Effects of soil amendment treatments on growth, yield and fruit quality of selected banana (*Musa* AAA) cultivars

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ABSTRACT

Banana cultivation in Sudan is restricted to the narrow strip of silt deposits along the banks of the Blue Nile and the River Nile. Hence, there is a need to expand banana cultivation in the high terrace, heavy clay soils. Banana performance in heavy clay soils is very poor, unless soil amendments are applied. Therefore, the objective of this research was to study the effects of soil amendment treatments on growth, yield and fruit quality of selected banana cultivars. The experiment was conducted in the Research Farm of the National Institute for the Promotion of Horticultural Exports, University of Gezira, during 2009-2011. Treatments consisted of three selected banana cultivars : Two introduced cultivars, namely, Grand Nain 1824 (GN) and William's Hybrid 172 (WH) and the local cultivar Dwarf Cavendish (DC). Soil amendment treatments were : 1, 50% heavy clay (HC) + 50% loam (L); 2, 50% HC + 50% chicken manure (CM); 3, 50% HC + 25% L + 25% CM; 4, 33% HC + 33% L + 34% CM; 5, 100% HC (control). Treatments were arranged in a randomized complete block design with three replicates. Results showed that the introduced cultivars GN and WH had more vigorous vegetative growth, higher yield components, total yield and better fruit quality than the local cultivar DC. Soil amendment treatments of 50% HC + 25% L + 25% CM and 33% HC + 33% L + 34% CM resulted in the most vigorous vegetative growth, the highest yield components and total yield and the best fruit quality, followed by 50% HC + 50% L and 50% HC +50%CM, whereas the least vegetative growth, the lowest yield components, total yield and the worst fruit quality were produced by bananas grown in 100% HC (control). In order to expand banana production for the local market and export, it is recommended to amend heavy clay soils with loams and chicken manure at 33% each and grow the introduced cultivars GN and WH.

INTRODUCTION

In Sudan, the banana industry is currently attracting much attention at both public and private levels due to the recognition of its positive contribution to individual and national income (Mahmoud *et al*., 2011).

The most widely distributed banana cultivars in the world are Williams, Grand Nain, Valery, Dwarf Cavendish, Rubusta, Americani and Lacatan (Robinson, 1996). The commonly grown banana cultivar in Sudan is the Dwarf Cavendish, which is a low yielder and does not meet international fruit quality requirements. In 1998, the National Institute for the Promotion of Horticultural Exports introduced six internationally popular banana clones, raised by tissue culture, from South Africa. The clones were Williams Hybrid 1 and 2, Grand Nain 1 and 2, Zelig and Bio. These clones were evaluated compared to the local cultivar Dwarf Cavendish. Results indicated that Williams Hybrid and Grand Nain were among the high yielding cultivars with an excellent fruit quality under Sudan conditions (Mahmoud and Elkashif, 2003; Elkashif and Mahmoud, 2005; Elkashif *et al.,* 2005; 2010; Elsiddig *et al.,* 2009; Mahmoud *et al.,* 2011).

Bananas are heavy feeders and require large amounts of nutrients especially N and K (Osman *et al.,* 2004; Elkhidir *et al.,* 2009). The best vegetative growth and the highest yield and yield components were obtained with the application of 207 g N/mat/year in combination with 41 g K/mat/year (Osman *et al.,* 2004).

Chicken manure (2.3% N) is an organic amendment that has been used successfully for centuries as a source of nutrients for crops (Brye *et al.*, 2005). It is generally considered the most valuable animal manure for use as a fertilizer due to its low water content and relatively high NPK and trace elements content (Ibrahim *et al.*, 2004). Moreover, if managed properly, it can save farmers money and represent an environmentally safe means of waste disposal, considering the large number of poultry farms in Sudan.

Chicken manure influences plants through its effect on the physical and chemical properties of soil and adds a concentrated, transportable and rapidly effective fertilizer to the nutrient cycle when and where they are needed. The relatively low yields of irrigated crops in the cracking soils of the central clay plains of Sudan are probably very much attributed to unfavorable physical characteristics of these soils (Ali and Adam, 2003).

The most positive results from the application of poultry manure have been achieved in the Savannah zone with a sub humid climate. Here, even relatively modest application of manure (5.0-7.0 t/ha) often led to a substantial improvement in soil physical properties and the carbon and nitrogen status of the soils (Khaleel *et al.*, 1981; Girma and Endale, 1995).

In Sudan, banana production is mainly restricted to the alluvial deposits of the River Nile, in Kassala State in Gash Delta, along the Blue Nile, Wad Ramli and Sururab north of Khartoum (Elkashif *et al*., 2005). Production is limited only to the alluvial deposits because the heavy clay soils are not suitable for banana production. Hence, despite the availability of large irrigated schemes in Sudan, bananas cannot be introduced to these schemes because of their heavy clay soils, which are compact, with poor physical properties and limited aeration. Hence, in order to increase banana acreage in heavy clay soils, their physical properties should be improved to suit banana culture.

Therefore, the objective of this research was to investigate the effects of some soil amendments on growth, yield and fruit quality of selected superior banana clones grown in heavy clay soils.

MATERIALS AND METHODS

A field experiment was conducted in the research farm of the National Institute for the Promotion of Horticultural Exports, University of Gezira, Wad Medani, Sudan during 2009-2011, lat. 19.5 N, long. 33.4 E and elevation of 407 m a.s.l. The area lies within an arid climate of hot summer and relatively cool winter. The effective rainfall, which is very fluctuating from year to year is from the end of June to the end of September, but July and August are the wettest months. The annual rainfall is between 240-300 mm and the rest of the year is dry. The daily maximum and minimum temperatures are between 32-44^{0}C and 12-26^{0}C, respectively.

