the data obtained showed significant differences between nutrient contents of amended soil and control soil (which had zero application of amendments). In the topsoil samples, for the macronutrient elements Ca, Mg, K, Na and P; 1 kg of *Tithonia* (T), 1 kg of water hyacinth (WH) and T+WH (0.75:0.25 kg) treatments were highly significant for Mg content compared to the control treatment (Table 2). The effective cation exchange capacity (ECEC) in topsoil samples was not significantly different in ECEC content value compared to control for all the treatments (Table 2).

In the subsoil, treatment of sole application T (1 kg) and WH (1 kg) were highly significant ($p<0.01$) for nutrient elements P and Na content in amended soil samples relative to control. Treatment T+WH at its treatment ratios of 0.5:0.5, 0.25:0.75 and 0.75:0.25 kg recorded significant values ($p<0.05$) for P, K and Ca nutrient elements, respectively. It was observed however that none of the treatments recorded significant increase in Mg content with regard to the control treatment (Table 3). ECEC values for subsoil samples showed only sole WH treatment (1 kg) as significant ($p<0.05$) for ECEC content in its amended soil compared to control treatment (Table 3).

Table 1: Nutrient element analyses of pre amended experimental soils

	Value	
Property	Top soil	Sub soil
pH (H_2O)	7.40	5.50
OC (%)	3.29	2.09
Total N (%)	0.153	0.145
Sand (%)	68.03	56.90
Silt (%)	12.01	10.04
Clay (%)	21.00	33.10
Available P (ppm)	55.62	23.83
Ca (C mol kg^{-1})	30.81	5.14
Mg (C mol kg^{-1})	3.02	1.51
K (C mol kg^{-1})	1.08	0.78
Na (C mol kg^{-1})	0.59	0.73
Exchangeable acidity	0.17	0.17
Zn (ppm)	2.66	1.61
Cu (ppm)	3.02	2.38
Mn (ppm)	230.78	79.18
Fe (ppm)	115.92	77.55
C/N ratio	21.50	14.41

With regard to the micronutrient elements Mn, Fe, Zn and Cu, sole treatment T (1 kg) was highly significant ($p<0.01$) for Fe, Cu and Zn content in the amended top soil samples compared to control (Table 2). Treatment T+WH (0.25:0.75 kg) and WH sole treatment (1 kg) had high significant effect on Mn and Fe as well as Fe and Cu nutrient elements content in amended topsoil samples compared to control soil.

In the subsoil samples, sole application of WH (1 kg) had highly significant effects on Mn, Cu and Zn contents of soil with regard to control. This was followed by treatment T+WH (0.25:0.75 kg) that had highly significant values for Mn and Fe contents in amended soil samples. Sole T treatment was significant ($p<0.05$) for Mn and Zn contents in amended soil respectively with regard to control (Table 3).

pH, %OC, %N and OM Content Analyses for Amended Soils

With regard to the pH values, percentage values for organic carbon (OC) and nitrogen (N) for top and subsoil samples respectively, it was observed that there was no significant difference in pH values for topsoil compared to control for all treatments applied (Table 2). A similar trend was observed in the amended subsoil samples, where there was no significant difference for pH values between treated soils and the control (Table 3). In the topsoil samples, all treatments were highly significant ($p<0.01$) for percentage N content in amended soils in regard to control (Table 2); with the exception of T+WH (0.5:0.5 kg). Conversely, only T in sole application (1 kg) was observed to have significant percentage N value with all other treatments recording values that were not significant compared to control in subsoil samples (Table 3). Also, percentage OC values treatments in the topsoil samples showed significant values for T+WH (0.25:0.75 kg) and (0.75:0.25 kg) while all other treatments were not significant with respect to control (Table 2). The percentage OC values for subsoil samples (Table 3) showed that sole applications of T and WH were highly significant ($p<0.01$) for soil OC values compared to control. Treatment T+WH (0.75:0.25 kg) was also significant ($p<0.05$) for % OC content in amended soils compared to control. All other treatments were not significant for OC content in their respective amended soils.

