



Response of Common Bean (*Phaseolus vulgaris* L.) Cultivars to Water Hyacinth (*Eichhornia crassipes* [Mart.] Solms) Compost in Kisumu, Kenya along the Lake Victoria Basin

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Authors' contributions

All the authors collaborated in carrying out this work. Authors OO, JMM, AA, DM and JM designed the study and supervised the field experiments. Author FK carried out the field experiments, collected the data, performed data analysis and compiled the first draft of the manuscript. All the authors read and approved the final manuscript.

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ABSTRACT

Aims: This study aimed at enhancing common bean production among the small holder farmers along the Lake Victoria basin, Kenya through the use of water hyacinth compost.

Study Design: Randomized Complete Block Design with a split-plot structure with three replications. The bean cultivars formed the main plots while fertilizers formed the sub-plots.

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Place and Duration of Study: Field trials were conducted on small holder farms in Kisumu, Lake Victoria basin during the short and long rains in 2012/2013.

Methodology: Fresh water hyacinth weeds were cut into smaller pieces and left to completely dry in the sun and allowed to decompose naturally for 45 days. The treatments consisted of control (no fertilizer), water hyacinth compost and diammonium phosphate (DAP) fertilizer (DAP). The fertilizers were applied at the rate of 46 kg ha⁻¹ of DAP or 8 T ha⁻¹ of compost along the rows and thoroughly mixed within the top 15 cm of soil to avoid direct contact with the seeds or the rhizobia inocula.

Results: Water hyacinth compost significantly ($P < 0.05$) increased nodulation and improved yield while diammonium phosphate also enhanced yield but suppressed nodulation of the beans. Other agronomic characteristics such as plant height, number of flowers and pods of beans were not significantly ($P > 0.05$) influenced with the application of either compost or diammonium phosphate.

Conclusion: Application of water hyacinth compost has the potential for use as an alternative to expensive inorganic nitrogenous fertilizers in restoring soil fertility and improving bean crop productivity in Kenya.

Keywords: *Diammonium phosphate; rhizobia inocula; nodulation; cultivars; agronomic characteristics.*

1. INTRODUCTION

Most smallholder farmers in Sub-Saharan countries particularly Kenya are faced with declining land and crop productivity [1]. Decline in soil fertility is caused by continuous cultivation of land without adequate addition of external nutrient inputs [2,3]. Nitrogen is one of the critical nutrients to plant growth and the most deficient element in smallholder farms that limits crop production. There are several options that are available to manage nitrogen in small holder farms.

Currently, chemical fertilizers are often considered to offer immediate solution to nutrient deficiencies in soil [4]. Unfortunately, these chemical fertilizers are expensive and therefore most small-holder farmers cannot afford them. Integration of legumes such as common bean (*Phaseolus vulgaris* L.) into existing cropping systems has the potential to reduce reliance on inorganic nitrogen. Common bean is the most important pulse crop in Kenya and is second only to maize as a food crop [5,6]. The national demand for this crop has been estimated at 500,000 metric tons per annum [6], and its demand is increasing at a higher rate than its production.

Unfortunately, small-holder farmers rarely apply nitrogenous fertilizers in bean production, relying mainly on the ability of the bean to fix its own nitrogen, despite the fact that beans are known to be poor nitrogen-fixers [7]. Apart from being an important source of cheap protein and income in many rural and urban households in Kenya, common bean can meet most of their N needs

and contribute to soil N through symbiotic nitrogen fixation. The other options that are used to replenish N include use of organic materials such as crop residues, animal manures and agroforestry tree prunings. Application of these organic materials to soils has multiple roles such as increasing the soil organic carbon content, soil microbial activity, and improves the soil structure and the nutrient status [8]. However, most of the commonly available organic materials on smallholder farms are of inadequate quantity and of poor quality to meet the crop nutrient demand [9]. The use of non-traditional, largely unexploited, organic resources to augment common organic inputs in crop production has received considerable research attention in the recent past [10]. One such organic material is the water hyacinth (*Eichhornia crassipes*), which is abundant in Lake Victoria. Water hyacinth is one of the world's most harmful weed because of its negative effects on waterways and people's livelihoods [11,12].