The soil at the experimental site is classified as fine, smectitic and isohyperthermic It is alkaline, cracked and calcareous vertisol. The clay content was around 50%. It is characterized by its low contents of organic matter(0.2%-0.3%) and low nitrogen content(0.02%-0.03%)(Soil Survey, 1999).

Treatments

Six months old sword suckers were taken from the cultivars Dwarf Cavendish (DC), William's Hybrid 172 (WH) and Grand Nain 1824 (GN). These suckers were transplanted in September 2009 in the research farm of the National Institute for the Promotion of Horticultural Exports. The land was ploughed, leveled and made into plots of 4 x 6 m. Each plot consisted of four plants.

Soil amendment treatments were :

(1) 50% heavy clay (HC) + 50% loam (L)

(2) 50% HC + 50% chicken manure (CM) (2.3% N) (55 t/ha).

(3) 50% HC + 25% L + 25% CM (36 t/ha).

(4) 33% HC + 33% L + 34% CM (27 t/ha).

(5) 100% HC (control).

The soil was dug out of pits 50 x 50 x 50 cm, then soil mixes were made according to the previously mentioned treatments and then soil mixes were returned back to the pits. Then suckers were planted in the pits at a spacing of 2 x 3 m.

Treatments were arranged in a randomized complete block design with three replicates. Cultural practices were carried out as recommended. Nitrogen in the form of urea (46% N) was applied to all treatments at the rate of 86 kg N/ha, one month after planting (Osman *et al*., 2004).

Growth measurements

Three months after planting, two plants from each plot were selected, tagged and used for growth measurements of the plant crop and the first ratoon. Plant height was measured at shooting from soil surface up to the base of the inflourescence. Pseudostem girth was measured 5 cm above the soil surface. Number of leaves and number of suckers per plant were counted at shooting.

Yield and yield components measurements

Bunches were harvested when fruits were at the mature green stage (full three quarters). Bunch weight, number of hands per bunch and total yield were determined for both the plant crop and the first ratoon.

Fruit quality

Banana hands were cut from the bunches harvested from the plant crop and the first ratoon. They were washed with tap water to remove dust and latex and then placed in cartons and stored in a cold room calibrated at 14^{0}C. The green life of fruits was determined as the number of days required for fruits to turn from dark green to light green in colour. At the end of the green life and when the hands turned to yellowish green in colour, they were dipped in Ethrel solution at a concentration of 2 ml/L and ripened at 20^{0}C. (Mahmoud and Elkashif, 2003).

Total soluble solids (TSS) of ripe fruits were measured according to the procedure described by Elkashif *et al*. (2005). Thirty grams of pulp were blended with 90 ml distilled water for two minutes and TSS of the extracts were measured using a hand refractometer (Model HRN-32).

Fruit taste was determined by a taste panel on a scale of 1 to 5 as follows : 1, unacceptable; 2, slightly acceptable; 3, acceptable; 4, good and 5, excellent.

Statistical analysis

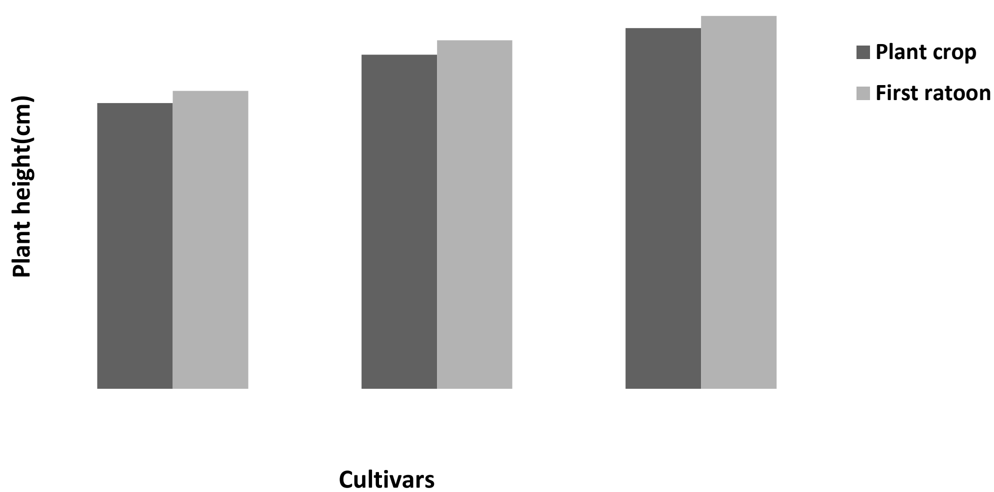
Data were subjected to the standard analysis of variance procedure. Treatment means were separated using Duncan's Multiple Range Test at 5% level of significance.

RESULTS AND DISCUSSION

Vegetative growth of banana cultivars

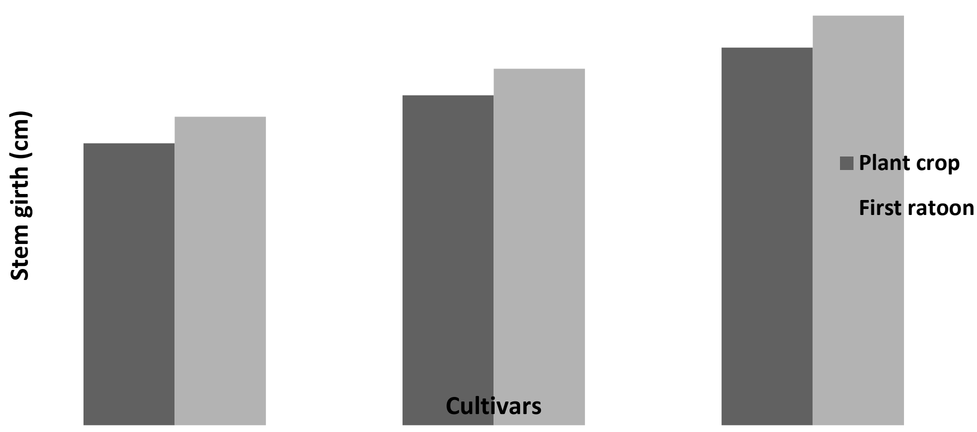
There were significant differences in vegetative growth parameters between banana cultivars. The introduced banana cultivars GN and WH had taller and thicker pseudostems (Figs. 1a and 1b) compared to the local cultivar DC in both the plant crop and the first ratoon.