Organic matter (OM) values for top soil samples had treatments T+WH (0.75:0.25 kg) with highly significant values ($p<0.01$) compared to control. T+WH (0.25:0.75 kg) was also significant compared to control. All other treatments were not significant (Table 2). For sub soil samples, sole

Table 2: Nutrient element analysis for amended and non amended topsoil samples (post-harvest)

Treatments	Ca	Mg	K	Na	ECEC
	---------------------------- (C mol kg^{-1})			---------------------------------	
A-*Tithonia* (1 kg)	43.89±2.42	5.78±0.14	1.97±0.26	0.77±0.04	52.38±2.73
B-Water hyacinth (1 kg)	49.33±0.40	5.79±0.11	2.19±0.03	0.80±0.03	58.30±0.48
C-T+WH (0.5:0.5 kg)	49.47±1.21	5.96±0.14	1.74±0.04	1.74±0.04	58.15±1.14
D-T+WH (0.25:0.75 kg)	44.25±1.26	5.37±0.06	1.97±0.05	0.73±0.04	52.90±1.28
E-T+WH (0.75:0.25 kg)	41.44±0.79	6.19±0.04	2.00±0.66	0.80±0.03	50.71±0.77
F-Control	44.08±2.20	5.14±0.09	2.11±0.03	0.89±0.01	52.52±2.33
DMCT q-value	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05
F versus A	0.09ns	4.27**	1.08ns	2.72ns	0.07ns
F versus B	2.79ns	4.32**	0.62ns	2.04ns	2.93ns
F versus C	2.87ns	5.45**	2.86ns	2.34ns	2.86ns
F versus D	0.20ns	1.54ns	1.11ns	3.63*	0.19ns
F versus E	1.41ns	7.03**	0.82ns	1.97ns	0.92ns

Treatments	P	Mn	Fe	Zn	Cu
	---		(ppm)	---	
A-*Tithonia* (1 kg)	75.24±3.41	185.25±4.72	92.83±2.71	1.73±0.15	1.91±0.06
B-Water hyacinth (1 kg)	70.22±2.11	179.70±4.20	87.87±3.19	1.28±0.02	1.66±0.10
C-T+WH (0.5:0.5 kg)	77.21±2.11	194.04±4.52	95.36±1.82	1.09±0.11	1.04±0.05
D-T+WH (0.25:0.75 kg)	67.30±1.22	167.58±2.39	81.67±3.90	1.11±0.05	0.95±0.04
E-T+WH (0.75:0.25 kg)	69.65±1.21	181.82±1.87	70.23±1.20	0.99±0.03	1.11±0.03
F-Control	82.31±1.73	189.52±6.85	65.86±1.15	1.14±0.05	0.99±0.01
DMCT q-value	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05
F versus A	1.09ns	0.72ns	8.39**	6.85**	15.76**
F versus B	1.86ns	1.66ns	6.84**	1.67ns	11.52**
F versus C	0.78ns	0.77ns	9.14**	0.58ns	0.80ns
F versus D	2.31ns	3.72**	4.91**	0.35ns	0.80ns
F versus E	1.95ns	1.30ns	1.36ns	2.02ns	2.06ns

Treatments	Sand	Silt	Clay	pH	OC	N	OM
	-----------------	(%)	----------------------		-----------	(%) ---------	
A-*Tithonia* (1 kg)	72.70±2.33	20.00±2.08	8.33±0.33	8.6±0.09	3.70±0.17	0.66±0.03	6.37±0.30
B-Water hyacinth (1 kg)	74.33±4.41	16.70±3.28	9.00±1.16	8.4±0.29	3.21±0.18	0.63±0.03	5.54±0.31
C-T+WH (0.5:0.5 kg)	79.00±1.73	14.67±1.20	6.67±1.76	7.9±0.19	3.28±0.02	0.54±0.01	5.66±0.03
D-T+WH (0.25:0.75 kg)	78.30±4.70	15.00±3.05	7.00±1.73	8.3±0.12	2.71±0.16	0.69±0.01	4.67±0.28
E-T+WH (0.75:0.25 kg)	69.67±3.28	22.00±3.51	8.33±1.20	8.0±0.12	2.37±0.04	0.58±0.02	4.09±0.07
F-Control	76.67±3.84	15.00±2.08	8.67±1.76	8.4±0.12	3.27±0.24	0.46±0.01	5.64±0.42
DMCT q-value	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05
F versus A	0.87ns	1.67ns	0.16ns	0.48ns	2.41ns	7.08**	2.42ns
F versus B	0.51ns	0.56ns	0.16ns	0.00ns	0.32ns	5.98**	0.32ns
F versus C	0.51ns	0.11ns	0.97ns	1.79ns	0.06ns	2.69ns	0.07ns
F versus D	0.36ns	0.00ns	0.81ns	0.36ns	3.17*	8.43**	3.16*
F versus E	1.52ns	2.53ns	0.16ns	1.67ns	5.09**	4.15**	5.09**