Along the Lake Victoria basin, the weed has caused devastating effects on aquatic life and the local community that depends on the lake. The weed is rich in nitrogen which could be as high as 3.2% of its dry matter [13]. It also has other macronutrients that are essential for plant nutrition [14,15]. Water hyacinth compost has been reported to enhance productivity in several crops e.g. tomatoes [16], rice [17] and *Zea mays* [18] and has the potential to be a cheaper source of N compared to commercial N fertilizers but is unlikely to supply all the N needed on smallholder farms. It is however likely to be a useful input in integrated soil fertility management of beans. The aim of this study was

to evaluate the effect of water hyacinth compost on the vegetative growth and yield of common bean.

2. MATERIALS AND METHODS

2.1 Study Site Description

The study was carried out in Korando B location within latitude 0° 20' S and 0° 50' S and longitude 33° 20' E and 33° 50' E, Kisumu district, western Kenya. The site is located at an altitude of 1300 meters above sea level with an annual relief rainfall of 1200-1300 mm and experiences bimodal rainfall pattern with long rains received between March and May and the short rains received between October and December every year. Kisumu soils are generally classified as Arenosols. The soils are coarse, weakly developed mostly sandy with an identifiable B horizon and clay content of less than 18% [19]. The site was selected based on agro-climatic conditions and prevalence of common bean cultivation. The other main crops grown include maize, sorghum, finger millet, sweet potatoes, groundnuts, kales and cotton. The soil samples were collected from a depth of 30 cm from 5 points (the centre and at the four corners) within the farm and thoroughly mixed, bulked and sub-sampled for chemical analysis. Soil samples were analyzed for pH, organic carbon (% C), total N (% N), available P and exchangeable bases according to procedures [20].

2.2 Preparation of the Compost

Fresh water hyacinth weeds were harvested from Lake Victoria, cut into smaller pieces and left to completely dry in the sun and allowed to decompose naturally above ground for approximately 45 days. The final compost was analyzed for the physical and chemical characteristics.

2.3 Experimental Design

The field experiments were conducted during the short rains and long rains in 2012/2013. The experiments were laid out in a randomized complete block design (RCBD) with a split plot arrangement and replicated three times. The common bean cultivars formed the main plots while fertilizers formed the sub-plots with a 1 m alley between the plots to minimize inter-plot

interference. The two common bean cultivars used for this study included a commercial cultivar: *Mwitemania* and a farmer-preferred cultivar: *Yellow* bean. The treatment consisted of control (no fertilizer), water hyacinth compost, inorganic fertilizer (DAP). The fertilizer were applied at the rate of 46 kg ha⁻¹ of DAP or 8 T ha⁻¹ of compost along the rows and thoroughly mixed within the top 15 cm of soil to avoid direct contact with the seeds or the rhizobia inocula. The *rhizobium* strain 446 inoculum was obtained from the MIRCEN Project, University of Nairobi. The size of each sub-plot was 1.50 × 2.55 m and seeds planted at 15 cm and 40 cm within and between rows. Rhizobium inoculant was applied at the rate of 100 gms of inoculant for 15 kg of seeds wetted with adhesive (gum Arabic solution). The moist seeds were mixed with the inoculant in the shade, sown immediately and covered with soil to minimize rhizobia exposure to the sun. Two to three seeds were placed in the furrows at the recommended spacing of 30 × 15 cm. The plants were later thinned to one per hole after emergence. After planting, the plants were monitored and managed using recommended agronomic practices [21].

2.4 Yield Assessment

Three to four plants were randomly selected from each sub-plot and dug out at 7 weeks after emergence and separated into shoots and roots. Soil was carefully washed from the roots, nodules isolated from roots and their numbers recorded for each plant. The shoots and roots were oven-dried at 70°C for 48 h for dry weight determination. At maturity, pods were harvested from each experimental plot, excluding the outer rows and the outer guard plants in each row, shelled and tagged for yield assessment. The grains were completely sun-dried and weighed. Yield parameters determined included plant height, leaf area, number of flowers and pods per plant and total grain yield. Seed yield per hectare were be extrapolated from the seed yield per plot.

2.5 Data Analysis

The data obtained from measurement of various growth and yield parameters was analyzed using analysis of variance (ANOVA) with SPSS computer software version 16 for Windows. Means were separated using Tukey's significant difference at 5% level.

3. RESULTS

3.1 Soil and Compost Analyses

Generally the physico-chemical analysis showed that the soil in the study site was relatively fertile based on organic C and total N, with a few exceptions the soil samples showed the locations had plenty of organic matter, available P and major cations (Table 1) while the composition of water hyacinth compost is shown in Table 2.