However, the local cultivar DC had significantly larger number of suckers per plant in both the plant crop and the first ratoon compared to the introduced cultivars GN and WH (Fig. 1c). The vigorous vegetative growth of GN and WH has been reported by previous workers (Mahmoud and Elkashif, 2003; Elkashif and Mahmoud, 2005; Elkashif *et al.*, 2005; Elsiddig *et al.*, 2009; Elkashif *et al.*, 2010).



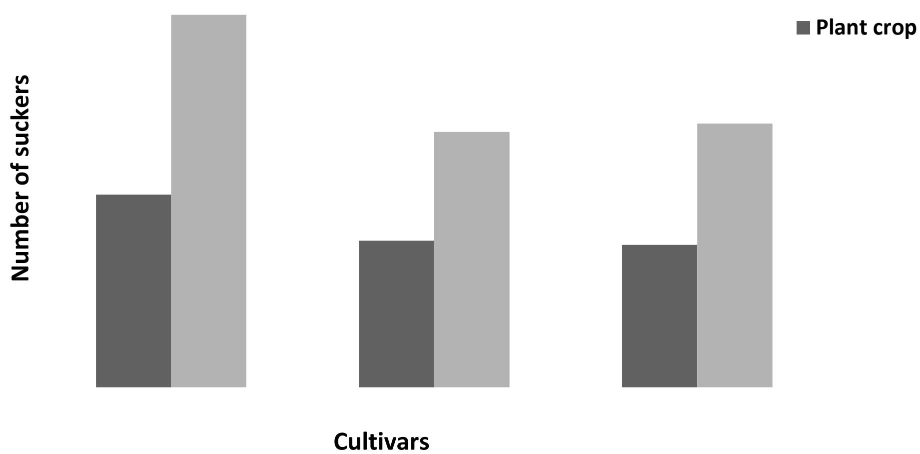
DC = Dwarf Cavendish, GN = Grand Nain, WH = Williams Hybrid.

Fig. 1-a. Plant height of banana cultivars**.**



DC = Dwarf Cavendish, GN = Grand Nain, WH = Williams Hybrid.

Fig. 1-b. Stem girth of banana cultivars**.**



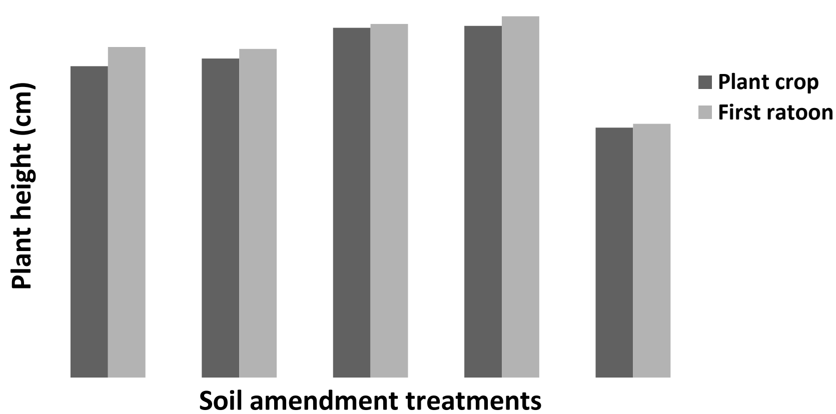
DC = Dwarf Cavendish, GN = Grand Nain, WH = Williams Hybrid.

Fig. 1-c. Number of suckers per plant of banana cultivars**.**

Effect of soil amendment treatments on vegetative growth

Soil amendment treatments had significant effects on vegetative growth parameters of both the plant crop and the first ratoon (Figs. 2 a, b and c.). Treatments of 50% HC + 25% L + 25% CM and 33% HC + 33% L + 34% CM significantly resulted in the most vigorous vegetative growth parameters, followed by treatments of 50% HC + 50% L and 50% HC + 50% CM in both the plant crop and the first ratoon.

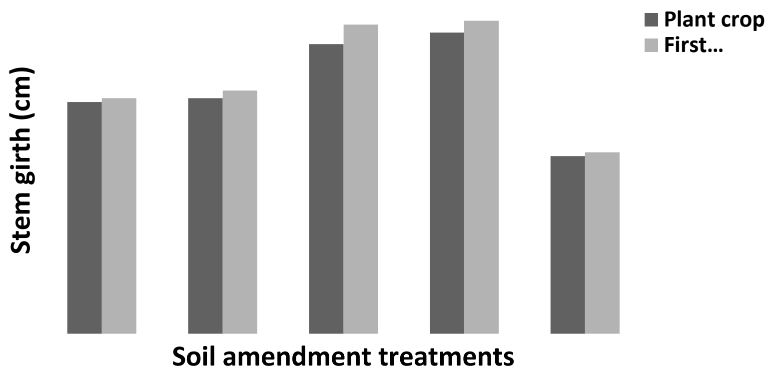
However, the treatment of 100% HC resulted in the least vegetative growth parameters in both the plant crop and the first ratoon (Figs. 2 a, b, and c). The addition of both loam and chicken manure to the heavy clay soil improved the physical characteristics, increased the porosity and enhanced the water infiltration rate of the heavy clay soil. Also, chicken manure provided nitrogen, macro and micronutrient to the banana plants, thus resulting in vigorous vegetative growth. Bananas grown in 100% heavy soil were stunted in growth compared to those which received amendment treatments because the roots of banana plants could not penetrate the compact heavy clay soils with poor physical characteristics. These results
confirm the findings of Ali and Adam (2003), Adam and Ali (2004), Mukhtar *et al.* (2004) and Sulfab *et al.* (2011). Ibrahim *et al.* (2004)
reported that application of chicken manure to muskmelons grown in heavy clay soils at the rate of 18 t/ha significantly increased vegetative growth and resulted in the highest yield and the best fruit quality. Similarly, Girma and Endale (1995) and Khaleel *et al.* (1981) reported that addition of animal manure improved the physical properties of soil and increased the availability of micronutrients. Also, addition of chicken manure increased soil fertility, increased soil organic matter (Agbede and Adekiya, 2012), reduced soil bulk density, increased soil water content (Brye *et al.*, 2005) and improved soil physical and chemical properties (Agbede *et al.*, 2008).



