Effects of water hyacinth (*Eichhornia crassipes* [mart.] solms) compost on growth and yield of common beans (*Phaseolus vulgaris*) in Lake Victoria Basin

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ABSTRACT

Water hyacinth (Eichhornia crassipes) has become a problem in water bodies all over the world. Various methods have been used to eradicate the macrophyte but with little success. The weed has high content of the nutrients absorbed from its environment. Hence there is need to assess the potential of utilizing the weed for commercial purposes such as compost to substitute the use of inorganic fertilizers which contributes to climate change. The objective of the study was to evaluate the effects of water hyacinth compost prepared using different treatments on the growth and yield of common beans. Field experiments were carried out at Otonglo Division in Kisumu County (Kenya) and greenhouse experiments were carried out at Kenyatta University. The water hyacinth compost was prepared using effective microorganisms (EM) solution, cattle manure and molasses separately as starter cultures for composting. The effect of compost on crop production was assessed by applying the compost to common beans (Rose coco) on separate growth pots in the greenhouse and plots in the field respectively. The treatments applied included compost prepared with EM (8.837 g/pot), compost prepared with cattle manure (8.837 g/pot), compost prepared with molasses (8.837g/pot), diammonium phosphate (DAP) fertilizer (70.7 mg N/pot), inoculum (beans treated with Rhizobium leguminosarum strain 446) and control (without fertilizer). For the field experiments, water hyacinth compost was applied at a rate of 5000 kg ha^{-1} and DAP at 40 kg N/ha. The experiments were laid out in a Randomized Complete Block Design with six treatments and three replications for each treatment in the greenhouse and five treatments replicated four times in three farmers' fields. Application of water hyacinth compost and DAP significantly influenced positively ($p \leq 0.05$) the growth of common beans. The best performance of Rose coco plants in terms of dry weight, root dry weight, number of nodules per plant, nodule dry weight and root collar diameter was recorded when the soil was amended with water hyacinth compost prepared with EM (WHE). Yield parameters such as 100 seed weight, grain yield and stover weight were significantly ($p < 0.05$) influenced when the soil was amended with various treatments in some farms. It can therefore be concluded that water hyacinth which is locally available and in large quantities (especially in lake Victoria) can be composted to prepare organic fertilizers and effectively used as an organic soil amendment to restore soil and increase common beans production.

Key words: Water hyacinth, compost, common beans, yield, Lake Victoria basin

1. Introduction

Recent census report on the population of the Lake Victoria Basin shows that about 80 % of the population is engaged in agricultural production (Albinus *et al*., 2008). These farmers continuously cultivate their land leading to a reduction in soil fertility and reduced crop productivity (Ojiem *et al*., 2000). Chemical fertilizers which are currently being used by farmers in the region are expensive; cause eutrophication hence emergence of algal blooms and increase the overall greenhouse gases such as the oxides of carbon and nitrogen leading to global climate change and environmental destruction (Khanal, 2009). The economic and environmental costs as a result of the use of the chemical fertilizers together with their negative impacts to the environment are now of global concern hence there is need to shift to sustainable organic farming practices such as the use of fertilizers produced from locally available organic materials. The use of organic fertilizers from unexploited natural resources perceived as weeds, such as the water hyacinth, would be a better alternative to improve soil fertility and increase crop yield.

Water hyacinth (*Eichhornia crassipes* [Mart.] *Solms*) is a free floating macrophyte in the family Pontedericeae, Liliales that grows in fresh water, but may be rooted in the mud, from where it draws all its nutrients directly. Wilson *et al.* (2005) recognized water hyacinth as the most harmful aquatic weed in the world due to its negative effects on people's livelihoods and waterways. Efforts to control the weed through chemical, physical and biological methods have all failed. However, there is a continued emphasis from some researchers that there is significant benefit to be obtained from seeing water hyacinth as a resource rather than a rogue plant (Abdel-Sabour, 2010; Anjanabha and Kumar, 2010). The weed is considered as a valuable source of macronutrients such as phosphorus, nitrogen and potassium that are essential for plant nutrition (Center *et al*., 2002; Sahu *et al*., 2002; Woomer *et al*., 2000). Due to the availability of water hyacinth in Lake Victoria in large quantities; it can be used as a material for production of organic fertilizer. The compost could then be applied to plants as a source of nitrogen, phosphorus and potassium (NPK) which are the macro nutrients that limit crop growth (Kwabiah *et al*., 2003; Wasonga *et al*., 2008).