3.2 Nodulation

The application of organic manure (water hyacinth compost) and nitrogen fertilizer (DAP) significantly ($P < 0.05$) influenced nodulation of the two non-inoculated common bean cultivars. *Mwitemania* cultivar grown in water hyacinth amended soil and control had the highest number of nodules while inoculant enhanced *rhizobium* root colonization in soil with no treatment while DAP suppressed nodulation (Fig.

1 and Table 3 a & b). The results show that water hyacinth compost enhances the build up or root colonization of *mwitemania* by the indigenous rhizobia populations but not in the local bean cultivar, *yellow bean*. *Yellow bean* recorded the least number of nodules in inoculated treatments except in non-inoculated control. No nodules were observed in non-inoculated *yellow bean* plants grown in DAP amended soil (Fig. 1).

3.3 Dry Matter Accumulation

All the treatments significantly influenced the dry matter ($p < 0.05$) of inoculated *yellow bean* plants (Table 4a) while there was no effect on the non-inoculated treatments (Fig. 2 and Table 4b). *Yellow bean* grown in soils amended with both DAP and the compost showed increased growth and hence accumulation of biomass compared to control. No significant ($p < 0.05$) differences were observed on the dry matter of inoculated and non-inoculated *Mwitemania* beans grown in the soil amendments (Table 4a & b).

Table 1. Physico-chemical characteristics of the soil at the experimental site

Chemical property	pH	OC (%)	N (%)	C:N	K (Cmol/kg)	Na (Cmol/kg)	P (ppm)	Ca (Cmol/kg)	Mg (Cmol/kg)	Zn (ppm)
Test value	4.13	2.5	0.24	10	0.45	0.1	19	2.5	0.8	1.6

Table 2. Physico-chemical characteristics of water hyacinth compost

Chemical Property	pH	OC (%) (Cmol/kg)	N (%) (Cmol/kg)	K (Cmol/kg)	Na (Cmol/kg)	P(ppm)	Zn(ppm)
Test value	8.37	12.23	1.33	2.5	2.1	98.0	3.21

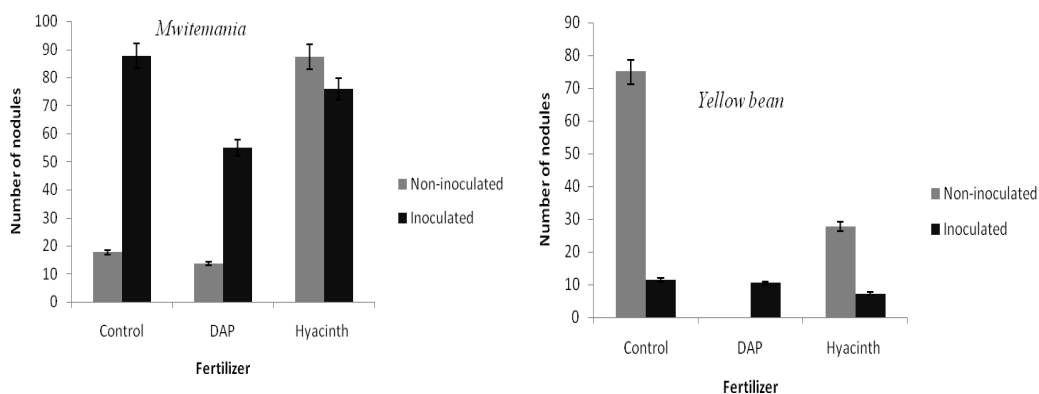


Fig. 1. Effect of *Rhizobium* inoculation on the number of root nodules per plant of *mwitemania* and *Yellow bean*

Table 3. Mean growth characteristics of non-inoculated a) *mwitemania* and b) *yellow bean* grown in soils amended with water hyacinth compost and DAP

a)

Treatment	Leaf Area	Height (cm)	No. of flowers	No. of pods	No. of nodules	Dry mass (g)	Yield (g) per plot
Control	40.70	3.53	17.00	13.67	17.67	4.80	123.64
DAP	44.13	3.43	18.00	15.33	13.67	5.77	121.48
Hyacinth	44.90	3.83	18.00	15.67	87.33	7.67	136.63
P value	0.459	0.705	0.935	0.729	0.004	0.079	0.846

b)