1 = 50% HC + 50% L, 2 = 50% HC + 50% CM, 3 = 50% HC + 25% L + 25% CM, 4 = 33% HC + 33% L + 34% CM, 5 = 100% HC.

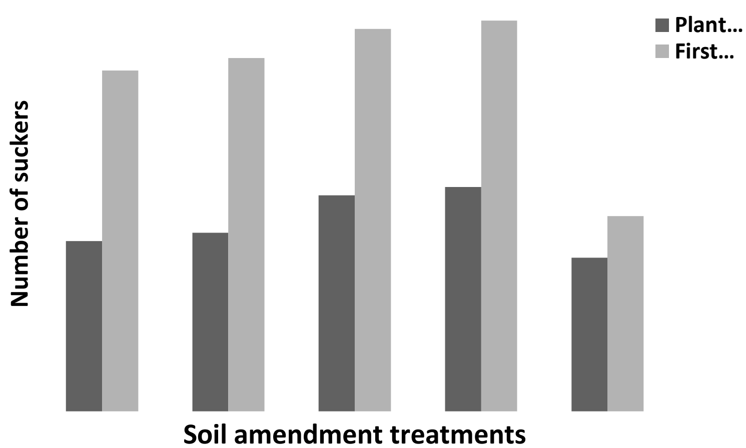
HC = heavy clay, L = loam, CM = chicken manure.

Fig. 2-a. Effects of soil amendment treatments on plant height.



1 = 50% HC + 50% L, 2 = 50% HC + 50% CM, 3 = 50% HC + 25% L + 25% CM , 4 = 33% HC + 33% L + 34% CM, 5 = 100% HC.
HC = heavy clay, L = loam, CM = chicken manure.

Fig. 2-b. Effects of soil amendment treatments on stem girth.



1 = 50% HC + 50% L, 2 = 50% HC + 50% CM, 3 = 50% HC + 25% L + 25% CM, 4 = 33% HC + 33% L + 34% CM, 5 = 100% HC.HC = heavy clay, L = loam, CM = chicken manure.

Fig. 2-c. Effects of soil amendment treatments on number of suckers per plant.

The interaction effects of banana cultivars and soil amendment treatments on vegetative growth were highly significant in both the plant crop and the first ratoon (Tables 1 and 2). The most vigorous vegetative growth was obtained by the introduced cultivars GN and WH grown in soil mixtures of 50% HC + 25% L + 25% CM and 33% HC + 33% L + 34% CM, followed by 50% HC + 50% L and 50% HC + 50% CM. However, the least vegetative growth was recorded for all cultivars grown in 100% HC in both the plant crop and the first ratoon. These results are in line with those reported by Mukhtar *et al.* (2004).

Table 1. Interaction effects of banana cultivars and soil amendment treatments on the vegetative growth of the plant crop.

Cultivars	Treatments	Plant height (cm)	Stem girth (cm)	No. of leaves	No.of suckers
	50% HC + 50% CM	144 e	57 c	14.0 d	3.5 c
	50% HC + 50% L	147 e	58 c	14.2 d	3.7 c
DC	50% HC + 25% L + 25% CM	150 d	61 c	14.6 d	4.1 b
	33% HC + 33% L + 34% CM	153 d	63 c	14.7 d	4.5 b
	100% HC (control)	141 f	45 d	13.1 e	3.2 c
	50% HC + 50% CM	160 c	70 b	16.0 b	4.5 b
	50% HC + 50% L	164 b	73 b	16.2 b	4.7 b
GN	50% HC + 25% L + 25% CM	181 a	78 a	17.3 a	5.3 a
	33% HC + 33% L + 34% CM	183 a	79 a	17.2 a	5.4 a
	100% HC (control)	149 d	52 d	15.1 c	3.7 c
	50% HC + 50% CM	163 c	72 b	16.1 b	4.5 b
	50% HC + 50% L	168 b	74 b	16.1 b	4.4 b
WH	50% HC + 25% L + 25% CM	182 a	80 a	17.3 a	5.3 a
	33% HC + 33% L + 34% CM	186 a	81 a	17.4 a	5.6 a
	100% HC (control)	151 d	53 d	15.6 c	4.1 b
Significance level		**	*	**	*
CV (%)		12.6	11.4	8.2	9.5

DC = Dwarf Cavendish, GN = Grand Nain, WH = William's Hybrid.
* and,** indicate significance at P<0.05 and 0.01 , respectively.
Means in columns having the same letters are not significantly different according to Duncan's Multiple Range Test at 5% level of significance.

Table 2. Interaction effects of banana cultivars and soil amendment treatments on the vegetative growth of the first ratoon.