Common beans (*Phaseolus vulgaris* L.) are the most commonly grown grain legumes that come second after maize as a subsistence crop (GoK, 2006). They serve as a source of proteins (contain 22 percent protein) which is relatively cheaper compared to animal proteins to majority of the population in Kenya (Karanja *et al*., 2007). Common beans are grown in pure stands by large scale farmers but commonly intercropped with maize by smallholder farmers (Kimenju *et al*., 2004). Like many legumes, beans thrive well in sufficiently aerated and well drained soils with a pH of 6.5 - 7.5 because they are very sensitive to soil acidity and an optimal amount of organic carbon above 2.4 percent (Baudoin *et al*., 2001). The optimum altitude should exceed 1000 m above sea level. Most common bean cultivars are short-season crops with a maturity period ranging from 65 to 110 days from emergence to physiological maturity hence two bean harvests per year (Buruchara, 2007). Kenya is among the major producers of beans in Africa, second after Uganda, but still experiences so much fluctuation in the yield (Katungi *et al*., 2009). The major factors causing the low production include pests and diseases, erratic rainfall and declining soil fertility which have resulted in low yields of 750 kg/ha, against a potential of 1500 – 2000 kg/ha (Fernández-Luqueno *et al*., 2012). Rose coco cultivar, which is a common high yielding variety in the bean producing regions, is losing its fame due to reduced soil fertility and unpredictable rainfall patterns as a result of climate change (Katungi *et al*., 2009). It is therefore critical that corrective measures are taken to restore soil fertility and mitigate climate change to enhance food security. The objective of the study was to assess the effectiveness of the organic fertilizer from composted water hyacinth on the growth and yield of common beans (*Phaseolus vulgaris*).

2. Materials and methods

2.1. Study site

The field experiments for the study were conducted at Korando sub location, Otonglo Division, Kisumu County in Lake Victoria Basin from November 2011 to December 2012. Three farmers' fields that lie within the Lake Victoria Basin and had no history of inorganic fertilizers application in the past six planting seasons were used. Farm A was located at 00^o 05' 40.4'' South and 034^o 41' 86.2'' East at an elevation of 1115 m above-sea-level, farm B was located at 00^o 05' 12.0'' South and 034^o 41' 61.3'' East at an elevation of 1133 m above-sea-level whereas farm C was located at 00^o 05' 16.7'' South and 034^o 42' 0.84'' East at an elevation of 1124 m above-sea-level. Planting was carried out during the long rain season between April and July, 2012. Greenhouse and laboratory experiments were carried out at the Department of Plant and Microbial Sciences in Kenyatta University from January 2012 to March 2012.

2.2. Preparation of water hyacinth compost

Water hyacinth was harvested manually, sun-dried and chopped into small pieces of about 5 cm. Above ground closed aerobic heap design was used to prepare the compost to maturity according to the procedure described by Tumuhairwe *et al*. (2009). The water hyacinth compost was prepared using effective microorganisms (EM) solution, cattle manure and molasses separately as starter cultures for composting.

2.3. Greenhouse experiments

Clean plastic pots measuring 15 cm diameter and 20 cm height were used. The pots were filled with soil and moistened by applying water until all the soil was thoroughly wet. Various fertilizer treatments were applied to each soil per pot and thoroughly mixed. Five viable common bean (Rose coco) seeds per pot of uniform size and shape were sown at a depth of 3 cm and one week after emergence, they were thinned to three seedlings per pot. The treatments administered were as follows: common beans with water hyacinth compost prepared with EM (WHE), common beans and water hyacinth compost prepared with cattle manure (WHC), common beans with water hyacinth compost prepared with molasses (WHM), common beans and nitrogen fertilizer (DAP at 70.70 mg N/pot), common beans inoculated with commercial inoculum, *Rhizobium leguminosarum* strain 446 and common beans with no fertilizer or compost (Control). Water hyacinth compost was applied at the rate of 8.84 g/pot. Watering of the pots was carried out by adding 100 ml of water on alternate days to each pot. Each treatment was replicated thrice on separate blocks and the pots arranged in a Randomized Complete Block Design. Sampling of plants was carried out on the 15^{th}, 30^{th} and 45^{th} day after emergence (DAE). The number of nodules per plant, nodule dry weight and root collar diameter of the common bean plants sampled was measured and recorded. The shoots and the roots of the plants were also separated; oven dried at a temperature of 60 ºC to a constant weight and their dry weights measured and recorded (Somasegaran and Hoben, 1994). Each greenhouse experimental set up was terminated after 45 days after planting. The experiment was repeated three times.

