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The performance of selected commercial organic fertilizers on the growth and yield of bush beans in Central Uganda

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To assess the quality of commercial organic fertilizers in Uganda market, a quick survey was conducted to establish the organic fertilizers being sold in Container village market in Kampala Capital City. Different products were found being sold as organic fertilizers. Four of these fertilizers are two solid (Biochar and Fertiplus) and two liquid (Biogrow and Digrow) selected for a field study. Field trials to assess the performance of the fertilizers and local farmyard manure on bush beans *(Phaseolus vulgaris*) were conducted at two locations (Kabanyolo and Nkozi) for two successive seasons in 2017 and 2018 using a randomized complete block design in four replications. Forty days after planting, fresh and dry weights were estimated while biomass and grain yield were determined at harvest. The results showed inconsistencies. For example, although Biochar was found to significantly (P=0.043) increase the mean fresh weight of bush beans in season 1 (2017) at both sites (Kabanyoro and Nkozi), this was not the case in season 2 (2018). Similar performance was found with the other treatments. The mean biomass did not increase significantly (P>0.05) in season 1 (2017) and season 2 (2018) at both locations. The results in season 2 (2018) showed no significant (P>0.05) increase in the mean yield. These results were attributed to the extreme weather conditions experienced in both seasons (severe drought during season 1 and heavy rains that led to prolonged vegetative growth during season 2). These field trials should be repeated under controlled environment to minimize the weather effect.

Key words: Organic fertilizers, plant growth, yield.

INTRODUCTION

Uganda is considered as one of the countries with highest soil nutrient depletion rates in the world; it has the lowest rates of annual inorganic fertilizer application – only 1.8 kg per ha (Namazzi, 2008). Consequently, most crops grown in the country produce only a small fraction of their potential yield (Tadele et al., 2017; Nabbumba and Bahigwa, 2003). This very low use of inorganic fertilizers is mostly attributed to the very high cost of these inorganic fertilizers and also to lack of knowledge by the majority smallholder farmers on the benefits of

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using inorganic fertilizers (Okoboi and Barungi, 2012). According to Namazzi (2008), the World Bank calculated that the value of replacing these depleted soil nutrients could be 20 percent of average rural Uganda household income. A recent survey conducted in the Container Village market in Kampala where most traders and farmers buy agro-inputs (Tugume, 2018) revealed that 95 percent of the agro-input shops visited in the village were stocking / selling both organic and inorganic fertilizers. It also revealed that the fertilizer market was dominated (82%) by liquid fertilizers which were organic fertilizers. High market dominance of these liquid organic fertilizers was that they are quite cheap compared to the solid inorganic fertilizers as one or two liters of the liquid organic fertilizers can cover an acre of crops through foliar application compared to 100 kg or more of solid inorganic fertilizers such as urea or NPK to cover same acre of crops. So smallholder farmers in Uganda have persistently shown no interest in adopting the use of inorganic fertilizers; they are increasingly being forced by circumstances to invest in use of both local manures and imported organic fertilizers to enhance soil productivity (Sheahana and Barrett, 2017; Nalubwama et al*.,* 2011; Kidd et al., 2001; Elzakker and Leijdens, 2000). Therefore, there is increasing demand for organic fertilizers in the country to improve crop productivity and farm returns to investment.

Currently there are many products on the agro input market in Uganda that are promoted and marketed as organic fertilizers and plant growth promoters. Unfortunately most of these products are not locally tested for their effectiveness as fertilizers. Therefore their ability to improve crop productivity is speculative. Government policies on the procurement and use of fertilizers are important determinants of the intensity of fertilizer use in a country and directly affect the profitability of fertilizer use by smallholder farmers (Bayite et al*.,* 2011). In Uganda, there has been limited policy regulation to guarantee the marketing and use of quality fertilizers, particularly organic fertilizers (MAAIF, 2016). Generally there is no evidence that shows that the products on the market are genuine organic fertilizers with the right and recommended quantity and quality of nutrients required to support proper crop growth and increase production in agriculture.

