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Full Length Research Paper

Effect of organo-mineral fertilizer on soil chemical properties, growth and yield of soybean

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A soil culture experiment was carried out in the greenhouse at Obafemi Awolowo University, Nigeria, to assess the effects of organo-mineral fertilizers consisting of water hyacinth compost at the rates of 0, 2.5 and 5 t/ha compounded with and without N (0 and 25 kg/ha urea) and P (0 and 26 kg/ha single superphosphate - SSP) on soil chemical properties, growth and yield of soybeans planted on Itagunmodi soil series (an ultisol). Two experiments were set up simultaneously. One set of plants was allowed to grow for 8 weeks and terminated at 50% flowering while the other was allowed to pod. The experiments were repeated to assess the residual effects of the treatments. In the first experiment, 5.0 t/ha water hyacinth compost + N and P (WC2F) significantly ($p<0.05$) improved plant height (PLHT) and shoot dry weight (SDW). Also, WC2F and in most cases, followed by WC2 (5.0 t/ha water hyacinth) had significant ($p<0.05$) residual effects on PLHT, NOLP (number of leaves per plant), SDW and RDW (root dry weight). The mean soil pH and available P for the two plantings were significantly ($p<0.05$) higher in both WC2 and WC2F than in the control. The mean exchangeable cations (Na, Ca and Mg) were also significantly higher in WC2 than the control. In the second experiment, CW2F followed by WC2 produced the highest pod and grain weights per plant (PWPP and GWPP). The lowest values for these parameters were obtained in the control. Similarly, WC2F and WC2, unlike the control and N and P only (F), had significant residual effects on the NOPP (number of pod per plant), PWPP and GWPP. It was concluded that WCF2 and WC2 were the best in enhancing both the growth and yield parameters of soybean. Hence, water hyacinth composted with N and P was a better source of nutrients for soybean production than their individual applications.

Key words: organomineral fertilzers, ultisol, water hyacinth compost, soybean.

INTRODUCTION

The soil, a central factor in crop production, is often limited in its capacity for sustainable agriculture as a result of degradation (FAO, 2004). With the current world population of 7 billion increasing by 1.4% annually, there must be substantial increase in crop production in order to provide adequate nutrition for the 8.3 billion people projected by 2025 (Mannion, 1998). To forestall possible famine, this target need to be achieved despite the continued deterioration and loss of prime agricultural land and static or declining crop production (Huang and Rozelle, 1995; Bramley et al., 1996; Rozelle et al., 1997; Savant et al., 1997). The challenge of adequate food production is more serious in Africa because the annual rate of population growth of 3% is higher than the world average. Moreover, over half of the African population is rural and directly dependent on locally-grown food crops harvested from the immediate environment (Bationo et al., 2003). With the increasing population pressure on land, the traditional bush fallow period for maintaining soil productivity under the shifting cultivation is no longer sustainable. This has led to intensification of cultivation on fertile lands and movement into marginal lands (Graham and Vance, 2000).

Mineral fertilizers are known to be sources of plant nutrients for increased crop production (Adeyemi, 1991;

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Hera, 1996). The applications of mineral fertilizers by peasant farmers have been significantly reduced recently due to scarcity and high costs (Akinrinde and Okeleye, 2005; Ogunlade et al., 2006). Such adverse side effects on the soil as acidity and Aluminium toxicity have also discouraged their use (Agboola, 1990).

Many researchers (Aoyama et al., 1999; Olayinka, 2009) have recommended the application of organic manures to tropical soils as sources of nutrients because the soils tend to be inherently low in soil organic matter (SOM), and low activity clays are predominant in the clay mineralogy (Okusami et al., 1997). Because organic manures are usually bulky, the complementary applications of organic manures and inorganic fertilizers have been advocated. Reports have indicated the beneficial effects of this practice in terms of improved soil fertility and balanced plant nutrition (Uyovbisere and Elemo, 2000; Ayoola and Agboola, 2002; Fandika et al., 2007; Ayeni, 2008; Olayinka, 2009).