2.4 Field experiments

Three researcher managed farmers' fields were prepared by disc plough followed by harrowing. Each field was then demarcated into four main blocks with five plots separated by 1 m paths to minimize inter-plot interference (Otieno *et al*., 2009). Viable and uniform seeds of Rose coco beans were planted in the plots in the field at the onset of rains in April, 2012. Two seeds per hole were planted with various treatments and two weeks after germination, they were thinned to one plant per hole after the first weeding. An inter-row spacing of 0.5 m and intra-row spacing of 0.25 m was used (Mbure *et al*., 2011). Forty common bean plants per plot were retained after thinning. First weeding was carried out in both farms at two weeks after emergence, after which the plants were top dressed using Calcium Ammonium Nitrate (CAN) fertilizer at a rate of 40 kg/ha for those plots that had been planted with nitrogen fertilizer (Hornetz *et al*., 2006). Second weeding was carried out four weeks later. The layout in each field was a Randomized Complete Block Design with four blocks hence four replications for each treatment. The treatments administered were as follows: common beans with water hyacinth compost prepared with EM (WHE), common beans and water hyacinth compost prepared with cattle manure (WHC), common beans and nitrogen fertilizer (DAP at 70.70 mg N/pot), common beans inoculated with commercial inoculum (*Rhizobium leguminosarum* strain 446) and common beans with no fertilizer or compost (Control). Water hyacinth compost was applied at the rate of 5000 kg/ha while DAP (NPK ratio was 18:46:0) was applied at the rate of 40 kg N/ha. CAN (26 % N) was applied at the rate of 40 kg N/ha to those plots that had been treated with DAP fertilizer. The data obtained from measurement of various growth and yield parameters were analyzed using one way ANOVA with SPSS computer software version 11.5 for Windows. Means were separated using Tukey's honest significant difference at 5% level.

3. Results

3.1. Growth parameters

The shoot dry weight of common beans for various treatments varied significantly on the 15th, 30th and 45th DAE (days after emergence) (p = 0.007 on the 15th DAE, p = 0.003 on the 30th DAE and p = 0.007 on the 45th DAE). Plants from potted soil amended with WHE recorded the highest mean shoot dry weight of 0.85 g and 2.7 g on the 15th and the 30th day respectively and was significantly different from the inoculum on the 15th and 30th DAE. The lowest shoot dry weight of 0.41 g per plant was recorded for the inoculated common beans (inoculum treatment) on the 15th DAE and was significantly different from DAP treatment that had a mean dry weight of 0.77 g per plant. Plants grown without any added fertilizer recorded the lowest mean shoot dry weight of 1.53 g on the 30th DAE and this was also significantly different from DAP that had a mean shoot dry weight of 2.56 g per plant. WHM treatment recorded a mean shoot dry weight of 2.09 g and the inoculated common beans weighed 1.71 g per plant on the 30th DAE. DAP treatment recorded a mean dry weight of 8.69 g which was the highest and significantly different from all other treatments on the 45th DAE. It was followed by WHE, WHM, WHC, inoculum and the control treatment that recorded a mean shoot dry weight of 5.08 g, 4.45 g, 3.42 g 3.3 g and 2.47 g respectively on the 45th DAE (Table 1).

Significant differences were recorded on the root dry weight of common beans grown under different soil amendments (p = 0.002 on the 15th DAE; p = 0.004 on the 30th DAE and p = 0.000 on the 45th DAE). A mean root dry weight of 0.04 g was recorded for the plants which were grown in the soil that was not amended on the 15th DAE and this was significantly lower compared to WHE and DAP treatments which had a root mean dry weight of 0.08 g and 0.07 g respectively (Table 2). The highest mean root dry weight on the 30th and 45th DAE, 0.26 and 1.17 g respectively, was recorded among plants grown on soils amended with WHE. Plants sampled from soils without any amendment recorded the least mean root dry weight of common beans on the 30th and 45th DAE (0.13 g and 0.61 g respectively). Bean plants treated with DAP, WHM, inoculum and WHC had a mean root dry weight of 0.89 g, 0.99 g, 0.81 g and 0.67 g respectively on the 45th DAE (Table 2).

There was no significant difference among treatments on the shoot dry weight of common bean plants in farm A (P = 0.302). WHE treatment recorded the highest mean shoot dry weight of 5.67 g among all treatments in the farm while inoculum treatment recorded the lowest shoot dry weight (Table 3). Soil amendments had no significant effect on the shoot dry weight (P = 0.181) at farm B. The control recorded the highest mean shoot dry weight (9.4 g) compared to other treatments while the inoculum led to production of plants with the least weight. Various soil amendments significantly affected the shoot dry weight at farm C (P = 0.032). WHE treatment produced the highest mean shoot dry weight (8.16 g) while DAP gave the least shoot dry weight (2.43 g) (Table 3). Soil amendments had no significant effect on the root dry weight of common beans at pod formation at farm A unlike farm B which was significantly different (P = 0.015). Amendment of the soil with WHE yielded the highest mean root dry weight (1.27 g) while the inoculum produced the least weight (0.77 g). Various soil amendments significantly affected the root dry weight at farm C (P = 0.029). WHE treatment produced the highest mean root dry weight (1.05 g) while DAP treatment had the least root dry weight (0.48 g) (Table 4).