*Significant at p<0.05, **Highly significant at p<0.01, ns: Not significant, DMCT: Dunnett's Multiple Comparison Test

applications of T and WH were highly significant for OM values; T+WH (0.25:0.75 kg) was also significant (p<0.05) compared to control (Table 3). All other treatments recorded were not significant compared to control with regard to organic matter content of soil samples.

Plant Nutrient Element Recovery from Topsoil Samples

The trend of macronutrient uptake in the top soil samples showed that maize biomass samples for all treatments recorded highly significant values for uptake of elements with regard to control. Biomass samples for T+WH (0.75:0.25 kg) were observed to have significant abundance (p<0.05) for macronutrient elements considered (that is, Ca, Mg, K, Na and P); closely followed by T+WH (0.5:0.5 kg) which was also significant for Ca, Mg, K and P uptake in its biomass samples with regard to control (Table 4).

Table 3: Nutrient element analysis of amended and non amended subsoil samples (post harvest)

Treatments	Ca	Mg	K	Na	ECEC
	(C mol kg^{-1})				
A-*Tithonia* (1 kg)	21.08±0.64	2.10±0.21	0.96±0.04	0.62±0.02	24.83±0.46
B-Water hyacinth (1 kg)	18.95±1.15	2.11±0.13	0.91±0.02	0.55±0.04	22.77±1.26
C-T+WH (0.5:0.5 kg)	21.21±0.74	2.11±0.08	0.71±0.01	0.51±0.01	24.62±0.66
D-T+WH (0.25:0.75 kg)	20.45±0.34	2.12±0.02	0.67±0.01	0.47±0.01	23.79±0.37
E-T+WH (0.75:0.25 kg)	23.69±1.95	2.06±0.22	0.83±0.04	0.54±0.06	27.25±1.73
F-Control	19.86±0.94	2.60±0.21	0.83±0.03	0.41±0.05	27.45±2.30
DMCT q-value	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05
F versus A	0.97ns	1.92ns	2.55ns	4.74**	1.87ns
F versus B	0.72ns	1.87ns	1.70ns	3.14*	3.34*
F versus C	1.08ns	1.86ns	2.35ns	2.22ns	2.02ns
F versus D	0.47ns	1.84ns	3.13*	1.38ns	2.61ns
F versus E	3.05*	2.06ns	0.00ns	2.98ns	0.15ns

Treatments	P	Mn	Fe	Zn	Cu
	(ppm)				
A-*Tithonia* (1 kg)	52.74±1.53	97.81±2.65	65.81±3.07	0.80±0.05	0.59±0.29
B-Water hyacinth (1 kg)	50.92±0.41	92.49±3.00	57.69±2.43	0.85±0.06	0.86±0.02
C-T+WH (0.5:0.5 kg)	51.13±0.69	74.78±2.80	50.58±0.42	0.71±0.02	0.76±0.04
D-T+WH (0.25:0.75 kg)	40.20±0.60	80.45±0.45	39.54±0.46	0.58±0.01	0.72±0.07
E-T+WH (0.75:0.25 kg)	45.65±3.34	68.32±1.51	50.22±4.52	0.71±0.03	0.62±0.02
F-Control	43.75±2.11	63.27±4.60	62.49±3.47	0.67±0.03	0.41±0.01
DMCT q-value	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05
F versus A	3.84**	9.87**	0.95ns	3.33*	1.44ns
F versus B	3.06*	8.35**	1.38ns	4.61**	3.72**
F versus C	3.15*	3.29*	3.42*	1.02ns	2.88ns
F versus D	1.51ns	4.91**	6.59**	2.30ns	2.58ns
F versus E	0.81ns	1.44ns	3.52*	0.94ns	1.72ns