Water hyacinth is an organic waste which impedes traffic on the creeks, reduces the oxygen concentration of the water. The biomass of this weed can be composted and used as organic fertilizer (Huang and Fang, 1999; Matsumura, 2002) for crop production, especially grain legumes which play an important role in the cropping systems in Africa by virtue of their short duration of growth, drought tolerance and ability to fix more than 250 kg N ha^{-1} nitrogen (N) biologically, depending on the genotype (Peoples et al., 1995). Soybean protein is now in high demand in industries in view of the high cost of other sources such as cowpea, meat, eggs and pork.

The aim of this study was, therefore, to determine the effect of organo-mineral fertilizer consisting of water hyacinth compost, inorganic N and P (phosphorus) on soil chemical properties, growth and yield of soybean.

MATERIALS AND METHODS

Soil sampling and preparation of organic and organo-mineral amendments

Top soil sample (0 to 20 cm) of Itagunmodi soil series (an Ultisol) was obtained from an uncultivated plot, bulked, air-dried, and passed through 2 mm sieve to remove extraneous materials. Water hyacinth *(Eichhornia crassipes* L.*)* was harvested, chopped into smaller pieces and composted in a jute bag over a period of 3 months with regular turning. Thereafter, the composted material was compounded with and without N (0 and 25 kg/ha urea) and P (0 and 26 kg/ha SSP), mixed and further composted for 1 month to obtain organo-mineral fertilizers.

Soil physico-chemical analyses

Soil particle size distribution was determined using the hydrometer method (Bouyoucos, 1962). Water holding capacity of the soil was determined using the core sampling method (Blake and Hartge, 1986). Soil pH was determined potentiometrically in a soil-solution ratio of 1: 2 in 0.01 M $CaCl_2$ using a glass electrode pH meter (Peech et al., 1953). Available P was determined using the Bray-1 method (Bray and Kurtz, 1945) and read at 660 nm wavelength after the development of the molybdenum blue colour. Exchangeable cations were extracted with 1 N ammonium acetate (NH_4OAc) at pH 7 and the determination of sodium (Na), calcium (Ca) and potassium (K) were done using flame photometer while magnesium (Mg) was determined using the ethylene-diaminetetraacetic acid (EDTA) titration method (Page et al., 1982). The total N contents were determined using micro-Kjeldahl diges-tion and distillation process (Bremner and Mulvaney, 1982).

Chemical analyses of fresh and composted water hyacinth

Portions of the fresh and composted water hyacinth were oven-dried at 65°C, ground with stainless steel mill and digested using concentrated H_2SO_4 and 30% H_2O_2. The contents of cations were read: K, Na, and Ca with flame photometer and Mg with Atomic Absorption Spectrophotometer. The organic carbon and total N contents of the organic materials were also determined using chromic acid digestion method of Allison (1965) and micro-Kjeldahl digestion and distillation process (Bremner and Mulvaney, 1982), respectively.

Greenhouse soil culture experiment

The study was carried out in the greenhouse at the Obafemi Awolowo University, Ile-Ife, Nigeria. Five kilograms (5 kg) of soil was amended with water hyacinth compost with and without N and P. The treatments were:

1. Soil only (Control)
2. Soil + N (25 kg/ha) + P (26 kg/ha) (F)
3. Soil + 2.5 t/ha water hyacinth compost (WC1)
4. Soil + WC1 + N (25 kg/ha) + P (26 kg/ha) (WC1F)
5. Soil + 5.0 t/ha water hyacinth compost (WC2)
6. Soil + WC2 + N (25 kg/ha) + P (26 kg/ha) (WC2F)

Where, WC= water hyacinth compost; F= Inorganic N and P; 1= 2.5 t/ha; 2 = 5.0 t/ha.