Nodulation in common beans differed significantly both on the 30th and 45th DAE under different soil amendments. The lowest number of nodules counted on the 30th DAE, two nodules per plant were from plants grown under DAP treatment while no nodules were obtained from plants grown with DAP amendment on the 45th DAE. All treatments had a significantly higher number of nodules compared to the control on the 30th DAE with the inoculum treatment recording the highest significant number of nodules (94 nodules per plant) followed by WHE at 56 nodules per plant, WHM at 54 nodules per plant, WHC at 50 nodules per plant and plants under the control treatment had 45 nodules per plant. WHE treatment had the highest mean number of nodules of 142 nodules per plant on the 45th DAE and this was statistically similar to WHM whose plants had 131 nodules per plant and the inoculum treatment which recorded a mean of 120 nodules per plant. Plants grown with WHC compost had 89 nodules per plant and those without any added fertilizer had 72 nodules per plant (Table 5). The lowest nodule dry weight per plant of 4.67 mg in the greenhouse was recorded on the plants grown under DAP treatment on the 30th DAE and this was significantly lower compared to all other treatments (P = 0.000). A mean weight of 109.33 mg was recorded as the highest among inoculated common beans on the 30th DAE (Table 5) followed by WHE, WHM, WHC and the control treatments which had a mean nodule dry weight of 109.33 mg, 99.33 mg, 93.17 mg and 86.50 mg respectively. Common beans grown in the soils amended with WHE recorded the highest mean dry weight of 249.17 mg and were not significantly different from WHM treatment that had a mean nodule weight of 231.17 mg on the 45th DAE. The inoculum, WHC and the control treatment recorded a mean nodule weight of 168.00 mg, 161.17 mg and 146.17 mg respectively (Table 5).

In the field, common beans grown on soil amended with WHE had 49 nodules per plant and this was the highest mean number of nodules in farm A at pod formation stage. The effect of WHE treatment was significantly different from the control treatment (P = 0.003) that had 7 nodules per plant and plants grown in soil amended with DAP nodules were not formed (Table 6). WHC treatment had 21 nodules per plant while the inoculated beans had 26 nodules per plant (Table 6). The highest mean number of nodules per plant, 24 nodules, at farm B during the pod formation stage was recorded in plants grown on soils amended with WHE. This treatment was significantly different (P = 0.003) from the inoculum treatment that had 2 nodules per plant and common bean plants on soils amended with DAP which had no nodules formed. WHC treatment had 14 nodules per plant while the control had 7 nodules per plant which was the lowest number of nodules formed (Table 6). The treatments had no significant effect on the number of nodules formed per plant (P = 0.051) at farm C. WHE treatment recorded a mean nodule number of 55 nodules which was the highest and was followed by the control, inoculum, WHC and DAP treatments that had 50, 33, 22 and 3 nodules per plant respectively (Table 6).

WHE treatment had the highest mean nodule dry weight of 86.25 mg per plant in farm A and was significantly different (P = 0.013) from plants with no added fertilizer (control) that recorded 7.75 mg per plant and DAP treatment where nodules were not formed. Nodules from inoculated common beans weighed 55.54 mg per plant while those from WHC treatment had 46.00 mg per plant. The highest mean nodule dry weight, 43.83 mg, at the farm B was recorded in soils amended with WHE and was significantly different (P = 0.003) from the inoculum treatment which had 2.25 mg per plant. WHC treatment recorded a mean nodule dry weight of 18.67 mg while the control had 14.63 mg per plant. At farm C, the treatments had a significant effect on the nodule dry weight per plant (P = 0.035). WHE treatment recorded a mean nodule dry weight of 103.67 mg per plant which was the highest and significantly different from DAP that had a mean nodule dry weight of 3.75 mg per plant. Nodules from inoculated common beans recorded a mean nodule dry weight of 69.08 mg while WHC treatment had 39.67 mg per plant (Table 7).

Highly statistically different root collar diameters were recorded in common beans grown under different soil amendments as shown in Table 8. DAP treatment produced the thickest plants which was significantly different from the other treatments at all days of sampling (on the 15th DAE, P=0.000; 30th DAE, P=0.000 and 45th DAE, P=0.000). The thinnest plants were produced on the 15th (3.00 mm) and 30th (3.67 mm) DAE in the inoculum treatment while the control experiment produced the least root collar diameter (3.83 mm) on the 45th DAE (Table 8).