Treatment	Leaf Area	Height (cm)	No. of flowers	No. of pods	No. of nodules	Dry mass (g)	Yield (g) per plot
Control	36.03	3.03	15.33	13.33	75.00	5.44	132.82
DAP	41.70	3.97	21.00	19.33	0.00	6.94	108.53
Hyacinth	31.30	4.00	17.67	15.00	27.33	5.83	93.063
P value	0.65	0.09	0.22	0.12	0.007	0.25	0.42

Table 4. Mean growth characteristics of inoculated a) *Yellow* and b) *Mwitemania* bean grown in soils amended with water hyacinth compost and DAP

a)

Treatment	Leaf Area	Height (cm)	No. of flowers	No. of pods	No. of nodules	Dry mass (g)	Yield (g) per plot
Control	30.67	4.00	15.33	21.67	11.85	2.56	30.67
DAP	34.43	4.167	12.33	11.33	10.50	9.21	34.43
Hyacinth	32.87	3.90	14.33	12.67	7.27	6.39	32.87
P value	0.881	0.809	0.839	0.504	0.368	0.002	0.881

b)

Treatment	Leaf Area	Height (cm)	No. of flowers	No. of pods	No. of nodules	Dry mass (g)	Yield (g) per plot
Control	30.67	4.00	15.33	21.67	11.85	2.56	30.67
DAP	34.43	4.167	12.33	11.33	10.50	9.21	34.43
Hyacinth	32.87	3.90	14.33	12.67	7.27	6.39	32.87
P value	0.881	0.809	0.839	0.504	0.368	0.002	0.881

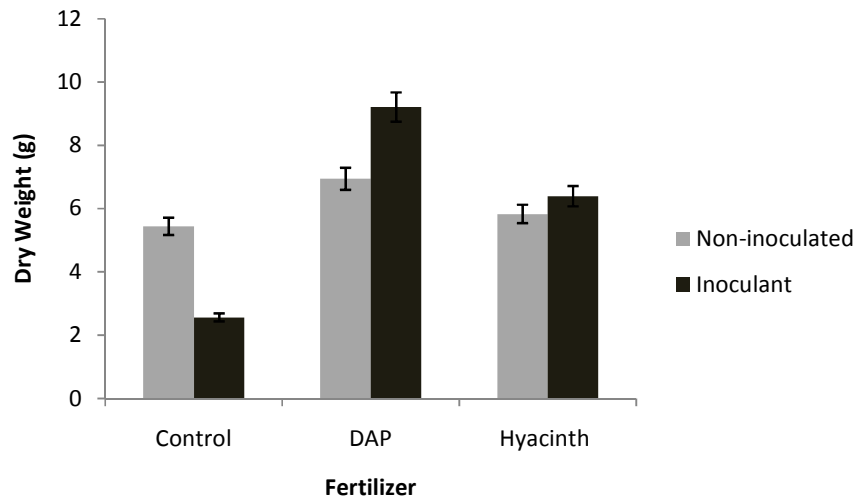


Fig. 2. Effect of *Rhizobium* inoculation on the dry weight (g) per plant of *Yellow* bean

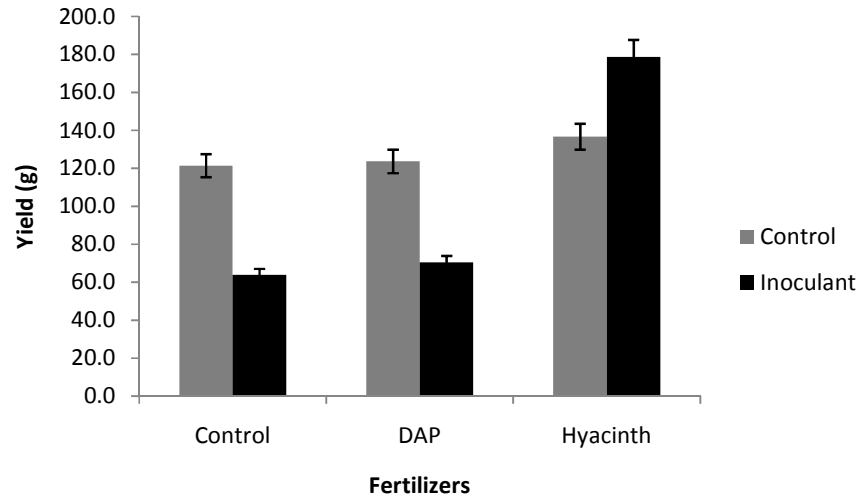


Fig. 3. Effect of *Rhizobium* inoculation on the yield per plot of *Mwitmania*

Table 5. Effect of cultivar and inoculation levels on the growth characteristics of common bean plants