The amended soils were each transferred into plastic pots (perforated at the bottom for free drainage and air movement), replicated thrice, arranged in a Completely Randomized Design (CRD) and watered to 70% of the soil's water holding capacity. Three (3) soybean seeds of an early maturing Tropical *Glycine max* (TGX1448-ZE) were planted per pot and later thinned to 2 at two weeks after planting. Two experiments were set up simultaneously. One set of plants was allowed to grow for 8 weeks and terminated at 50% flowering while the other was allowed to pod. In the first set of plants, and at harvesting (8 weeks after planting), all plant heights were taken using meter rule and thereafter, the shoots were cut at 2 cm above the soil surface while the roots were carefully harvested. The fresh shoots and roots were weighed and later oven-dried in paper bags at 65°C to constant weight for the determination of dry matter yields and later ground in a micro-hammer stainless steel mill prior to chemical analyses. In the second experiment, the number of pods, pod weight and grain weight per plant were determined. The experiments were repeated to evaluate the residual effects of the amendments. The soil in each pot was sub-sampled and analyzed for pH, organic carbon, available P and exchangeable cations at the end of each planting.

Data analyses

The data collected were analyzed using the analysis of variance (ANOVA) technique and means were separated using Duncan's

Table 1. Physical and chemical properties of the soil used for the greenhouse study.

Property	Value
Sand (gkg^{-1})	310
Silt (gkg^{-1})	230
Clay (gkg^{-1})	460
Textural class	Clay
FMC (%)	22.3
pH (H_2O)	4.4
pH (0.01 M $CaCl_2$)	4.1
Organic carbon (gkg^{-1})	11
Total N (gkg^{-1})	5.8
Available P ($mgkg^{-1}$)	21.34
Exchangeable cations (cmol/kg)	
Ca	5.1
K	0.21
Mg	3.21
Na	0.28

New Multiple Range Test (DNMRT) at 5% level of probability with the SAS Software Package.

RESULTS AND DISCUSSION

Properties of the soil and organic amendments

The properties of the soil, fresh and composted water hyacinth (WC) used as soil amendments in the greenhouse experiments are shown in Tables 1 and 2. The textural classification of the soil was clay, comprising 310, 230 and 460 gkg^{-1} sand, silt and clay, respectively. The pH of the soil showed acidic reaction (pH 4.1). The WC compost contained 15.3% organic carbon (OC) and was therefore, a good source of OC to the soil which had 1.1% (11 gkg^{-1}) OC and within the medium soil fertility range (Adepetu, 1990). The compost had total N content (1.05%) higher than that of the soil (0.58% N) which was however, higher than the critical minimum (0.11% N) required for Nigerian soils (Adepetu, 1990). The compost also had high P content (0.67%) while the soil had 0.002% (21.34 gkg^{-1}) available P which however, was within the high fertility range. A P content of 0.001% (10 mg/kg) was considered as the critical minimum for crop production (Agboola and Corey, 1973; Adeoye and Agboola, 1985). The contents of cations in the compost were the following: 4.81% K, 0.67% Ca, 0.02% Mg and 0.48% Na while the soil had the following contents of exchangeable cation in cmol/kg: 5.1 Ca, 0.21 K, 3.21 Mg and 0.28 Na. The soil was high in the exchangeable cations based on the critical levels of 2.5, 0.16 and 0.20 cmol/kg Ca, K and Mg, respectively (Adeoye and Agboola, 1985; Akinrinde and Obigbesan, 2000).

The contents of all nutrients in the compost were virtually higher than in the fresh material. The compost in addition had low C: N ratio of 15: 1 which was less than 30: 1, above which N immobilization will set in (Olayinka, 2001). Hence, mineralization of nutrients is made possible and faster. The increased contents of nutrients in the compost could be attributed to loss of C as CO_2 during the composting process. Heavy metal contents (Cd, Pb, Zn, As, and Cu) of the compost were also analyzed to ascertain its suitability as source of plant nutrients without constituting health hazard to man in the long run. The values obtained were however, lower than the maximum permissible levels in sewage sludge used in agriculture (Lixandru et al., 2010) as shown in Table 2.