3.2. Yield parameters

Grain yield was significantly influenced by the various soil amendments in farms A and C but not at Farm B (Table 9). WHE treatment produced the highest significant (P = 0.03) grain yield (1715.64 kg/ha) of common beans while the control produced the least (796.49 kg/ha) in farm A. At farm B, the control produced the highest while inoculum treatment yielded the least quantity but the yield from various treatments was not significantly different (P = 0.413). At farm C, WHC produced the highest grain yield (1632.77 kg/ha) while DAP treatment produced the least (1066.81 kg/ha) (Table 9).

The mean dry weight of 100 seeds randomly sampled from the total grains in farm A was statistically different among various treatments (P = 0.03). Soil amended with WHC resulted in producing the heaviest 100 seeds (50.21 g) while inoculum treatment yielded the lightest seeds (40.23 g) which were statistically similar to the seeds from the control treatment. At farm B, the treatments had no significant effect on the weight of 100 seeds (P = 0.188). DAP treatment resulted to the seeds with the highest 100 seed weight (46.37 g) while inoculum yielded the lowest (40.28 g). At farm C, amendment of the soil with DAP resulted to the production of the heaviest 100 seed weight (47.01 g) although this mean weight was not statistically different from the other amendments (P = 0.25) and the inoculum treatment yielded the lightest 100 seed weight (42.09 g) (Table 10).

Soil amendment had no significant effect on the stover weight of common beans at farm A (P = 0.429) unlike farm B and farm C which recorded significant differences (P = 0.007). WHC treatment led to the production of the heaviest common beans stovers (534.09 kg/ha) while control gave the lightest stovers (343.31 kg/ha) in Farm A (Table 11). At the farm B, highly significant differences (P = 0.007) were recorded on the stover weight when soil was amended with different treatments. DAP treatment produced the heaviest stovers in the other two farms while WHC gave the least stover weight in farm B (350.76 kg/ha) and inoculum treatment in farm C (371.91 kg/ha) (Table 11).

4. Discussion

Compost and DAP increased the biomass of the shoot more compared to the control and inoculated beans probably due to the release of considerable amounts of nutrients, especially nitrogen and phosphorus, to the plant during mineralization. These nutrients were utilized in chlorophyll formation for photosynthesis hence better plant development (Kamanu *et al*., 2012). The low shoot dry weight recorded in farm C could be attributed to the water logged plots that enhanced the leaching of highly soluble nutrients from DAP. The high root dry weight could have been attributed to the high amounts of organic matter in compost which could have increased the moisture retention of soil, improved dissolution of nutrients particularly phosphorus and soil structure hence better root growth and nutrient uptake (Olupot *et al*., 2004). These results conform to findings of Amitava *et al*. (2008) and Chukwuka and Amotayo (2008, 2009) who reported enhancement in growth parameters of rice, corn and onions using water hyacinth compost. DAP and compost significantly increased the root collar diameter of both plants in the greenhouse compared to the control due to the availability of nutrients that were utilized by the plants to amass their dry weights hence producing bigger plants with a statistically higher root collar diameter. Similar findings were reported by Chukwuka and Amotayo (2008, 2009).

Inoculation of common beans has been reported to significantly increase the nodule number and nodule dry weight due to the extra nitrogen that is fixed in the soil and utilized by the plant (Botha *et al.*, 2001; Javaid and Mahmoud, 2010; Mabood *et al.*, 2005). Contradictory results obtained in this study could have been due to the ineffectiveness of the *Rhizobium* strain inoculated to fix nitrogen in the greenhouse. Poor performance of the strain in the field could have been further attributed to the strain being outcompeted by the indigenous rhizobia that are better adapted to the field conditions. Chemining'wa *et al.* (2004) and

Otieno *et al.* (2009) also reported increased number of nodules and their mean dry weight per plant which neither translated to an increase in the plant dry weight nor grain yield. Compost produced a significantly higher number and dry weight of nodules on the 45th day after emergence in the greenhouse while DAP suppressed nodulation. Addition of high amounts of nitrogen through DAP could have led to inhibition of early cell division in the cortex hence suppressing nodulation while the higher nodulation with compost application could be attributed to the phosphorus added in the phosphorus deficient potted soil that played a role in nodule initiation, growth and functioning (Carsky, 2003; Gentili *et al.*, 2006; Woomer *et al.*, 2003). Nitrogen is released by compost slowly hence does not inhibit nodulation while the phosphorus in DAP could have been fixated due to the acidity enhanced by DAP during nitrification where a proton (H^+) was released thus could not have initiated nodulation. The high nodulation and development of effective nodules with a pink interior colour due to the presence of leghaemoglobin could have also contributed to the higher plant dry matter among beans treated with water hyacinth compost. Other studies have also reported similar findings (Chemining'wa *et al.,* 2004; Otieno *et al.,* 2009).

