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Effects of Planting Methods on Growth, Yield and Fruit Quality of Selected Banana (*Musa* AAA) Clones

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Abstract: This study was conducted at the experimental farm of the National Institute for the Promotion of Horticultural Exports, University of Gezira, Sudan, during 2007/08. The objective was to study the effects of planting methods on growth, yield and fruit quality of three banana clones. Methods of planting were planting banana suckers in flats, furrows or in beds. In-row and inter-row spacing of planting was 3m and 2m, respectively. Three banana clones were used, namely, Williams Hybrid (WH), Grand Nain (GN) (introduced clones) and the local clone Dwarf Cavendish (DC). Split-plot design with three replicates was used, where planting methods were the main plots and banana clones were the sub-plots. Results showed that planting methods had significant effects on vegetative growth, yield and fruit quality of bananas, regardless of the clone used. Furrow planting resulted in the tallest plants with the thickest pseudostems and the highest yield followed by the flat method and then bed method. The introduced clones WH and GN were taller, with thicker pseudostems and higher yields than the local clone DC. The clone WH, planted in furrows, took the longest duration from planting to shooting; however, it took the shortest period from shooting to harvesting. The highest total soluble solids of fruits were obtained by the bed planting method.

Key words: Planting system; banana clones; vegetative growth; yield fruit quality

INTRODUCTION

Banana production in Sudan is concentrated in the alluvial deposits along the Blue Nile, Gash delta (Kassala State), Wad Ramli (Khartoum State) and in the River Nile State (Elkashif *et al.* 2005). The area under banana

cultivation in Sudan was estimated at 127,000 ha (FAO 2009). Banana production is generally practiced in small holdings for the local markets; however, in recent years, banana has attracted attention as an important crop for export to some countries in the Middle East (Hamid 1992).

The most extensively grown banana clone in Sudan is the Dwarf Cavendish. It is a low yielder, has small-sized fingers and does not compete well in the international markets. During the last few years; however, several internationally known banana clones have been introduced and evaluated under Sudan conditions. Results showed that most of the introduced clones were superior in yield and fruit quality than the locally-grown Dwarf Cavendish clone (Bakhiet and Ali 2001; Mahmoud and Elkashif 2003; Bakhiet 2006).

Banana planting method is one of the most important cultural practices required for optimum growth and high yield. There is no standard planting method for banana in Sudan. However, planting methods are controlled by the environmental conditions, cultural practices, soil type, irrigation system, land topography and locality (Samson 1992). In Sudan, bananas are usually grown in flat plots. The land is normally ploughed, leveled and made into plots of different sizes. Banana suckers are usually grown at a spacing of 3m x 3m (Mahmoud *et al.* 2010). Hence, research work is needed to investigate the performance of bananas under different planting methods. Therefore, the objective of this study was to find out the optimum planting method for the selected banana clones.

MATERIALS AND METHODS

Experimental site

This study was carried-out at the National Institute for the Promotion of Horticultural Exports (NIPHE) Research Farm at Hantoub area along the eastern bank of the Blue Nile (lat. 14.5°N, and long. 33.4°E). The area lies within an arid climate of summer rains and relatively warm winter.

The average summer temperature is around 40°C and may increase to 44°C during May and June, while during winter the average day temperature is around 20°C. The region is dry most of the year except for

the period from July to September where it receives around 200-350 mm of rainfall.
The soil at the experimental site is mostly alluvial silts (flood deposits) of the Blue Nile. The soil can be classified as fine, smectitic, isohyperthermic, typic, haplocombids (Soil Survey Staff 1999). The soil pH is around 7.5.

Differential treatments
Three banana clones, namely, Dwarf Cavendish (DC), Grand Nain (GN) and Williams Hybrid (WH) were used in this study. The clones GN and WH were introduced from South Africa. Five months old uniform sword suckers were used as planting materials. The three banana clones were planted either in flats, furrows or beds. The flat method had 4m x 6 m plots and each plot consisted of four plants spaced at 2m x 3m apart. The furrow method was made at 3m spacing between furrows. The suckers were planted in the furrows at a spacing of 2m between them. The bed in the bed method was 1.0 m in width and the suckers were planted in the middle of each bed at a spacing of 2m between plants. All treatments were spaced at 3m between rows and 2 m between plants.