Treatments	Sand	Silt	Clay	pH	OC	N	OM
	(%)				(%)		
A-*Tithonia* (1 kg)	80.00±1.45	5.33±0.58	5.33±0.88	4.93±0.15	1.57±0.12	0.33±0.02	2.70±0.21
B-Water hyacinth (1 kg)	85.70±0.88	8.33±0.33	6.00±0.58	5.00±0.41	1.33±0.16	0.28±0.01	2.30±0.28
C-T+WH (0.5:0.5 kg)	84.00±2.65	10.33±1.86	5.67±0.88	4.80±0.17	1.00±0.03	0.23±0.02	1.74±0.04
D-T+WH (0.25:0.75 kg)	84.33±2.73	10.67±1.76	5.33±1.33	4.80±0.12	1.12±0.02	0.29±0.01	1.95±0.04
E-T+WH (0.75:0.25 kg)	85.33±0.88	9.67±0.88	5.00±0.00	5.00±0.15	1.00±0.02	0.29±0.02	1.72±0.04
F-Control	84.33±2.03	10.33±0.88	5.33±0.67	4.70±0.21	0.85±0.03	0.25±0.02	1.47±0.06
DMCT q-value	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05
F versus A	0.94ns	1.21ns	0.00ns	0.93ns	7.90**	3.34*	7.86**
F versus B	0.53ns	1.04ns	0.69ns	1.06ns	5.32**	1.31ns	5.31**
F versus C	0.13ns	0.00ns	0.34ns	0.40ns	1.74ns	0.87ns	1.75ns
F versus D	0.00ns	0.17ns	0.00ns	0.53ns	3.06*	1.45ns	3.07*
F versus E	0.40ns	0.35ns	0.34ns	1.33ns	1.59ns	1.60ns	1.58ns

*Significant at p<0.05, **Highly significant at p<0.01, ns: Not significant, DMCT: Dunnett's Multiple Comparison Test

For the micronutrients Fe, Cu, Zn and Mn, all treatments showed a trend wherein plant biomass samples for T+WH (0.75:0.25 kg) were significant ($p<0.01$) for uptake of all micronutrient elements considered. Biomass samples for T sole treatment (1 kg) was also highly significant ($p<0.01$) for Mn, Fe and Cu uptake from amended soil samples. WH sole treatment (1 kg) and T+WH (0.25:0.75 kg) were significant ($p<0.05$) for Mn and Zn as well as Mn and Fe elements uptake respectively in their amended soil samples.

N uptake by maize biomass samples in topsoil samples showed that T+WH (0.25:0.75 kg) and (0.75:0.25 kg) as well as WH (1 kg) were highly significant ($p<0.01$) for N uptake within its biomass samples with regard to control (Table 4).

Table 4: Nutrient element uptake values for maize test crop in topsoil samples (post harvest)

Treatments	Ca	Mg	K	P	Na	Mn
	(%)				(ppm)	
A-*Tithonia* (1 kg)	1.88±0.09	0.64±0.01	0.89±0.08	0.27±0.01	23.77±2.33	9.87±0.14
B-Water hyacinth (1 kg)	1.62±0.04	0.50±0.01	0.89±0.05	0.31±0.01	19.66±0.78	8.24±0.74
C-T+WH (0.5:0.5 kg)	2.30±0.02	0.72±0.02	0.59±0.01	0.32±0.02	27.04±0.27	10.05±0.09
D-T+WH (0.25:0.75 kg)	1.36±0.04	0.59±0.01	0.60±0.02	0.36±0.03	27.81±1.59	12.53±0.17
E-T+WH (0.75:0.25 kg)	2.05±0.04	0.64±0.01	0.75±0.03	0.24±0.01	18.50±1.78	8.31±0.65
F-Control	1.02±0.04	0.48±0.01	0.90±0.01	0.42±0.02	30.35±3.38	6.79±0.14
DMCT q-value	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05
F versus A	18.69**	6.86**	0.37ns	6.86**	2.51ns	6.21**
F versus B	14.77**	0.80 ns	0.27 ns	5.62**	4.56**	3.26 *
F versus C	30.88**	11.51**	7.83**	5.11**	1.41ns	7.36**
F versus D	8.69**	5.44**	7.80**	3.06*	1.09ns	12.95**
F versus E	25.12**	7.67**	3.96**	9.03**	5.06**	4.94**