Bush beans however are cultivated and produced in all districts in Uganda but commonly in central, eastern and western parts of Uganda (FAO, 2017). They are often cultivated by smallholder farmers on wide range of soils (Tugume, 2018; Sibiko, 2012). Farmers grow both local varieties like yellow, kanyebwa and improved varieties of NABE and K series. The NABE series is more tolerant to droughts, diseases and therefore adapted to face unreliable rains and rainfall variability induced by climate change (FAO, 2017). The study used NABE 17 variety that is tolerant to diseases and also commonly grown by farmers with high acceptability in the market. Bush beans are also selected due to their positive response to Nitrogen nutrient fertilizers at vegetative stage whichincreases the plant yield (Henson and Bliss, 1991). Therefore the purpose of this study was to assess the performance of a few selected commercial organic fertilizers on the market in Uganda in increasing the growth and yield of bush beans that are commonly cultivated by smallholder farmers in most parts of the country.

MATERIALS AND METHODS

Location of the study

The study was conducted at Kabanyolo near Makerere University Agricultural Research Institute, Kabanyolo (MUARIK), located 17 km north of Kampala and at Equator Valley Farm of Uganda Martyrs University near Nkozi Trading Centre located about 80 km south west of Kampala on the Kampala-Masaka highway. Both sites are located in the Lake Victoria Crescent agroecological zone in central Uganda (Figure 1). They both receive an average annual precipitation of about 1200 mm and two dry periods in June to July and December to February. The monthly average temperature in season one from March to June is 22°C for both locations; 20 and 21.3°C from September to December for both Kabanyolo and Nkozi sites (Mibulo and Kigundu, 2018; Mpigi District local Government; 2015). Both sites have sandy clay to sandy clay loam soils with 54-76% sand, 4 - 14% silt, and 20- 42% clay (Table 1).

This study included six treatments consisting of four commercial organic fertilizers (Biochar, DIgrow, Fertiplus, Biogrow), local farmyard manure and a control for two consecutive seasons using a randomized complete block design in four replicates. Plot size was 4m by 3m and beans were spaced 50cm by 20 cm with two seeds planted in each hole.

Samples of the selected organic fertilizers, soils from the experimental fields at Kabanyolo and Equator Valley Farm in Nkozi and local farmyard manure were collected and taken for physical and chemical analysis by Soil, Plant and Water Analytical Laboratory of the Department of Agricultural and Environmental sciences at Makerere University to establish their nutrient contents. These samples were analyzed using routine procedures outlined by Okalebo et al. (2002) and other standard operating procedures (SOPs) that are internationally recommended.

Experimental set up and management

Fertilizer application

The rates, method and time of application of the organic fertilizers were determined according to the manufacturers' recommendations (Table 1). The liquid fertilizers, Biogrow and DIgrow, were applied at vegetative stage, three weeks after planting, when nitrogen is sufficiently needed by beans for shoot development and at flowering 6 weeks for high pod development (Henson and Bliss, 1991).

Planting

Experimental plots were planted with bush bean *(Phaseolus vulgaris),* variety NABE 17, and an improved variety tolerant to drought stress and are early maturing at 58-70 days. Planting was done at the first week of October 2017 in the first season and in the second week of March 2018 in second season. The seed rate was two seeds per hole at a spacing

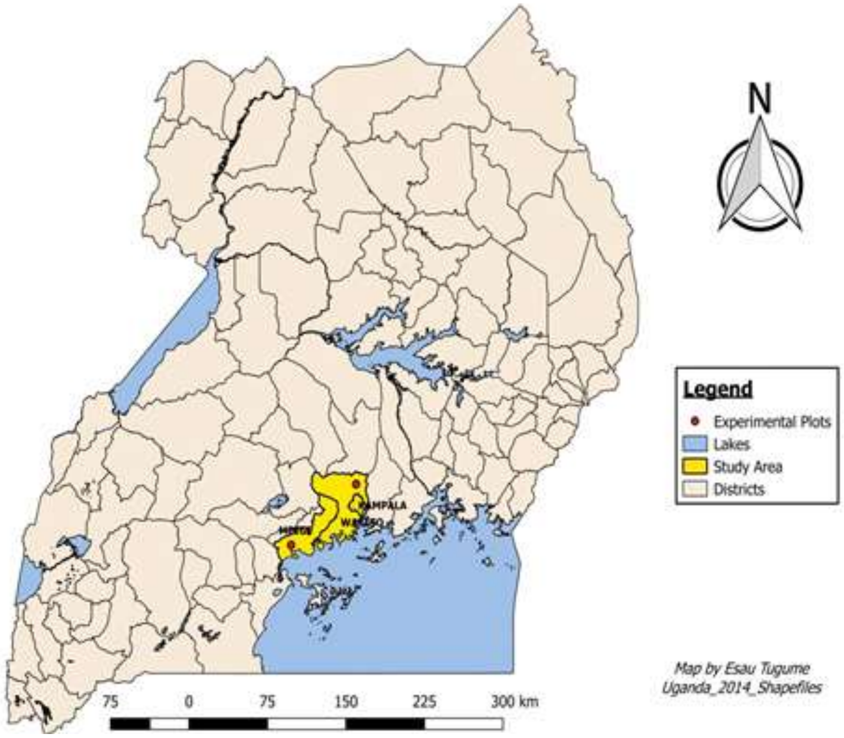

Figure 1. Map of Uganda showing the location of the experimental sites.