Cultivars	Treatments	Plant height (cm)	Stem girth (cm)	No. of leaves	No. of suckers
	50% HC + 50% CM	145 e	56 c	14.3 d	3.5 c
	50% HC + 50% L	147 e	59 c	14.5 d	3.7 c
	50% HC + 25% L + 25% CM	153 d	63 c	14.8 d	4.1 b
DC	33% HC + 33% L + 34% CM	155 d	66 c	14.8 d	4.5 b
	100% HC (control)	140 f	43 d	13.3 e	3.2 c
	50% HC + 50% CM	163 c	71 b	16.1 b	4.5 b
	50% HC + 50% L	165 b	74 b	16.2 b	4.7 b
	50% HC + 25% L + 25% CM	183 a	80 a	17.5 a	5.3 a
GN	33% HC + 33% L + 34% CM	185 a	81 a	17.6 a	5.4 a
	100% HC (control)	148 d	51 d	15.3c	3.7 c
	50% HC + 50% CM	165 c	73 b	16.2 b	4.5 b
	50% HC + 50% L	170 b	74 b	16.1 b	4.4 b
	50% HC + 25% L + 25% CM	185 a	82 a	17.5 a	5.3 a
WH	33% HC + 33% L + 34% CM	187 a	82 a	17.7 a	5.6 a
	100% HC (control)	150 d	51 d	15.5 c	4.1 b
Significance level		**	*	*	*
CV (%)		13.7	12.2	9.3	9.2

DC = Dwarf Cavendish, GN = Grand Nain, WH = William's Hybrid.
HC = heavy clay, CM = chicken manure, L =loam.

* and ** indicate significance at P<0.05 and 0.01, respectively.
Means in columns having the same letters are not significantly different according to Duncan's Multiple Range Test at 5% level of significance.

Effects of banana cultivars on yield components and total yield

Banana cultivars differed significantly in yield components and total yield in both the plant crop and the first ratoon. The introduced cultivars GN and WH produced the heaviest bunches, the largest number of hands per bunch and the highest total yield in both the plant crop and the first ratoon compared to the local cultivar DC (Figs. 3 a, b, and c). This result was supported by the vigorous vegetative growth of these cultivars previously reported (Figs.1a, b and c) which was culminated in high photosynthetic

efficiency and consequently high yield components and total yield, as compared to the local cultivar DC. The superiority of these introduced cultivars makes them good candidates to replace the local cultivar DC and hence promote the export industry of bananas in Sudan. These results confirm the previous findings about the excellent performance of these introduced cultivars (Elkashif and Mahmoud, 2005; Elkashif *et al.*, 2005; Elsiddig *et al.*, 2009; Elkashif *et al.*, 2010; Mahmoud *et al.*, 2011).

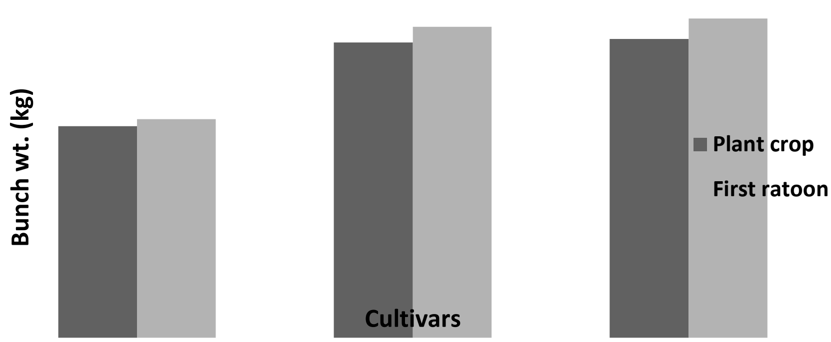
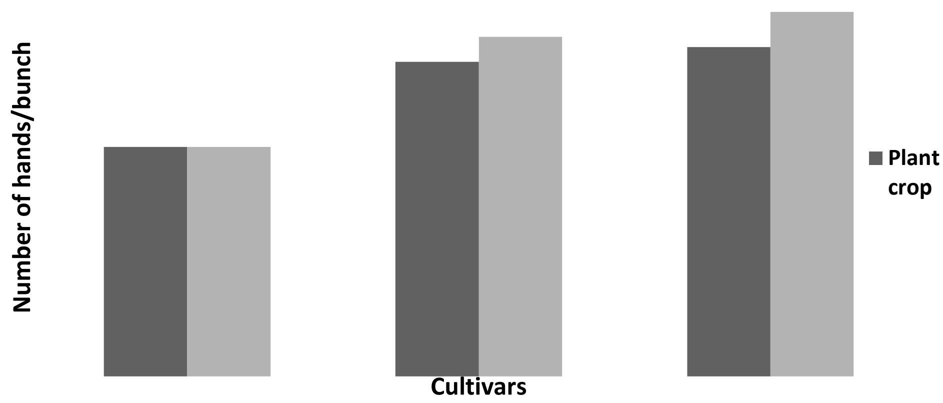
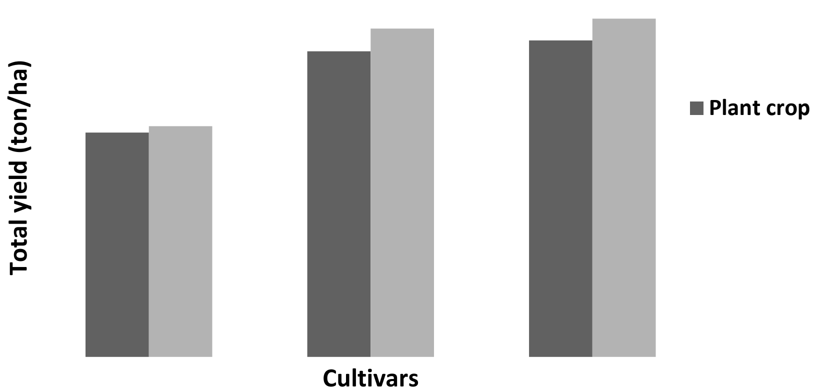


Fig. 3-a. Bunch weight of banana cultivars.