Source of variation	df	Leaf area	Plant height	Flower count	Pod count	Nodule count	Dry weight	Yield (g)
Cultivar	2	0.312	0.373	0.741	0.595	0.658	0.853	0.009*
Inoculation (I)	2	0.006	0.071	0.014	0.222	0.037	0.012	0.005*
Cultivar x Inoculation	4	0.151	0.457	0.516	0.326	0.146	0.672	0.036*

Asterisk indicates the significant effect, ($p < 0.05$)

3.4 Plant Agronomic Traits and Yield Characteristics

The agronomic traits of plants and yield characteristics of beans grown in soil amended with water hyacinth compost, DAP and control did not show any significant ($p < 0.05$) differences. Largest leaf area of the plants was observed in non-inoculated *mwitemania* beans under DAP treatment but decreased in inoculated plants (Table 3b). In *Yellow* bean, no variation occurred in the leaf area under different treatments. Plant height, number of flowers and pods per plant of both inoculated and non-inoculated cultivars were not influenced by the application of DAP and water hyacinth manure as compared to the control. Non-inoculated *yellow* bean in DAP amended soils had the highest number of flowers while the highest number of pods was recorded in inoculated un-amended soil. There was significant difference in yield per plot of inoculated *Mwitmania* bean ($p < 0.05$). The highest yield was recorded in water hyacinth compost [467.27 kg/ha] as compared to DAP [166.98 kg/ha] and control [184.10 kg/ha] (Table 4b and Fig. 3) There was

no interaction between cultivar and inoculant on the growth of bean plants except the yield (Table 5).

4. DISCUSSION

Incorporation of water hyacinth into soil crop system has increased the yield of many crops [8]. The current study showed that inoculation of the seeds did not influence most of the measured variables, conforming to previous studies that showed insignificant response to *Rhizobium* inoculation in common bean in low-N soils in western Kenya [22]. Lack of response due *Rhizobium* inoculation has been attributed to the competition between the indigenous *Rhizobia* population in soil and inoculum strains [23]. There is evidence that certain *Rhizobia* strains are only able to improve N_2 -fixation and yields in specific common bean cultivars [24], and this could contribute to the frequent low yields resulting from inoculation [25]. Inorganic fertilizer (DAP) improved yield per plot but reduced the number of nodules and nodule dry weight per plant. The addition of organic fertilizer has been reported to improve the plant characteristics and

increased the yield [26]. Nodulation inhibition and reduction in dry weight due to external N fertilizer application have been reported [4,27]. Other legumes such as French beans grown without N fertilization had many nodules in their roots per plant [28]. The absence of nodules in inoculated beans could be due to poor inoculant quality and incompatibility of the inoculant strain with the *mwitemania* and *yellow* bean cultivars. The non significance influence on plant height, leaf area, number of flowers and pods and grain yield could be due to moderate amount of nitrogen presence in the experimental site. Maximum plant height and leaf area observed in soils amended by DAP and water hyacinth compost were similar to those reported [29]. Organic compost and inorganic fertilizer (Urea) enhanced plant growth and nutrient uptake as compared with the control [30]. Improved leaf area in plants observed after organic manure application could be due to the rapid conversion of nitrogen content of leaves to protein leading to a larger leaf area of the beans [31,32]. The higher yield in inoculated *mwitemania* plants could be due to the low N status in soil. Improved yields have been observed in legumes grown in N deficient soils amended with of inorganic fertilizer [33]. The inability of water hyacinth compost to significantly increase grain yield could be due to its slow release of nutrients. It has been reported that application of compost over longer period of time produced better yields than inorganic fertilizer due to its slow but steady release of nutrients [34]. Compost regulates the soil pH by binding the exchangeable Aluminium ions releasing plant nutrients slowly which insignificantly improves yield during the first season following application [35]. The soil status could have contributed to minimum response of bean to inoculation and fertilizers.

5. CONCLUSIONS

Inorganic fertilizer improved the yield of common bean, however extensive use of chemical fertilizers in agriculture is currently under debate due to environmental concern and fear for consumer health. The use of water hyacinth unlike other common organic materials on smallholder farms, which are often not available in adequate amounts, provides an alternative to expensive inorganic nitrogenous fertilizers. The compost is rich in N and other macronutrients that are essential for plant nutrition and can be used to restore declining land and crop productivity.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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