An increase in grain yield after the application of DAP could be attributed to the readily available nitrogen and phosphorus supplied by the fertilizers applied especially during grain filling and development period of the plants. Compost did not significantly increase grain yield due to its slow release of nutrients. Okoko and Makworo (2000) reported that continuous application of compost over time produced significantly better results than inorganic fertilizer due to its slow but steady release of nutrients but not in the first season of application. Manure effectively regulated the soil's acidity probably by binding the exchangeable aluminium ions in the acidic soils besides releasing plant nutrients slowly hence equally produced higher but insignificant grain yields (Tejada *et al*., 2006; Onwonga and Lelei, 2010). The lower yields observed in the control could have been due to reduced nitrification rates and phosphorus fixation in the acidic soils that rendered nitrogen and phosphorous unavailable for plant uptake thus lower yield (Onwonga and Lelei, 2010). Farm B recorded lower grain yields than farm A and farm C probably due to lack of sufficient nitrogen in the soil which stressed the plant especially at the initial growth stages thus the crops exhibited chlorosis and retarded growth hence lower yields. The acidity of the soil could also have caused phosphorus fixation which made it unavailable to the plants hence no significant difference between the plants in the treated plots and the control (Fardeau and Zapata, 2002; Kamanu *et al*., 2012).

The stover weight was higher in plants grown in soil amended with DAP compared to other amendments probably due to release of considerable amounts of nutrients, especially nitrogen and phosphorus, to the common bean plant during mineralization that were utilized for photosynthesis hence better plant development (Kamanu *et al*., 2012).

5. Conclusion

Water hyacinth compost increased the growth of common beans. This is therefore an indicator of better yields if proper farm management is practiced under favourable environmental conditions. DAP also performs well in crop production but its adverse effects on the soil and the environment makes its use undesirable. Although the field results indicate that common bean production without fertilizer application in some farms is possible, there is fear that without replenishment, the macronutrients could be depleted leading to low yields. Farmers within the Lake Victoria basin should make use of compost from water hyacinth which is locally available, plentiful and inexpensive as an organic soil amendment for improved common bean production.

TABLES

Table 1

Mean shoot dry weight (g) of common beans grown in the greenhouse under different soil amendments.

Mean shoot dry weight (g)			
Treatment	**15 DAE**	**30 DAE**	**45 DAE**
WHC	0.56±0.05^{abX}	1.99±0.22^{abcX}	3.42±0.44^{aX}
WHM	0.71±0.07^{ab}	2.09±0.22^{abc}	4.45±0.61^{a}
WHE	0.85±0.13^{b}	2.7±0.33^{c}	5.08±0.92^{a}
DAP	0.77±0.07^{b}	2.56±0.20^{bc}	8.69±0.75^{b}
Inoculum	0.41±0.04^{a}	1.71±0.14^{ab}	3.3±0.43^{a}
Control	0.66±0.09^{ab}	1.53±0.14^{a}	2.47±0.28^{a}

^{X}Means within the column followed by the same letters are not significantly different at $p > 0.05$.

WHE - Water hyacinth compost prepared using EM treatment, WHC - Water hyacinth compost prepared using cattle manure treatment, WHM - Water hyacinth compost prepared using molasses, DAP - Diammonium phosphate (Nitrogen fertilizer), DAE - Days after emergence.

Table 2

Mean root dry weight (g) of common beans grown in the greenhouse under different soil amendments.

Mean root dry weight (g) of common beans			
Treatment	**15 DAE**	**30 DAE**	**45 DAE**
WHC	0.05±0.01^{abX}	0.22±0.02^{abX}	0.67±0.03^{abX}
WHM	0.06±0.01^{ab}	0.23±0.03^{ab}	0.99±0.11^{bc}
WHE	0.08±0.01^{b}	0.26±0.03^{b}	1.17±0.06^{c}
DAP	0.07±0.00^{b}	0.23±0.03^{ab}	0.89±0.08^{abc}
Inoculum	0.06±0.01^{ab}	0.17±0.01^{ab}	0.81±0.11^{ab}
Control	0.04±0.01^{a}	0.13±0.02^{a}	0.61±0.03^{a}

^{X} Means within the column followed by the same letters are not significantly different at $p > 0.05$.

WHE - Water hyacinth compost prepared using EM treatment, WHC - Water hyacinth compost prepared using cattle manure treatment, WHM - Water hyacinth compost prepared using molasses treatment, DAP - Diammonium phosphate (Nitrogen fertilizer), DAE - Days after emergence.

Table 3

Mean shoot dry weight (g) per plant of common beans at pod formation grown in three farms under different soil amendments at Korando B during the long rainy season of 2012.