DC = Dwarf Cavendish, GN = Grand Nain, WH = Williams Hybrid.

Fig. 3-b. Number of hands/bunch of banana cultivars.

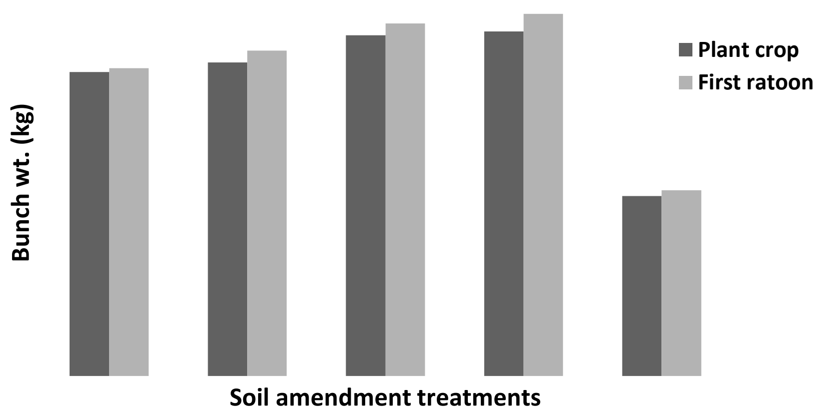


Effects of soil amendment treatments on yield components and total yield of the plant crop and the first ratoon

Soil amendment treatments had highly significant effects on yield components and total yield of both the plant crop and the first ratoon (Figs. 4 a, b, and c). The heaviest bunches, the largest number of hands per bunch and the highest total yields were produced by the treatments of 33% HC + 33% L + 34% CM and 50% HC + 25% L+ 25% CM , followed by the treatments of 50% HC+ 50% L and 50% HC + 50% CM, whereas the lowest yield components and total yields were produced by bananas grown in 100% HC in both the plant crop and the first ratoon (Figs. 4 a, b, and c). These results are supported by the vigorous vegetative growth caused by these soil amendment treatments

(Figs. 2 a, b and c). This was due to the fact that the addition of both loamy soil and chicken manure to the heavy clay soil improved its physical and chemical properties, increased its porosity and water retention capacity and increased the availability of macro and micronutrients. These tremendous improvements in the growth media of bananas resulted in more vigorous vegetative growth (Figs. 2 a, b and c).

and consequently higher yield components and total yield as compared to the control (100% HC). These results support the findings of previous workers
who showed the efficiency of animal manures in increasing the yield of many crops such as mango (Ewida *et al.*, 2013), wheat (Adam and Ali, 2004), musckmelons (Ibrahim *et al.*, 2004), sugarcane (Mukhtar *et al.*, 2004), white yam (Agbede and Adekiya, 2012), tomato (Adekiya and Agbede, 2009), and sorghum (Agbede *et al.*, 2008).



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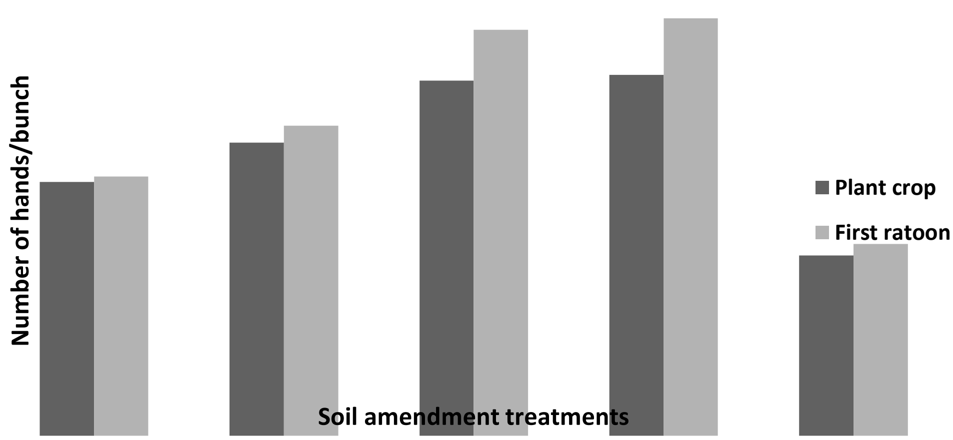
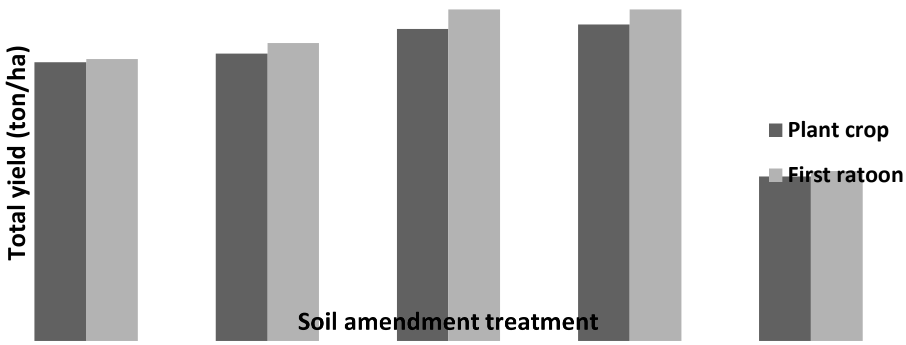


1 = 50% HC + 50% L, 2 = 50% HC + 50% CM, 3 = 50% HC + 25% L + 25% CM, 4 = 33% HC + 33% L + 34% CM, 5 = 100% HC.
HC = heavy clay, L = loam, CM = chicken manure.

Fig. 4-b. Effects of soil amendment treatments on number of hands/bucnh.



1 = 50% HC + 50% L, 2 = 50% HC + 50% CM, 3 = 50% HC + 25% L + 25% CM, 4 = 33% HC + 33% L + 34% CM, 5 = 100% HC.
HC = heavy clay, L = loam, CM = chicken manure.