Effect of treatments on soil pH, organic carbon (OC) and available P contents at the end of two consecutive 8 weeks planting of soybean

The mean soil pH values obtained in WC2F and WC2 were significantly ($P<0.05$) higher than in the control and F (Table 3). Generally, in all treatments except F, the pH of the soil after the two croppings increased over the initial value of 4.1 and this could mean that the compost supplied basic cations into the soil (Ramaswami and Son, 1996; Olayinka et al., 1998). The low pH value obtained with the inorganic fertilizer application might be due to the acid-yielding property of urea fertilizer that served as the source of starter N. In terms of OC contents, there was no significant ($p>0.05$) difference between the treatments. This might be due to the relatively high initial soil OC content (Adeoye and Agboola, 1985). The low OC content obtained with F might be due to enhanced mineralization of the native soil organic carbon (Agboola, 1990). The available P was significantly ($p<0.05$) increased in WC2, WC2F and WC1F over the control, respectively. Other treatments were however, not significantly different from the control. Water hyacinth, from its chemical composition, is very rich in P; this could have resulted in the increase in soil available P, and especially, in the treatments combined with starter P. Generally, the increases observed in soil pH, available P and OC, from the different rates of sole applications of the water hyacinth compost as well as their combinations with starter N and P were in line with the findings of Odedina et al. (2007) and Ayeni (2008, 2010).

Effect of treatments on contents of exchangeable cations at the end of two consecutive 8 weeks planting of soybean

There was no significant ($p>0.05$) difference between all the treatments for K (Table 4). While there was no significant difference between the remaining treatments, WC2 significantly ($p>0.05$) increased exchangeable Na, Ca and Mg over the control. The high values of exchangeable

Table 2. Chemical properties of fresh and composted water hyacinth (dry weight) used for the study.

Chemical properties	Water hyacinth		Maximum permissible levels (mg/kg)		
	Fresh	Compost	Romania (Ord. 344/2004)	EU86/278/ECC	USA (EPA 503/1999)
C (%)	37.44	15.31			
N (%)	0.84	1.05			
P (%)	0.92	0.67			
K (%)	2.25	4.81			
Ca (%)	0.28	0.67			
Mg (%)	0.02	0.02			
Na (%)	1.14	0.48			
C:N	45	15			
Cd (mg/kg)	5.13	6.50	10	20-40	85
Pb (mg/kg)	30.00	31.25	300	750-1200	840
Zn (mg/kg)	27.50	48.00	2000	2500-4000	7500
As (mg/kg)	6.88	7.50	10	-	-
Cu (mg/kg)	72.25	72.50	500	1000-1750	4300

Table 3. Soil pH, organic carbon and available P contents at the end of two consecutive 8-weeks planting of soybean (*Glycine max* L. Merrill) in the greenhouse.

Treatments	pH (0.01M $CaCl_2$)	OC (%)	P (mg/kg)
Control	4.15^{*bc**}	1.44^{ab}	13.1^{4b*}
Fertilizer(F)	4.07^{c}	1.27^{b}	23.02^{ab}
WC1	4.39^{ab}	2.03^{ab}	22.88^{b}
WC1F	4.27^{abc}	2.23^{ab}	23.86^{a}
WC2	4.50^{a}	2.50^{ab}	30.07^{a}
WC2F	4.45^{a}	1.56^{ab}	24.52^{a}

*Each value is the mean for two plantings of soybean; ** Means in a column with similar letter(s) are not significantly different ($p<0.05$) according to Duncan's New Multiple Range Test. Where, F = fertilizer; WC= water hyacinth compost; 1= 2.5 t/ha; 2 = 5.0 t/ha.

Table 4. Exchangeable cation contents (cmol/kg) at the end of two consecutive 8-weeks planting of soybean (*Glycine max* L. Merrill) in the greenhouse.