Table 1. Organic fertilizers used in the study, their rates, method and time of application.

Fertilizer type	Recommended rate of application	Stage of application
Biochar (solid pellets)	1500 Kg ha^{-1}	At planting using broadcasting and incorporation into the seedbed
Fertiplus (solid pellets)	1500 Kg ha^{-1}	At planting using broadcasting and incorporation into the seedbed
Farmyard manure (solid)	5000 Kg ha^{-1}	At planting using broadcasting and incorporation into the seedbed
DIgrow (liquid)	1 L ha^{-1}	Foliar application carried out at 3 weeks after planting and 1 week after onset of flowering
Biogrow (liquid)	500 ml ha^{-1}	Foliar application carried out at 3 weeks after planting and 1 week after onset of flowering

of 50 by 20 cm.

Weeding

First weeding was done three weeks after planting; before application of liquid organic fertilizers and the second weeding was done in the sixth week after planting.

Data collection

Plant fresh and dry weight

At the onset of flowering (40 days after planting), a representative sample of five bean plants was randomly selected and uprooted from each plot in the experimental field and immediately weighed using an electronic weighing balance to record plant fresh weight at that stage. The five bean plants uprooted from each plot were then put in well-labeled paper bags and dried under shade for a period of two weeks then measured using the same electronic weighing scale.

Harvest and yield measurement

Harvesting was done at 10 weeks after planting when all bean plants and pods were completely dry. Hand pulling was used to uproot the bean plants from the soil and all the plants from each plot were carefully packed in a large well labeled polythene bag (sack) and weighed to obtain the biomass yield from each plot. Bean plants were then dried for five days before threshing to obtain the grain yield from each plot. Finally, the bean grain from each plot was weighed using an electronic spring balance. This was done following one of the methods of measuring crop yield outlined in FAO (2018).

Table 2. Laboratory analysis results of the organic fertilizers and local farmyard manure used in the study.

Fertilizer	pH	O. M. (%)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Na (%)
Biochar	-	-	3.02	0.34	0.82	2.52	0.83	0.63
Biogrow	4.63	-	0.34	0.31	1.47	2.52	0.87	0.50
DIgrow	6.60	-	1.23	2.31	1.85	2.21	0.77	0.63
Fertiplus	-	-	3.25	3.40	1.83	3.57	1.21	0.84
Kabanyolo manure	-	12.08	1.40	1.90	1.05	2.63	0.88	0.68
Nkozi manure	-	14.29	1.26	2.20	1.05	3.15	1.08	0.63

The sign (-) refer that this parameter not analyzed; the obtained results carried by laboratory Analysis at Soil, Plant and Water Analytical Laboratory of Makerere University.

Table 3. Soil sample analysis results for two seasons at Kabanyolo and Nkozi.

Soil parameter	Kabanyolo		Nkoz1	
	1st season field	2nd season field	1st sesoan field	2nd season field
pH	6.54	6.89	5.47	6.40
OM (%age)	3.51	3.51	3.22	2.63
N (%age)	0.20	0.21	0.18	0.16
P (mg/kg)	2.56	4.13	16.00	16.73
K (Cmoles/kg)	0.27	0.41	0.27	0.68
Ca (Cmoles/kg)	7.69	7.88	6.66	7.93
Mg(Cmoles/kg)	2.10	2.24	1.87	2.13
Na (Cmoles/ kg)	0.23	0.21	0.28	0.37
Textual %ages				
Sand	54.00	56.00	76.00	68.00
Clay	42.00	30.00	20.00	26.00
Silt	4.00	14.00	4.00	6.00
Textual characterization	Sandy clay	Sandy clay loam	Sandy loam	Sandy clay loam

Statistical data analysis

The experimental design was randomized complete block design with four replicates. The obtained data were submitted to analysis of variance according to GenStat 14 Edition package. Differences among treatment means were determined using Duncan's multiple range test.