Fig. 4-c. Effects of soil amendment treatments on total yield.

The interaction effects of banana cultivars and soil amendment treatments on yield components and total yield were highly significant in both the plant crop and the first ratoon (Tables 3 and 4). Yield components and total yields of the first ratoon were slightly higher than those of the plant crop. The highest yield components and total yield were obtained by the introduced clones GN and WH grown in soil amendment treatments of 50% HC + 25% L + 25% CM and 33% HC + 33% L + 34% CM in both the plant crop and the first ratoon. However, the lowest values of yield components and total yield were obtained by all cultivars grown in 100% HC in both the plant crop and the first ratoon. These results are in agreement with those reported by Sulfab *et al.* (2011), Agbede and Adekiya (2012) and Ewida *et al.*, (2013).

Table 3. Interaction effects of banana cultivars and soil amendment treatments on yield components and total yield of the plant crop.

Cultivars	Treatments	Bunch wt. (kg)	No. of hands/bunch	Total yield (ton/ha)
	0% HC + 50% CM	0.4 d	.8 d	7.2 d
	0% HC + 50% L	0.8 d	.7 d	7.8 d
	0% HC + 25% L + 25% CM	2.6 c	.2 c	0.8 c
DC	3% HC + 33% L + 34% CM	2.9 c	.5 c	1.3 c
	00% HC (control)	8.5 e	.2 e	4.0 e
	0% HC + 50% CM	6.5 b	.1 b	7.2 b
	0% HC + 50% L	6.6 b	.2 b	7.4 b
	0% HC + 25% L + 25% CM	8.5 a	.3 a	0.5 a
GN	3% HC + 33% L + 34% CM	8.7 a	.4 a	0.9 a
	00% HC (control)	0.3 d	.3 e	7.0 d
	0% HC + 50% CM	6.4 b	.3 b	7.1 b
	0% HC + 50% L	6.7 b	.5 b	7.6 b
	0% HC + 25% L + 25% CM	8.6 a	.5 a	0.7 a
WH	3% HC + 33% L + 34% CM	8.8 a	.2 a	1.0 a
	00% HC (control)	1.4 d	.1 e	8.8 d
Significance level		*		*
CV (%)		6.3	7.2	5.7

DC = Dwarf Cavendish, GN = Grand Nain, WH = William's Hybrid.
HC = heavy clay, CM = chicken manure, L =loam.
* and ** indicate significance at P<0.05 and 0.01, respectively.Means in columns having the same letters are not significantly different according to Duncan's Multiple Range Test at 5% level of significance.

Table 4. Interaction effects of banana cultivars and soil amendment treatments on yield components and total yield of the first ratoon.

Cultivars	Treatments	Bunch wt. (kg)	No. of hands/ bunch	Total yield (ton/ha)
DC	50% HC + 50% CM	11.2 d	5.7 d	18.5 d
	50% HC + 50% L	11.7 d	5.6 d	19.3 d
	50% HC + 25% L + 25% CM	13.3 c	6.1 c	21.9 c
	33% HC + 33% L + 34% CM	13.8 c	6.3 c	22.8 c
	100% HC (control)	9.4 e	4.8 e	15.5 e
GN	50% HC + 50% CM	17.3 b	7.3 b	28.5 b
	50% HC + 50% L	17.5 b	7.6 b	28.9 b
	50% HC + 25% L + 25% CM	20.7 a	8.5 a	34.2 a
	33% HC + 33% L + 34% CM	21.7 a	8.7 a	34.9 a
	100% HC (control)	11.5 d	5.4 a	18.9 d
WH	50% HC + 50% CM	17.2 b	7.2 b	28.4 b
	50% HC + 50% L	17.7 b	7.5 b	29.2 b
	50% HC + 25% L + 25% CM	19.6 a	8.1 a	32.3 a
	33% HC + 33% L + 34% CM	20.1 a	8.4 a	33.2 a
	100% HC (control)	12.2 d	5.6 d	20.1 d
Significance level		**	*	**
CV (%)		15.2	16.1	15.5

DC = Dwarf Cavendish, GN = Grand Nain, WH = William's Hybrid.
HC = heavy clay, CM = chicken manure, L =loam.
* and ** indicate significance at $P<0.05$ and 0.01, respectively.
Means in columns having the same letters are not significantly different according to Duncan's Multiple Range Test at 5% level of significance.

Effects of banana cultivars on fruit green life, TSS content and taste

Banana cultivars differed significantly in their fruit green life, TSS content and taste of both the plant crop and the first ratoon (Table 5). The introduced cultivars GN and WH had longer green lives than that of the local cultivar DC in both the plant crop and the first ratoon. However, the local cultivar DC had a higher TSS content and a better taste than the introduced cultivars GN and WH in both the plant crop and the first ratoon. These results are in agreement with those reported by Elkashif *et al.* (2005). Similarly, Mahmoud *et al.* (2011) reported that the green lives of the introduced cultivars GN and WH were significantly longer than that of the local cultivar DC, which makes them good candidates for cultivation and export because their fruits have a better keeping quality than those of DC.

Table 5. Main effects of banana cultivars on fruit green life and quality of the plant crop and the first ratoon.

Cultivars	Green life (day)	TSS (%)	Taste
	Plant crop		
DC	14.6 b	21.5 a	4.2 a
GN	17.4 a	19.6 b	3.3 b
WH	17.8 a	19.7 b	3.5 b
Sig. level	**	*	*
CV (%)	11.4	10.2	9.5
	First ratoon		
DC	14.5 b	21.8 a	4.3 a
GN	17.7 a	19.2 b	3.4 b
WH	17.9 a	19.5 b	3.5 b
Sig. level	**	*	*
CV (%)	12.3	11.4	8.6

DC = Dwarf Cavendish, GN = Grand Nain, WH = William's Hybrid, TSS = total soluble solids.
* and ** indicate significance at P<0.05 and 0.01, respectively.
Means in columns having the same letters are not significantly different according to Duncan's Multiple Range Test at 5% level of significance.