Treatments	Fe	Zn	Cu	N	Fat	MC
		(ppm)			(%)	
A-*Tithonia* (1 kg)	12.32±0.73	3.25±0.39	0.94±0.01	2.62±0.09	0.33±0.01	0.26±0.01
B-Water hyacinth (1 kg)	10.95±0.87	3.21±0.01	0.85±0.06	2.96±0.08	0.23±0.01	0.29±0.04
C-T+WH (0.5:0.5 kg)	16.47±0.39	2.45±0.04	0.81±0.02	2.25±0.05	0.30±0.02	0.30±0.02
D-T+WH (0.25:0.75 kg)	10.63±0.38	1.99±0.06	0.74±0.05	1.85±0.04	0.22±0.01	0.21±0.01
E-T+WH (0.75:0.25 kg)	10.63±0.61	3.06±0.05	0.91±0.02	1.66±0.04	0.31±0.01	0.18±0.01
F-Control	12.61±0.13	2.41±0.01	0.78±0.03	2.34±0.04	0.31±0.02	0.20±0.03
DMCT q-value	If q> 2.983, p<0.05	If q> 2.983, p<0.05	If q> 2.983, p<0.05	If q> 2.983, p<0.05	If q> 2.983, p<0.05	If q> 2.983, p<0.05
F versus A	0.45ns	7.02**	3.81**	2.72ns	0.73ns	1.28ns
F versus B	2.83ns	7.52**	2.07ns	6.68**	4.55**	2.40ns
F versus C	6.57**	0.41ns	0.90ns	0.96ns	0.55ns	2.59ns
F versus D	3.37*	3.95ns	0.90ns	5.18**	4.73**	0.09ns
F versus E	3.37*	6.11**	3.59*	7.22*	1.49ns	0.55ns

*Significant at p<0.05, **Highly significant at p<0.01, ns: Not significant, DMCT: Dunnett's Multiple Comparison Test

Table 5: Nutrient element uptake values for maize test crop in subsoil samples (post harvest)

Treatments	Ca	Mg	K	P	Na	Mn
	(%)				(ppm)	
A-*Tithonia* (1 kg)	0.54±0.02	0.41±0.01	0.32±0.00	0.24±0.02	18.32±0.37	2.59±0.12
B-Water hyacinth (1 kg)	0.44±0.03	0.31±0.02	0.31±0.01	0.25±0.01	20.11±0.24	1.99±0.02
C-T+WH (0.5:0.5 kg)	0.41±0.01	0.29±0.01	0.29±0.01	0.18±0.01	21.14±0.73	1.48±0.07
D-T+WH (0.25:0.75 kg)	0.49±0.01	0.30±0.01	0.32±0.01	0.21±0.01	20.88±0.79	2.06±0.04
E-T+WH (0.75:0.25 kg)	0.39±0.01	0.23±0.01	0.32±0.20	0.17±0.01	22.72±2.26	1.82±0.11
F-Control	0.50±0.01	0.30±0.03	0.24±0.01	0.20±0.02	25.03±0.64	1.89±0.03
DMCT q-value	If q> 2.983, p<0.05	If q> 2.983, p<0.05	If q> 2.983, p<0.05	If q> 2.983, p<0.05	If q> 2.983, p<0.05	If q> 2.983, p<0.05
F versus A	1.54ns	6.26**	4.96**	2.57ns	2.51ns	5.36**
F versus B	2.30ns	0.48ns	4.01**	2.71ns	4.56**	0.77ns
F versus C	3.91**	0.09ns	3.23*	0.99ns	1.41ns	3.12*
F versus D	0.56ns	0.26ns	5.23**	0.59ns	1.09ns	1.31ns
F versus E	4.33**	3.26*	4.83**	1.58ns	5.06**	0.47ns