Mean shoot dry weight (g) of common beans			
Treatment	**Farm A**	**Farm B**	**Farm C**
WHE	5.67±0.83^{aX}	8.7±1.94^{aX}	8.16±1.78^{bX}
WHC	4.62±0.64^{a}	7.88±1.15^{a}	6.65±1.63^{ab}
DAP	5.32±0.79^{a}	7.57±1.19^{a}	2.43±0.32^{a}
Inoculum	3.41±0.29^{a}	4.86±0.69^{a}	5.34±0.49^{ab}
Control	4.22±1.17^{a}	9.40±1.5^{a}	6.02±1.28^{ab}

^{X} Means within the column followed by the same letters are not significantly different at $P > 0.05$.

WHE - Water hyacinth compost prepared using EM treatment, WHC - Water hyacinth compost prepared using cattle manure treatment. DAP - Diammonium phosphate (Nitrogen fertilizer)

Table 4

Mean root dry weight (g) per plant of common beans at pod formation grown in three farms under different soil amendments at Korando B during the long rainy season of 2012.

Mean root dry weight (g) of common beans			
Treatment	**Farm A**	**Farm B**	**Farm C**
WHE	0.88±0.08[aX]	1.27±0.15[bX]	1.05±0.13[bX]
WHC	0.81±0.08[a]	1.06±0.14[ab]	0.98±0.21[ab]
DAP	0.71±0.04[a]	0.89±0.08[ab]	0.48±0.09 [a]
Inoculum	0.80±0.08[a]	0.77±0.09 [a]	0.78±0.06[ab]
Control	0.72±0.08[a]	1.21±0.13[ab]	0.98±0.11[ab]

[X] Means within the column followed by the same letters are not significantly different at P > 0.05.

WHE - Water hyacinth compost prepared using EM treatment, WHC - Water hyacinth compost prepared using cattle manure treatment. DAP - Diammonium phosphate (Nitrogen fertilizer)

Table 5

Mean number of nodules and mean dry weight of nodules of common beans grown in the greenhouse under different soil amendments.

Mean number of nodules and mean nodule dry weight (mg)				
	30 DAE		**45 DAE**	
Treatment	**Nodule number per plant**	**Nodule dry weight (mg)**	**Nodule number per plant**	**Nodule dry weight (mg)**
WHC	50±5.07[bX]	93.17±8.61[bX]	89±4.72[bX]	161.17±6.96[bX]
WHM	54±5.045 [b]	99.33±9.23[b]	131±6.53[c]	231.17±12.83[c]
WHE	56±2.18 [b]	109.33±7.20[bc]	142±6.96[c]	249.17±9.94[c]
DAP	2±1.13 [a]	4.67±2.82 [a]	0±0.00 [a]	0±0.00 [a]
Inoculum	94±5.62 [c]	134.17±8.26 [c]	120±6.41[c]	168.00±15.70[b]
Control	45±4.28[b]	86.50±7.61 [b]	72±6.66[b]	146.17±9.79[b]

[X] Means within the column followed by the same letters are not significantly different at P > 0.05.

WHE - Water hyacinth compost prepared using EM treatment, WHC - Water hyacinth compost prepared using cattle manure treatment, WHM - Water hyacinth compost prepared using molasses treatment.. DAP - Diammonium phosphate (Nitrogen fertilizer), DAE - Days after emergence.

Table 6

Mean number of nodules per plant of common beans at pod formation stage grown in three farms under different soil amendments at Korando B during the long rainy season of 2012.

Mean number of nodules at pod formation stage			
Treatment	**Farm A**	**Farm B**	**Farm C**
WHE	49±10.92[bX]	24±7.00[bX]	55±15.26[aX]
WHC	21±9.36[ab]	14±6.36[ab]	22±7.99[a]
DAP	0±0.00[a]	0±0.00[a]	3±2.83[a]
Inoculum	26±13.79[ab]	2 ±1.00[a]	33±12.03[a]
Control	6±2.13[a]	7±3.66[ab]	50±21.21[a]

[X] Means within the column followed by the same letters are not significantly different at P > 0.05.

WHE - Water hyacinth compost prepared using EM treatment, WHC - Water hyacinth compost prepared using cattle manure treatment. DAP - Diammonium phosphate (Nitrogen fertilizer)

Table 7

Mean dry weight of nodules per plant of common beans at pod formation stage grown in three farms under different soil amendments at Korando B during the long rainy season of 2012.

Mean dry weight (mg) of nodules at pod formation stage			
Treatment	**Farm A**	**Farm B**	**Farm C**
WHE	86.25±29.41[bX]	43.83±16.48[bX]	103.67±31.62[bX]
WHC	46.00±21.99[ab]	18.67±8.61[ab]	39.67±17.41[ab]
DAP	0.00±0.00[a]	0.00±0.00[a]	3.75±3.75[a]
Inoculum	55.54±21.09[ab]	2.25±1.64[a]	69.08±22.88[ab]
Control	7.75±4.11[a]	14.63±4.24[ab]	96.92±35.3[ab]

[X] Means within the column followed by the same letters are not significantly different at P > 0.05.