Effects of soil amendment treatments on banana fruit green life, TSS content and taste

The effects of soil amendment treatments on fruit green life, TSS content and taste were significant in both the plant crop and the first ratoon (Table 6). The longest green life, the highest TSS content and the best taste were recorded for bananas which received the treatments 50% HC + 25% L + 25% CM and 33% HC + 33% L + 34% CM , followed by the treatments 50% HC + 50% L and 50% HC+50% CM in both the plant crop and the first ratoon. However, the shortest green life, the lowest TSS content and worst taste of fruits were recorded for bananas which were grown in 100% HC in both the plant crop and the first ratoon (Table 6). This was most probably due to the fact that these soil amendment treatments resulted in healthy, well developed mature green fruits which could be stored for a longer period of time and then ripen normally to give good fruit quality characteristics, compared to poorly developed fruits which were produced in heavy clay soils.

Table 6. Main effects of soil amendment treatments on fruit green life and quality of the plant crop and the first ratoon.

Treatments	Green life (day)	TSS (%)	Taste
	Plant crop		
50% HC + 50% CM	16.4 b	19.4 b	3.5 b
50% HC + 50% L	16.1 b	19.6 b	3.6 b
50% HC + 25% L + 25% CM	18.7 a	21.7 a	4.5 a
33% HC + 33% L + 34% CM	18.8 a	21.5 a	4.7 a
100% HC (control)	14.2 c	17.3 c	2.5 c
Sig. level	**	*	*
CV (%)	12.1	13.7	8.5
	First ratoon		
50% HC + 50% CM	16.6 b	19.2 b	3.6 b
50% HC + 50% L	16.2 b	19.3 b	3.5 b
50% HC + 25% L + 25% CM	18.5 a	21.6 a	4.6 a
33% HC + 33% L + 34% CM	18.7 a	21.5 a	4.7 a
100% HC (control)	14.5 c	17.4 c	2.4 c
Sig. level	**	*	*
CV (%)	13.5	12.4	9.3

HC = heavy clay, CM = chicken manure, L =loam.

TSS = total soluble solids.

* and ** indicate significance at P<0.05 and 0.01, respectively.

Means in columns having the same letters are not significantly different according to Duncan's Multiple Range Test at 5% level of significance.

RCOMMENDATIONS

Based on the results of this study, it is recommended to :

1. Grow the introduced Grand Nain 1824 and Williams Hybrid 172 banana cultivars and gradually replace the local cultivar DC in order to establish a good foundation for the banana export industry in Sudan.
2. It is possible to expand banana production area in the irrigated heavy clay soils, provided that they are amended with loamy soils and chicken manure at 33% each (36 kg of chicken manure/ha).

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تأثير مستصلحات التربة على نمو وانتاجية و نوعية الثمار لبعض الأصناف المختارة من الموز (*Musa* AAA)

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الخلاصة

تنحصر زراعة الموز في السودان على الشريط الضيق للتربة الغرينية على ضفاف النيل الأزرق ونهر النيل. هنالك حاجة ماسة للتوسع في زراعة الموز في السودان ولذلك لا بد من محاولة زراعته في الاراضي الطينية الثقيلة و التي لا تصلح لزراعة الموز إلا إذا تمت بعض المعالجات. لذلك فإن الهدف من هذا البحث هو دراسة تأثير بعض مستصلحات التربة على النمو ومكونات الإنتاج والإنتاج الكلي لثلاثة أصناف منتخبة من الموز في هذا النوع من الأراضي. أجريت التجربة في مزرعة بحوث المعهد القومي لتنمية الصادرات البستانية بجامعة الجزيرة خلال الفترة 2009-2011. اشتملت المعاملات على ثلاثة أصناف منتخبة من الموز: صنفان مستجلبان من خارج السودان وهما جراندنين 1824 (GN) وهجين وليامز172 (WH) بالإضافة إلى الصنف المحلي الكافندش القزم (DC). إشتملت مستصلحات التربة على: (1) 50% تربة طينية ثقيلة + 50% تربة غرينية ، (2) 50% تربة طينية + 50% ماروق دواجن ، (3) 50% تربة طينية + 25% تربة غرينية + 25% ماروق دواجن، (4) 33% تربة طينية + 33% تربة غرينية + 34% ماروق دواجن ، (5) 100% تربة طينية (شاهد). أستخدم تصميم القطع العشوائية الكاملة بثلاثة مكررات . أظهرت النتائج أن الأصناف المستجلبة من الخارج GN وWH كانت أفضل في النمو الخضري وأعلى إنتاجية وأفضل جودة للثمار من الصنف المحلي DC. معاملات مستصلحات التربة 50% تربة طينية + 25% تربة غرينية + 25% ماروق دواجن و 33% تربة طينية و33% تربة غرينية و34% ماروق دواجن أعطت أفضل نمو خضري وأعلى إنتاجية وأفضل نوعية للثمار ، تليها المعاملات 50% تربة طينية + 50% تربة غرينية و50% تربة طينية + 50% ماروق دواجن. أما زراعة الموز في الأراضي الطينية الثقيلة بدون مستصلحات أدت إلى أقل نمو خضري وأقل إنتاجية وأدنى نوعية للثمار. لذلك لكي يتم التوسع في زراعة الموز فى الاراضى الطينية الثقيلة للسوق المحلي والتصدير ، فإنه يوصى بإضافة التربة الغرينية و ماروق الدواجن بنسبة 33% لكل منهما وزراعة الأصناف المستجلبة GN و WH.