Treatments	K	Ca	Mg	Na
Control	0.13*	2.25^{c**}	0.82^{c}	0.16^{b}
Fertilizer (F)	0.15	2.42^{c}	1.03^{bc}	0.16^{b}
WC1	0.17	2.85^{abc}	1.20^{abc}	0.21^{ab}
WC1F	0.22	2.99^{abc}	1.39^{abc}	0.20^{ab}
WC2	0.25	3.77^{a}	1.76^{ab}	0.24^{a}
WC2F	0.23 NS	3.42^{abc}	1.27^{abc}	0.21^{ab}

*Each value is the mean for two plantings of soybean; ** Means in a column with similar letter(s) are not significantly different ($p<0.05$) according to Duncan's New Multiple Range Test. Where, F = fertilizer; WC= water hyacinth compost; 1= 2.5 t/ha; 2 = 5.0 t/ha.

exchangeable Na and Ca obtained at WC2 might not be unconnected with the high Na and Ca contents of the water hyacinth compost. The contents of exchangeable cations were lower than the initial contents at the end of the plantings. This could be attributed to uptake of these nutrients by the soybean plants. Generally, the exchangeable cations were increased over the control, although insignificantly, by the different levels water hyacinth

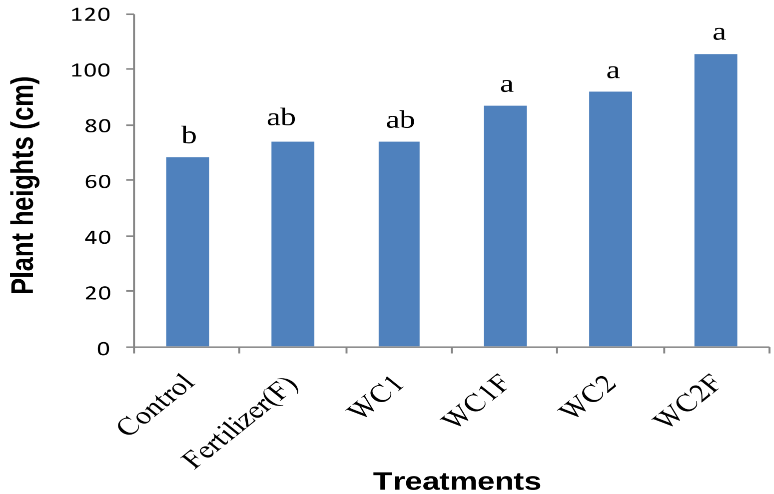

Figure 1. Soybean (*Glycine max* (L.) Merrill) mean plant heights at the end of the 8 weeks of the first and the second 8-weeks planting in the greenhouse. Means with similar letter(s) are not significantly different (p<0.05) according to Duncan's New Multiple Range Test. Where, F = fertilizer; WC= water hyacinth compost; 1= 2.5 t/ha; 2 = 5.0 t/ha.

compost applied individually or combined with inorganic fertilizers. This trend was in line with earlier reports of increases in soil exchangeable cations with the application of organic wastes applied individually or combined with inorganic fertilizers (Olayinka and Adebayo, 1983; Olayinka, 1990; Odedina et al., 2007; Ayeni, 2008, 2010; Oladipo et al., 2010).

Effect of treatments on soybean (*Glycine max* L. Merrill) agronomic parameters at the end of two consecutive 8-weeks planting

Plant heights (PLHT) and number of leaves per plant (NOLP)

At the end of the 8 weeks of the first and the second plantings, the plant heights were significantly ($p<0.05$) increased over the control by WC2F (Table 5). The remaining treatments were not significantly ($p<0.05$) different from the control. The mean plant heights for the two croppings (Figure 1) obtained in WC2F, WC2 and WC1F were significantly ($p<0.05$) higher than in the control. The improved plant heights by the treatments could be as a result of favourable soil pH and better nutrient supply by them (Lopes et al., 1996; Yamagata and Otami, 1996).