Treatments	Fe	Zn	Cu	N	Fat	MC
		(ppm)			(%)	
A-*Tithonia* (1 kg)	4.69±0.20	0.47±0.02	0.18±0.01	0.67±0.02	0.11±0.01	0.12±0.01
B-Water hyacinth (1 kg)	3.95±0.19	0.40±0.02	0.14±0.00	0.60±0.02	0.10±0.00	0.15±0.02
C-T+WH (0.5:0.5 kg)	4.12±0.14	0.48±0.01	0.20±0.00	0.81±0.01	0.09±0.00	0.13±0.01
D-T+WH (0.25:0.75 kg)	5.15±0.15	0.38±0.02	0.17±0.01	0.70±0.01	0.12±0.01	0.17±0.01
E-T+WH (0.75:0.25 kg)	3.58±0.09	0.48±0.02	0.19±0.01	0.91±0.02	0.13±0.01	0.24±0.06
F-Control	3.93±0.20	0.25±0.06	0.15±0.01	0.71±0.02	0.09±0.01	0.16±0.01
DMCT q-value	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05	If q>2.983, p<0.05
F versus A	3.24*	8.62**	2.63ns	0.86ns	1.86ns	2.38ns
F versus B	0.06ns	5.11**	0.34ns	2.74ns	1.17ns	0.95ns
F versus C	0.80ns	8.75**	3.88**	2.86ns	0.71ns	1.65ns
F versus D	5.21**	4.89**	1.88ns	0.41ns	3.29*	0.73ns
F versus E	1.48ns	8.88**	3.13*	5.59**	3.57*	0.73ns

*Significant at p<0.05, **Highly significant at p<0.01, ns: Not significant, DMCT: Dunnett's Multiple Comparison Test

Plant Nutrient Element Recovery from Subsoil Samples

The trend of macronutrient uptake in the sub soil samples showed that maize biomass samples for all treatments recorded highly significant ($p<0.01$) values for uptake of elements with regard to control. T+WH (0.75:0.25 kg) was observed to show significant abundance of macronutrient elements Ca, Mg, K and Na; closely followed by sole T and WH (1 kg) which were also highly significant for Mg and K as well as K and Na elements respectively with regard to control (Table 5).

Micronutrient elements uptake showed a trend where plant biomass samples for sole T (1 kg) were highly significant ($p<0.01$) for uptake of micronutrient elements Mn, Fe and Zn in its amended soil samples. Biomass samples of T+WH (0.5:0.5 kg) and T+WH (0.75:0.25 kg) were significant for Zn and Cu as well as Fe and Zn elements uptake respectively in their amended soil samples.

N uptake by maize biomass samples in subsoil samples showed that T+WH (0.75:0.25 kg) was the only significant treatment ($p<0.01$) for N uptake within its biomass samples with regard to control (Table 5).

DISCUSSION

Soil samples amended by treatments of sole organic amendment application (1 kg) and combined ratios of both amendments (0.5:0.5, 0.25:0.75 and 0.75:0.25 kg) generally showed significant difference for all nutrient elements content in amended soil samples compared to control treatment. It was observed however that combined treatment T+WH at its various ratios and sole T and WH applications (1 kg) on the whole showed no statistical significance for macronutrient elements content in the amended topsoil samples except for Mg. This indicates that sole application of organic amendments or in combination does not always contribute high amounts of mineralized nutrients to amended soils when applied. This explains the trend of no significant difference for effective cation exchange capacity (ECEC) values in topsoil samples for all treatments. On the other hand, sole treatments of T and WH (1 kg) showed high significant difference for macronutrient element content in their amended subsoil samples. This observed trend in the subsoil samples may be due to significant organic matter addition to subsoil by organic amendments; which provided stable soil aggregate conditions and prevented eroding/leaching of valuable nutrients from subsoil samples. Thus application of organic amendments in eroded sites may have more pronounced impact on soil chemical and physical properties. Mbagwu and Piccolo (1989) reported that repeated application of organic residues to soil improves physico-chemical properties of such soils. Studies by Stark *et al*. (2006) showed that addition of green manures to soil improved soil biology by increasing soil microbial biomass and activity. Vinten *et al*. (2002) also reported increase in microbial activity following application of organic amendments to soil, thus suggesting a more responsive microbial community. The importance of beneficial microbes in building a healthy soil microenvironment through enhancement of natural soil processes cannot be overemphasized.