WHE - Water hyacinth compost prepared using EM treatment, WHC - Water hyacinth compost prepared using cattle manure treatment. DAP - Diammonium phosphate (Nitrogen fertilizer)

Table 8

Mean root collar diameter (mm) of common beans grown in the greenhouse at Kenyatta University under different soil amendments.

	Root collar diameter (mm) of common beans		
Treatment	**15 DAE**	**30 DAE**	**45 DAE**
WHC	3.58±0.35[abcX]	4.25±0.21[abX]	4.58±0.20[abcX]
WHM	3.87±0.09[bcd]	4.33±0.21[ab]	5.00±0.22[bcd]
WHE	4.08±0.08[cd]	5.0±0.00[bc]	5.25±0.36[cd]
DAP	4.63±0.18[d]	5.58±0.2[c]	5.83±0.17[d]
Inoculum	3.0±0.13 [a]	3.67±0.25[a]	4.25±0.17[ab]
Control	3.17±0.17[ab]	3.75±0.21[a]	3.83±0.17[a]

[X] Means within the column followed by the same letters are not significantly different at P > 0.05.

WHE - Water hyacinth compost prepared using EM treatment, WHC - Water hyacinth compost prepared using cattle manure treatment, WHM - Water hyacinth compost prepared using molasses treatment, DAP - Diammonium phosphate (Nitrogen fertilizer), DAE - Days after emergence.

Table 9

Grain yield of common beans grown in four farms under different soil amendments at Korando B during the long rainy season of 2012.

Grain yield (Kg/ha) of common beans			
Treatment	**Farm A**	**Farm B**	**Farm C**
WHE	1715.64±76.7[bX]	1191.44±95.59[a]	1458.56±87.89[bcX]
WHC	1455.6±375.62[ab]	1235.95±74.54[a]	1632.77±97.66[c]
DAP	1453.47±88.14[ab]	1277.9±144.27[a]	1066.81±111.3[a]
Inoculum	1052.02±158.40[ab]	953.08±45.54 [a]	1311.18±41.93[abc]
Control	796.49±75.45 [a]	1423.95±318.6[a]	1224.92±78.72[ab]

Means within the column followed by the same letters are not significantly different at P > 0.05.

WHE - Water hyacinth compost prepared using EM treatment, WHC - Water hyacinth compost prepared using cattle manure treatment. DAP - Diammonium phosphate (Nitrogen fertilizer)

Table 10
100 seed weight of common bean grains grown in four farms under different soil amendments at Korando B during the long rainy season of 2012.

100 seed weight (g)			
Treatment	**Farm A**	**Farm B**	**Farm C**
WHE	44.27±2.11^{abX}	40.95±1.88^{aX}	46.33±1.8^{aX}
WHC	50.21±1.72^{b}	41.52±0.99^{a}	43.60±0.88^{a}
DAP	46.00±0.70^{ab}	46.37±1.75^{a}	47.01±1.00^{a}
Inoculum	40.23±2.22^{a}	40.28±1.49^{a}	42.09±0.63^{a}
Control	40.45±1.25^{a}	41.88±2.58^{a}	44.9±2.80^{a}

^{X} Means within the column followed by the same letters are not significantly different at P > 0.05.
WHE - Water hyacinth compost prepared using EM treatment, WHC - Water hyacinth compost prepared using cattle manure treatment. DAP - Diammonium phosphate (Nitrogen fertilizer)

Table 11: Stover weight of common beans grown in four farms under different soil amendments at Korando B during the long rainy season of 2012.

Stover weight (kg/ha)			
Treatment	**Farm A**	**Farm B**	**Farm C**
WHE	375.76±41.40^{ax}	488.62±62.89^{ax}	568.14±105.01^{abx}
WHC	534.09±146.17^{a}	350.76±38.10^{a}	559.63±101.44^{ab}
DAP	489.31±22.01^{a}	740.01±58.34^{b}	704.92±29.82^{b}
Inoculum	399.81±37.25^{a}	371.48±65.46^{a}	371.91±23.48^{a}
Control	343.31±81.29^{a}	453.54±95.81^{a}	464.5673.57^{ab}

^{X} Means within the column followed by the same letters are not significantly different at P > 0.05.
WHE - Water hyacinth compost prepared using EM treatment, WHC - Water hyacinth compost prepared using cattle manure treatment. DAP - Diammonium phosphate (Nitrogen fertilizer)

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