The NOLP were not significantly ($p>0.05$) affected by the treatments at the end of the first 8 weeks of planting, but were significantly ($p<0.05$) higher than in the control with WC2F, WC2 and WC1F at the end of the second planting. The NOLP was significantly ($p<0.05$) increased 105% by WC2F over the control at the end of the second planting. These findings, including the mean NOLP for the two croppings (Figure 2), followed the same trend as that of plant height. These trends might be attributed to the high contents of N and P in the water hyacinth compost and those added in the organo-mineral formulation coupled with their low C: N ratios which enhanced nutrient mineralization.

Shoot and root dry weight (SDW and RDW)

While the WC2F 2and WC significantly ($p<0.05$) increased only the SDW over the control at the end of the first planting, it was WC2F only that significantly ($p<0.05$) increased both the SDW and the RDW at the end of the second planting. Other treatments were at the end of the second planting, however, not significantly different from the control (Table 5). Moyin-Jesu and Adekayode (2010) earlier reported that organic fertilizers in forms of wood ash, poultry manure and pig manure significantly ($P<0.05$) increased plant height, stem girth, leaf area, leaf number, root length and fresh shoot weight, leaf N, P, K, Ca and Mg of African cherry nut seedlings (*Chrysophyllum albidium* L.) as well as soil pH and organic matter compared to the control.

Dry matter yield (DMY)

At the end of the first planting, the DMY was not significantly ($p>0.05$) affected by the treatments (Table 5a). However, at the end of the second planting, it was significantly ($p<0.05$) higher with the organo-mineral fertilizers WC2F and WC1F than in the control, while the DMY obtained in WC2F was significantly ($p<0.05$) higher

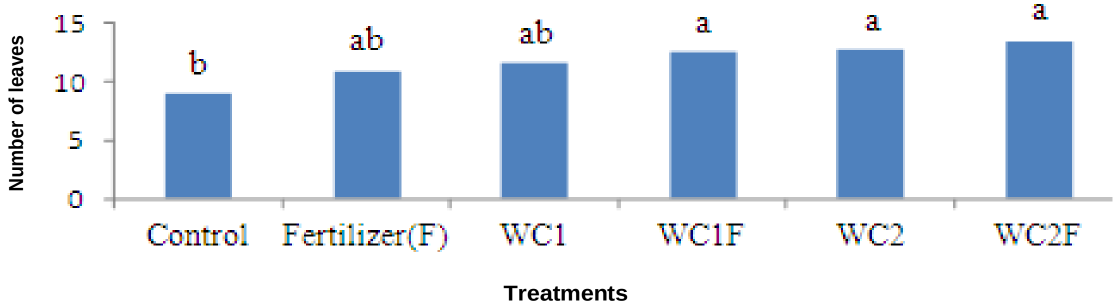

Figure 2. Soybean (*Glycine max* (L.) Merrill) mean number of leaves at the end of the first and the second planting in the greenhouse. Means with similar letter(s) are not significantly different ($p<0.05$) according to Duncan's New Multiple Range Test. Where, F = fertilizer; WC= water hyacinth compost; 1= 2.5 t/ha; 2 = 5.0 t/ha.

Table 5. Soybean (*Glycine max* (L.) Merrill) agronomic parameters at the end of the first (**a**) and the second (**b**) 8-weeks planting in the greenhouse.

Treatments	PLHT (cm)	NOLP	DMY (g)	SDW (g)	RDW (g)
(a)					
Control	63.85^{c}*	11.33	1.41	1.19^{c}	0.23
Fertilizer(F)	69.10^{bc}	11.50	1.56	1.44^{abc}	0.19
WC1	77.17^{abc}	11.33	1.51	1.33^{bc}	0.18
WC1F	70.43^{abc}	12.67	1.87	1.53^{abc}	0.26
WC2	78.60^{abc}	13.00	1.77	1.62^{ab}	0.30
WC2F	87.33^{a}	2.04 NS	2.04 NS	1.74^{a}	0.23 NS
(b)					
Control	73.00^{b}	6.67^{b}	1.06^{c}	0.93^{b}	0.29^{b}
Fertilizer (F)	79.33^{b}	10.33^{ab}	1.33^{bc}	0.99^{b}	0.29^{b}
WC1	70.83^{b}	11.67^{ab}	1.53^{bc}	1.25^{b}	0.29^{b}
WC1F	103.33^{ab}	12.33^{a}	1.91^{b}	1.48^{b}	0.30^{b}
WC2	105^{ab}	12.33^{a}	1.78^{bc}	1.59^{b}	0.32^{b}
WC2F	123.83^{a}	13.67^{a}	3.12^{a}	2.46^{a}	0.66^{a}