RESULTS AND DISCUSSION

Laboratory analysis results

The results of the laboratory analysis of the organic fertilizers and local farmyard manures used in the study are presented in Table 2, while those of soil samples collected from the experimental fields at Kabanyolo and Equator Valley Farm in Nkozi are presented in Table 3. The results in Table 2 show that these materials had good contents of the major plant nutrients Beside the analysis of the experiment soil as presented in Table 3 indicate that it was sandy and had low content of organic matter, therefore, the selected organic fertilizers and manures were expected to have significant effects on bean growth and yield on these soils.

Effect of selected organic fertilizers and local manure on the plant fresh weight of bush beans

Table 4 shows results of plant fresh weight mean at 40 days after planting. These results show significant difference (P=0.043) between the fertilizers and control treated plots in season 1 (2017) at Kabanyolo. Fertiplus and Biochar significantly increased the fresh weight of the bean plants (143.5 and 135.0 g) as compared with the control and other treatments. Biogrow fertilizer did not significantly differ from the control in increasing mean vegetative fresh weight of bush beans (*P. vulgaris*).

At Nkozi in season 1 (2017), application of organic fertilizers did not result in any significant increase in plant fresh weight (P=0.140). However, amendment of soil with Biochar produced a slightly higher increase in plant fresh weight (131.25 g) compared to the control (73.00 g) and

Table 4. Effect of selected organic fertilizers and manure on mean plant fresh weight mean (g) at 40 days after planting.

Treatment	1st season		2nd season	
	Kabanyolo	Nkozi	Kabanyolo	Nkozi
Control	92.20^{a}	73.00^{a}	481.8^{a}	311.0^{a}
Biogrow	94.80^{a}	80.75^{a}	522.8^{a}	314.5^{a}
DIgrow	118.0^{ab}	90.50^{ab}	531.0^{a}	322.5^{a}
Cow dung	131.5^{ab}	102.25^{ab}	533.0^{a}	343.8^{ab}
Fertiplus	135.0^{b}	102.25^{ab}	534.8^{a}	361.0^{ab}
Biochar	143.5^{b}	131.25^{b}	570.5^{a}	449.5^{b}
e.s.e	12.35	14.58	52.0	38.0
P.Value	0.043	0.140	0.906	0.158

Means with similar letters in each column are not significantly different at P≥0.05. Means were separated by Duncan's multiple range tests. e.s.e is the estimated standard error of mean.

other treatments. In season 2 (in 2018), there was no significant increase in plant fresh biomass at both sites but Biochar again performed better than other treatments. Therefore Biochar consistently performed better than the other treatments in both seasons and across the two locations. This may be attributed to its nutrient composition especially nitrogen and its ability to release nutrients into the soil for plant uptake that consequently facilitated plant growth. Relatedly Islam et al. (2016) reported that vermicompost significantly increased the plant height of long and bush beans. Similar results were reported by Singh and Chauhan (2009) in bush beans. Pulak (2014) also found that organic growth promoters significantly increased the plant growth of chick peas with respect to height and branching. Such insignificant increase in plant fresh weight mean concur with findings of Karambu (2013), who reported that soya bean plant height was insignificantly affected by farm yard and poultry manure. Shehata and Helaly (2010) also reported that pod length in bush bean (*P. vulgaris*) was not significantly different when treated with vermicompost and ordinary compost. Insignificant increase in fresh weight can be attributed to slight differences in the nutrient composition of organic fertilizers as well as slow mineralization of cow dung that affect nutrient uptake by plants (Otieno et al., 2007).

The differences in mean plant fresh weight of bush beans under similar treatments from different locations and seasons could be attributed to climatic factors such as rainfall distribution and soil properties. In season 1 (2017) little rain distributed at the start of the growing season affected the physiological processes and consequently affected the plant growth. It is well known that rainfall increases soil moisture availability which affects mineralization of soil nutrients which could have affected plant nutrient absorption. This argument agree with Vanlauwe et al. (2002) who noted that variability in climatic factors such as rainfall and temperature make the synchrony between nutrient release from tree litter and crop nutrient uptake become difficult goal to achieve in practical terms. Jonasson et al*.* (2004) also reported that insufficient moisture or warming in soils limit the response of crop to N nutrient which hinders plant physiological activities. In season 2, rainfall was adequately distributed in Kabanyolo and Nkozi sites which could have led to leaching of important organic nutrients available in organic fertilizers and leading to insignificant increase in the mean of plant fresh weight of bush beans. Rainfall distribution could have affected positively the soil nutrient mineralization process resulting from available organic matter and nitrogen which lead to equal distribution and nutrient availability for plant uptake across all treatments, consequently leading to high insignificant increase in plant fresh weight.