The micronutrient status of amended topsoil samples was significantly improved by sole application of T, closely followed by T+WH (0.25:0.75 kg) and WH sole treatment (1 kg) with regard to the control treatment. Gachengo *et al*. (1999) reported relatively high concentrations of other nutrients in *Tithonia* green biomass other than N, P and K. The application of *Tithonia* biomass has been reported by Niang *et al*. (1996) to have produced greater maize yield compared to biomass of other common shrubs and trees in Western Kenya. Gunnarssen and Petersen (2006) also highlighted that using composted water hyacinth material could serve as quality manure for improving soil fertility conditions and thus crop yields on the whole. These observed phenomena of significant increase of macro and micronutrient elements contents in amended soils with regard to control indicates the high fertilizing potentials of both *Tithonia* green biomass and composted water hyacinth.

The pH values for both sub and topsoil samples were not significantly affected by all treatments as regards control treatment probably due to high buffering action of the organic amendments applied as treatments in the soil samples. ECEC values in both amended top and subsoil samples were not significant for all treatments compared to control, which may indicate steady levels of exchangeable elements in investigated soil samples which remained constant despite addition of organic amendments to soil samples.

High occurrence of N and P increase quantity and activity of soil microorganisms in soils (Marin, 2004), whose beneficial activities in creating and sustaining a healthy soil environment cannot be overemphasized. All treatments, except T+WH 0.5:0.5 kg showed high significant difference in % N content with regard to control treatment in the topsoil samples. This trend appears to be reversed however in the subsoil samples. Here only *Tithonia* in sole application (1 kg) is observed to have significant effect on % N content in its amended soil sample compared to control. This observation indicates the high leaching prone feature of the experimental soil being amended. Lal (1993) reported that soil erosion and compaction as major management constraints for the Koalinitic Alfisols of the savanna forest transition zones and sub humid savanna of tropical Africa. This inadvertently implies that addition of significant amounts of organic matter to these tropical soils can help reduce the trend of soil nutrient depletion and leaching problems of soils found in the tropics. The organic matter (OM) status of amended topsoil samples showed *Tithonia* and water hyacinth [T+WH (0.75:0.25 kg) and (0.25:0.75 kg)] as significant for OM content in their amended soils compared to control. This observation buttresses the assertion that *Tithonia* can perform well as top quality organic manure with good fertilizing value (Olabode *et al*., 2007); while water hyacinth compost acting as soil conditioner improves soil properties by building soil organic matter (Cooperband, 2002; Gunnarsson and Petersen, 2006).

Sole applications of T and WH are the most significant treatments ($p<0.01$) for OM values for their amended subsoil samples compared to control. The combination T+WH (0.25:0.75 kg) was also significant for OM values in their subsoil samples. Studies by Spaccini *et al*. (2002) showed that application of organic residues to soils could increase soil organic matter (SOM), buffer soil, improve aggregate stability and enhance water retention capacity of soils. This trend indicates the potential ability and capacity of each of these organic resources to significantly build organic matter in eroded soils when applied to such soils.

High significant macronutrient and micronutrient elements uptake by maize plant biomass for T+WH in amended topsoil samples indicates combination of organic amendments may be more useful for nutrient addition to top and sub soils than sole applications of these amendments.

CONCLUSION

It is important to state that application of these organic materials to nutrient depleted or poorly buffered tropical soils goes beyond just increasing or replenishing nutrient element content of soils so amended. Application of these organic residues to nutrient depleted soils goes a long way in ensuring a sound nutrient management system within the soil ecosystem over a sustained period by improving physical, chemical and biological properties of such soils.

ACKNOWLEDGMENTS

The authors wish to acknowledge with thanks the kind assistance of the Senate of the University of Ibadan for providing the research grants and materials used in the study. We also appreciate Mr. Basil Ohaegbulem of the Analytical Laboratory, International Institute of Tropical Agriculture for his expert handling of the soil, compost and manure analyses.

REFERENCES

Basak, M.N., 1948. Water Hyacinth Compost. 1st Edn. Alipore, West Bengal Government Press, SR Calcutta, India .

Bationo, A., J. Kihara, B. Vanlauwe, B. Waswa and J. Kimetu, 2006. Soil organic carbon dynamics, functions and management in West African agroecosystems. Agric. Syst., 94: 13-25.

Chukwuka, K.S. and E.O. Omotayo, 2008. Effects of *Tithonia* green manure and water hyacinth compost application on nutrient depleted soil in South-Western Nigeria. Int. J. Soil Sci., 3: 69-74.