*Means in a column with similar letter(s) are not significantly different ($p<0.05$) according to Duncan's New Multiple Range Test. Where, WC= water hyacinth compost; 1= 2.5 t/ha; 2 = 5.0 t/ha; PLHT= Plant height; NOLP= number of leaves per plant; DMY= dry matter yield, SDW = shoot dry weight; RDW = root dry weight.

than those of other treatments obtained in WC1F was not significantly different from the remaining treatments, except the control. The trend in the first planting might be due to the initial medium to high fertility status of the soil according to Adeoye and Agboola (1985), which therefore moderated the effects of the treatments. As at the second planting, however, some nutrients would have been depleted thus, allowing the treatments especially the organo-mineral fertilizers to exhibit their residual effects.

A review of the results obtained for all the soybean agronomic parameters considered here, indicated that the organic amendments at the levels supplied, with and without inorganic forms of N and P were capable of supplying the nutrients needed for the soybean plant growth. It should be noted that legumes require little or no external N source for their growth and development (Afolabi, 1980; Daramola et al., 1982). The 5.0 t/ha water hyacinth compost with, and without starter N and P (WC2F and WC2) effectively enhanced the growth parameters of the test crop. There was also an increase in the values of the parameters measured with increase in the rate of compost and organo-mineral fertilizer application. Lopes et al. (1996) and Yamagata and Otami (1996) also reported increases in the growth of legumes with the application of manures. A significant increase in dry matter yield of greenhouse grown maize with incurporated inorganically-amended sawdust was attributed to the higher levels of soil N and P (Olayinka and Adebayo, 1985). The improvement in the growth parameters of the

Table 6. Soybean yield parameters at the end of the first (**a**) and second (**b**) harvest in the greenhouse.

Treatments	NOPP	PWPP (g)	GWPP (g)
a			
Control	11.67*	2.73b	1.84^{b}
Fertilizer(F)	11.67	3.21ab	2.08^{b}
WC1	15.67	2.50b	1.77^{b}
WC1F	12.67	3.36ab	2.47^{ab}
WC2	17.00	4.23a	2.92^{ab}
WC2F	17.33 NS	4.39a	2.94^{a}
b			
Control	9.00^{de}	1.37^{ef}	0.65^{c}
Fertilizer(F)	9.67^{cde}	1.58^{def}	0.91^{bc}
WC1	10.67^{bcde}	1.64^{cde}	0.93^{bc}
WC1F	12.33^{abc}	1.98^{abcd}	1.19^{ab}
WC2	13.33^{ab}	2.07^{ab}	1.20^{ab}
WC2F	14.00^{a}	2.26^{a}	1.34^{a}

*Means in a column with similar letter(s) are not significantly different ($p<0.05$) according to Duncan's New Multiple Range Test. Where, WC= water hyacinth compost; 1= 2.5 t/ha; 2 = 5.0 t/ha; NOPP= number of pods per plant; PWPP= pod weight per plant; GWPP= grain weight per plant.

soybean crop by the organic and organo-mineral fertilizers over the control could therefore, be attributed to the nutrient contents of the fertilizers which encouraged better vegetative growth. This observation is in line with Adebayo and Akoun (2000) and Moyin-Jesu (2007, 2010) who reported that organic manures supported crop growth performance and increased crop yield.