Effect of selected commercial organic fertilizers and local manures on plant dry weight of bush beans *(P. vulgaris)*

Results presented in Table 5 indicate no significant increase in the mean value of vegetative dry weight of bush beans in plots treated with fertilizers and control (P=0.06) in season 1(2018) at Kabanyolo site. There was an observed significant difference in increase of plant dry weight mean in plots treated with Biochar (29.75 g) and Cow dung (27.75 g) compared to other fertilizers and control (17.00 g) treatment. At Nkozi site, there was no significant difference in increase of mean weight of bush beans (P=0.140) in season 1(2017) (Table 5). Mean value of plant dry weight in bush beans differed significantly in plots treated with Biogrow (28.75 g) as compared with control treatment (17.50 g).

Data results of season 2(2018) as presented in Table 5 also showed no significant difference in dry weight as affected by fertilizer and control (P=0.906, P=0.158) in both locations. The effect of different organic fertilizers on the mean vegetative fresh weight was found not significant as compared with control. The effect of organic fertilizers in increasing plant dry weight may be

Table 5. Effect of selected commercial organic fertilizers and local manures on the plant dry weight.

Location	1st season		2nd season	
	Kabanyolo	Nkozi	Kabanyolo	Nkozi
Treatment	Mean dry weight (g)	Mean dry weight (g)	Mean dry weight (g)	Mean dry weight (g)
Control	17.00[a]	17.50[a]	63.25[a]	49.00[a]
Biogrow	21.75[ab]	28.75[b]	63.25[a]	51.50[a]
DIgrow	22.25[ab]	23.75[ab]	71.75[a]	45.75[a]
Fertiplus	25.25[ab]	23.00[ab]	63.00[a]	47.00[a]
Cow dung	27.75[b]	17.25[a]	64.00[a]	58.25[a]
Biochar	29.75[b]	19.25[ab]	68.50[a]	52.00[a]
e.s.e	2.8	3.4	6.1	4.6
P.Value	0.062	0.183	0.618	0.468

Means with similar letters in each column are not significantly different at P≥0.05. Means were separated by Duncan's multiple range tests. e.s.e is the estimated standard error of mean.

attributed to the high rain fall distribution that facilitated vegetative growth leading high shoot formation with high water content. The water content could have been lost in evaporation and transpiration processes leading to also equal loss of water content in the bush bean shot system during drying process. The results are also in agreement with Islam et al. (2016) who recorded that vermin compost was found to be not significantly different from control in increasing mean dry biomass plant height of yard long beans. A contrasting finding confirmed non-significant effect on plant height as a result of spray of varied concentration of panchagavya foliar application on green gram (Somasundaram et al*.,* 2003). However, the results contradicted with Valdez et al*.* (2011) who reported that significant increase was observed in total shoot, root and pod biomass of legumes grown under vermin compost.

Effect of selected commercial organic fertilizers and local manure on the plant biomass of bush beans *(P.vulgaris)*

Figures 2 and 3 show mean biomass yield in season 1(2017) and 2(2018), respectively. No significant difference was recorded in season 1, (P=0.55 and P=0.22) and season 2 (P=0.6 and P=0.07) in mean biomass yield of bush beans at Kabanyolo and Nkozi. However, fertilizers Biogrow (0.1715 kg) were significantly different from other fertilizers and control in increasing the mean biomass yield of bush beans in season 1(2018) at Nkozi. Similarly Biochar (0.256 kg) was significantly higher than the control in season 2 (2018) at Nkozi. Fertilizer treatments produced higher mean biomass yield of bush beans in both season in Nkozi than in Kabanyolo.

The lack of response in bean biomass yield to the application of organic fertilizers and local manure could be attributed to severe drought which seriously affected the field trials during the first season and excessive rainfall during the second season that resulted into high vegetative growth especially since soils had relatively adequate nitrogen and organic matter content. This can also be attributed to high rainfall distribution that tends to encourage high mineralization of applied organic fertilizers and stored soil nutrients thereby increasing nutrient uptake and exponential shoot development forming large plant canopy that affect flowering and pod formation.