Cooperband, L., 2002. Building soil organic matter with organic. Center Integrated Agric. Syst. University Wisconsin- Madison. http://www.cias.wisc.edu/pdf.

Gachengo, C.N., 1996. Phosphorus release and availability on addition of organic materials to phosphorus fixing soils. M.Sc. Thesis. Moi University, Eldoret, Kenya.

Gachengo, C.N., C.A. Palm and C. Othieno, 1999. Tithonia and senna green manures and inorganic fertilizers as phosphorus sources for maize in Western Kenya. Agro. For. Syst., 44: 21-26.

Gunnarsson, C.C. and C.M. Petersen, 2006. Water hyacinth as a resource in agriculture and energy production: A literature review. Waste Manage., 27: 117-129.

Jama, B., C.A. Palm, R.J. Buresh, A. Niang, C. Gachengo, G. Nziguheba and B. Amadalo, 2000. *Tithonia diversifolia*, a green manure for soil fertility Improvement in Western Kenya: A review. Agro. For. Syst., 49: 201-221.

Lal, R., 1993. Technological Options Towards Sustainable Agriculture for Different Ecological Regions in the SSA. In: Technologies for Sustained Agriculture in the Tropics. Ragland, J. and R. Lal (Eds.). ASA special Publication, Madison, Wis. USA., pp: 295- 308.

Lloyd, R.H. and S.R. Anthony, 1999. Soil nutrient management for sustained food crop production in upland farming systems in the tropics. J. Soil Crop Sci., Department College Station Tennessee 77843, USA., http//www.agnet.org.

Marin, J.A., 2004. Bioremmediacion, mediate, tecnicos biologicas de hidroccarburos, contenidos en lodos de refineria. Ph.D Thesis, Murcia University Spain.

Mbagwu, J.S.C. and A. Piccolo, 1989. Changes in soil aggregate stability induced by amendment with humic substances. Afr. J. Biotech., 5: 1058-1061.

Niang, A., B. Amadalo, S. Gathumbi and C.O. Obonyo, 1996. Maize yield response to green manure application from selected shrubs and tree species in western Kenya: A preliminary assessment. East Afr. Agric. For. J., 62: 199-207.

NIMET, 2007. Meteorological Data for Ibadan Synoptic January to October. Retrieved from NIMET Sub-Station, Ibadan, Oyo State, Nigeria.

Nziguheba, G., R. Merckx, C.A. Palm and P. Mutuo, 2002. Combined uses of *Tithonia diversifolia* and inorganic fertilizers for improving maize production in a phosphorus deficient soil in Western Kenya. Agrofor. Syst., 55: 165-174.

Olabode, O.S., S. Ogunyemi, W.B. Akanbi, G.O. Adesina and P.A. Babajide, 2007. Evaluation of *Tithonia diversifolia* (Hemsl.) A gray for soil improvement. World J. Agric. Sci., 3: 503-507.

Oyetunji, O.I., I.J. Ekanakaye and O. Osonubi, 2001. Influence of yam fungi on cassava-maize intercrop in an alley cropping system. Proceedings of African Crop Science Conference, Uganda,

Soil Survey Staff, 2003. Soil Taxonomy and Classification. U.S. Dept. Handbook 436. U.S. Govt. Printing Office, Washington D.C.

Sonke, D., 1997. *Tithonia* weed a potential green manure crop. Echo. Dev. Notes, 57: 5-6.

Spaccini, R., A. Piccolo, J.S.C. Mbagwu, T.A. Zena and C.A. Igwe, 2002. Influence of the addition of organic residues on carbohydrate content and structural stability of some highland soils in Ethiopia. Soil Use Manage., 18: 404-411.

Sridhar, M.K.C. and G.O. Adeoye, 2003. Organo-mineral Fertilizers from Urban wastes: Development in Nigeria. The Nigerian Field, 68: 91-111.

Stark, C., L.M. Condron, A. Stewart, H.J. Di and M.O. Collaghan, 2006. Influence of organic and mineral amendments on microbial soil properties and processes. Applied Soil Ecol., 35: 79-93.

Vinten, A.J.A., A.P. Whitmore, J. Bloem, R. Howard and F. Wright, 2002. Factors affecting N immobilization/mineralization kinetics for cellulose, glucose and straw amended sandy soils. Biol. Fert. Soils, 36: 190-199.