Effect of treatments on number of pods (NOPP), pod and grain weight of soybean (*Glycine max* L. Merrill) at the end of the first and the second harvest

Tables 6a and b showed the effects of the treatments on the number of pods, pod and grain weights per plant at the end of the 1st and 2nd plantings in the greenhouse. The treatments did not significantly ($p>0.05$) affect NOPP at the end of the first planting. At the end of the second planting, the NOPP in WC1F, WC2 and WC2F were significantly ($p<0.05$) higher than in the control. The results were similar for both pod and grain weights per plant (PWPP and GWPP) except that in the first planting, the PWPP obtained in both WC2 and WC2F were significantly ($p<0.05$) higher than in the control while the GWPP was only significantly ($p<0.05$) higher in WC2F than in the control, while the PWPP obtained in WC2 and WC2F were significantly ($p<0.05$) higher at the end of the 1st planting; those in WC1F, WC2 and WC2F were significantly ($p<0.05$) higher than in the control at the end of the 2nd planting. Furthermore, the means of the grain yield (GWPP) for the 2 plantings (Figure 3) were significantly ($p<0.05$) higher in WC2F, WC2 and WC1F than in the control.

These results indicated good performances of the composted water hyacinth with and without N and P additions, which might be partly due to the high nutrient contents of the compost. Barker (1997) had earlier reported that, for compost to be described as having fertilizing capabilities and for it to be used in agriculture, the total N (TN) content must be over 1% on dry weight basis. This condition was satisfied by the water hyacinth compost which had total N (TN) content of 1.05%. The improvement of grain yield by the compost was in line with the report of Yamagata and Otami (1996).

In conclusion, since P fixation in Ultisol is known to constitute a limiting factor to productivity, capturing inorganic P by organic complexes (for example, water hyacinth which is equally high in P) during composting and later made available to plants when brought to the field could prove a good agricultural practice for this type of soil. The results from this study showed that soybean agronomic parameters and yield parameters such as PLHT, NOLP, SDW and RDW, DMY and NOPP, PWPP and GWPP were significantly increased by the treatments. The application of 5 t/ha water hyacinth compost with and without starter N and P (WC2F and WC2) performed better than other treatments in increasing the soybean agronomic and yield parameters. In addition, the soil pH, organic carbon, available P and exchangeable cations (Ca, K and Mg) were increased by both the

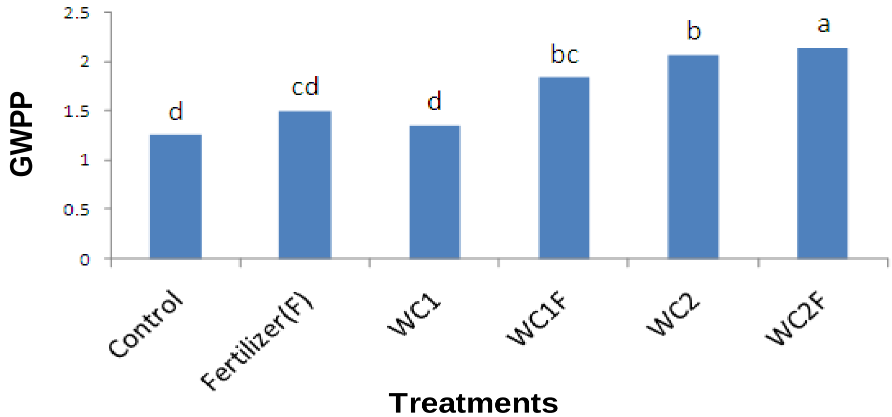

Figure 3. Soybean (*Glycine max* (L.) Merrill) mean grain weight per plant (GWPP) at the end of the 12 weeks of the first and the second planting in the greenhouse. Means with similar letter(s) are not significantly different ($p<0.05$) according to Duncan's New Multiple Range Test. Where, F = fertilizer; WC= water hyacinth compost; 1= 2.5 t/ha; 2 = 5.0 t/ha.

organic and organo-mineral fertilizers.

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