The results concur with Islam et al*.* (2016) who reported no significant increase in the mean dry pod weight of long beans in plots treated with vermin compost compared to control. Shehata et al. (2011) also reported that almost similar trend was observed when vermin compost did not significantly increase the pod length of bush beans compared to compost treated plots. In contradictory view, results of this study disagree with Lalljee (2006) findings who reported that in vermin compost treatment, pod dry weight of the legumes was significantly higher than in plants from compost and farmer's practice treatments.

Effect of commercial organic fertilizers on the grain weight mean of bush beans

Results presented in Table 6 show the grain yield mean of bush beans (in $Kgha^{-1}$) for season two. No grain yield was recorded in season one because field trials in both locations were severely affected by drought.

In season 2(2018), no significant increase in grain yield weight mean was observed in both locations. All fertilizer treated plots did not significantly differ from the control in increasing grain yield of bush beans. Season two, grain yield was most likely positively affected by the adequate rainfall distribution that influenced mineralization of soil

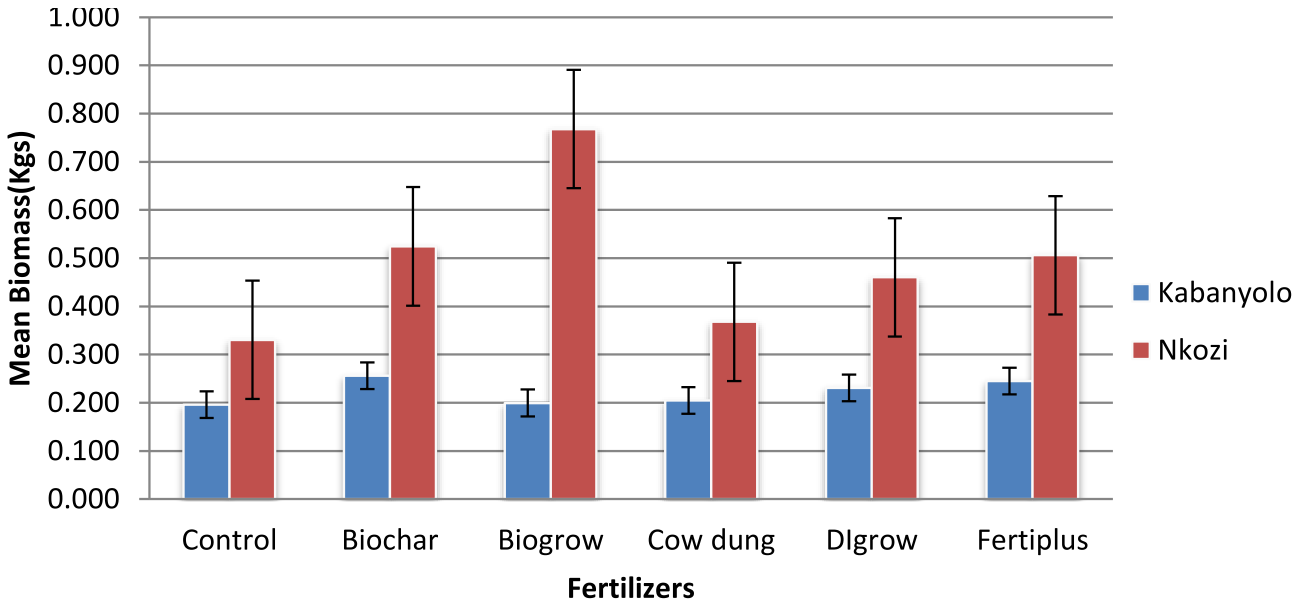

Figure 2. Yield biomass mean at Kabanyolo and Nkozi in season 1 (2017).
Source: Field experimental data, season 1(2017).

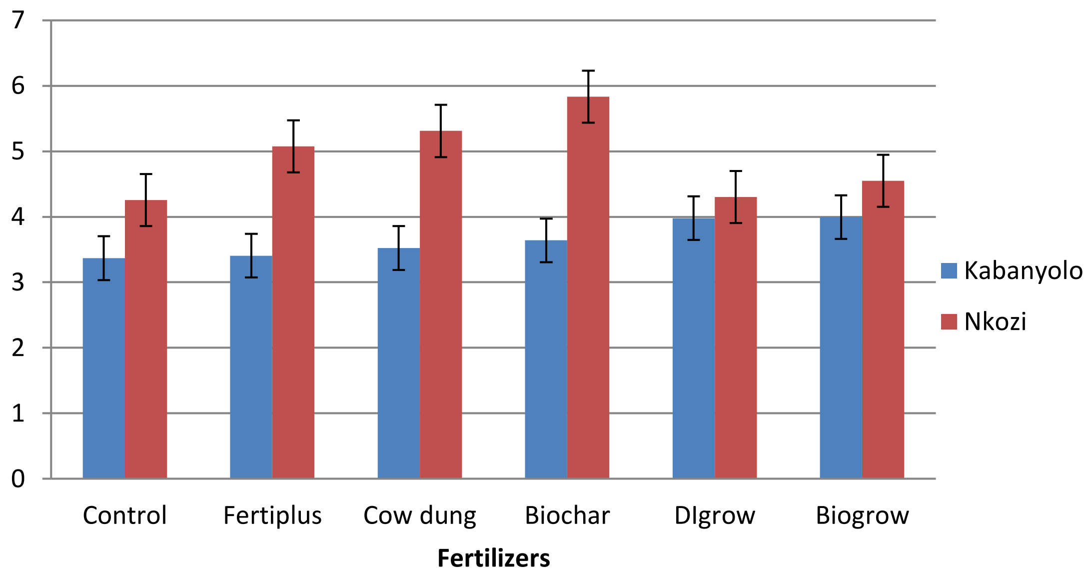

Figure 3. Yield biomass mean at Kabanyolo and Nkozi in season 2 (2018).
Source: Field experimental data, season 2 (2018).

nutrients leading to high nutrient plant nutrient uptake. This could have encouraged high photosynthetic rates facilitating exponential development of growth and yield parameters. Karambu (2013) reported closely related finding that different soil amendments did not differ significantly from each other and control in increasing mean stover yield of TGX Variety of Soybean. Since all soil samples from the experimental plots were found containing nitrogen levels (Table 3), high rain fall distribution could have facilitated quick nutrient release and absorption by plants leading to increase physiological development of bush beans in season 2, 2018. Organic fertilizer laboratory results in Table 2 also confirm that some organic fertilizers were deficient of major macro nutrients which could have led to insignificant effect on the grain yield of bush beans

Table 6. Effect organic fertilizers on grain yield mean of bush beans.

Location	Season 2, 2018	
	Kabanyolo	Nkozi
Fertilizers	Mean grain weight ($Kg^{-1}ha$)	Mean grain weight ($Kg^{-1}ha$)
Control	1565[a]	1406[a]
Cow dung	1581[a]	1525[a]
DIgrow	1637[a]	1450[a]
Biogrow	1607[a]	1623[a]
Fertiplus	1570[a]	1629[a]
Biochar	1584[a]	1804[a]
e.s.e	107.89	144.39
P.Value	0.997	0.45

Means with similar letters in each column are not significantly different at P≥0.05; Means were separated by Duncan's multiple range test. e.s.e is the estimated standard error of mean.

compared to control treatments.

Conclusion

The main aim of this study is to assess the quality of selected commercial organic fertilizers on the market in comparison with local farm yard manure.

(i) The nutrient content reported on the labels were varying from laboratory reports which justifies the current problem of adulteration and marketing of counterfeit agro input products in Ugandan markets.
(ii) Results also showed that local manure had higher nutrient content compared to some of the organic fertilizer brands like Biogrow. Therefore, farmers can use locally available farm yard manure which is less costly and cheap to access than Biogrow fertilizers.
(iii) The performance of the selected organic fertilizers was not consistent in season 1(2017) and 2(2018) in both locations and therefore need to be tested in more confined environment to control of extreme weather factors for more subsequent seasons to have conclusive results on their effects on growth and yield of bush beans.

Recommendation

(i) There is need to conduct regular laboratory tests on organic fertilizers sold in the market to check the nutrient composition reported on the product labels by manufacturers
(ii) It is recommended that these field trials should be repeated under controlled environment to minimize the extreme weather effect.
(iii) Establishing different application levels and frequency regimes would also guarantee an opportunity to measure the extent of the effect at different rates and frequencies. This will also help to establish what are the sufficient quantities needed to be applied to obtain significant production output.
(iv) The future studies should focus on exploring the effect of organic fertilizers on the growth and yield parameters of bush bean (P. vulgaris) or other crops grown under greenhouse or controlled environment and sterilized growing medium.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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