The clones were transplanted in the field on July 2007. The plots were irrigated every 5 to 7 days according to the weather conditions. Nitrogen in the form of urea was applied at the rate of 400 g per mat/year in split doses every four months.

Growth parameters
Three months after planting, two plants from each experimental unit were randomly selected, tagged and used for determination of growth parameters. Growth parameters were expressed in terms of height and girth (diameter) of pseudostem, number of leaves, leaf area, and number of days from planting to shooting and from shooting to harvesting.
Pseudostem height was measured at 5 cm from the soil surface to the point of the intersection of petioles of the two youngest leaves. Pseudostem girth was measured at5 cm above the soil surface using a

measuring tape. Number of leaves per plant was counted monthly. Leaf area was calculated as the product of length and width multiplied by a factor of 0.8 (Murray 1960). Number of days from planting to shooting and from shooting to harvesting was recorded.

Yield components

Banana bunches were harvested when fruits were at the mature green (full three quarters) stage. Total bunch weight was determined. Bunches were de-handed and hands and stalks were separately weighed. Number of hands and total number of fingers per bunch were counted.

Fruit (finger) quality measurements

Fruit samples of approximately 4-6 kg (2-3 hands of medium size) were taken from each treatment, dipped in Ethrel solution at a concentration of 1mL/liter (450 ppm ethylene) for two minutes, and ripened in a cold room calibrated at 20°C and 70% relative humidity. Colour change was determined according to a scale of 1 – 6, where 1: dark green; 2: light green; 3: pronounced yellow; 4: predominantly yellow; 5: yellow with green tips and 6: full yellow.

For determination of total soluble solids (TSS), thirty grams of pulp tissue were taken from ripe fruit, blended in 90 mL distilled water and then filtered. A single drop of the filtrate was placed on a hand refractometer and total soluble solids (TSS) were determined.

Experimental design and statistical analysis

The experimental design was a spit-plot design with three replicates. The methods of planting were allotted to the main plots and the banana clones were to the sub-plots. There were 27 experimental units. All parameters were recorded using the plant crop. Data were subjected to analysis of variance. Mean separation was done according to Duncan's Multiple Range Test (DMRT) at 5% level of significance.

RESULTS AND DISCUSSION

The vegetative growth parameters of banana clones at shooting are shown in Table 1. Results showed significant differences in pseudostem height and girth among banana clones. The tallest pseudostem and biggest stem

girth measurements were associated with WH whereas DC resulted in the lowest pseudostem height and the smallest girth. There were no significant differences in number of leaves per plant among the three banana clones. The introduced clones (WH and GN) demonstrated more vigorous vegetative growth than the locally grown cultivar DC. Similar results were obtained for vegetative growth parameters of these clones grown in Kassala State, Eastern Sudan (Bakhiet 2006; Elkashif *et al.* 2005). Other investigators reported large variations in pseudostem height and girth measurements among cultivars in the Cavendish subgroup (Morton 1987; Robinson 1996). Pseudostem height and girth are very important growth parameters in arid and semi-arid tropical regions. Shorter plants with large stem girths offer good protection against uprooting and wind damage frequently observed in that climate.

Table 1. Main effects of banana clones on vegetative growth parameters of the plant crop of banana

Banana clone	Pseudostem height (cm)	Pseudostem girth (cm)	Number of leaves/ plant
DC	144 c	58 c	13.0
GN	170 b	68 b	14.4
WH	182 a	72 a	14.7
Sig. level	*	*	NS

DC = Dwarf Cavendish, GN = Grand Nain and WH = Williams Hybrid.
Means in columns followed by the same letter(s) are not significantly different at $P \geq 0.05$ level according to Duncan's Multiple Range Test.
* and NS indicate significance at 0.05 and not significant, respectively.

The main effects of planting methods on vegetative growth of banana clones are shown in Table 2. Results showed that the furrow planting method produced the tallest pseudostems and the largest girths followed by the flat planting method and then the bed method. This was probably because the furrow planting method provided more irrigation water than the other two methods and hence resulted in more vigorous vegetative growth. Since bananas were planted in alluvial silt deposits (Soil Survey Staff 1999), there was no problem of water logging. The poor vegetative growth obtained with the bed planting method was most probably due to

the lack of sufficient irrigation water which was caused by the fast percolation of water in the light silt soils.

Table 2. Main effects of planting method on vegetative growth parameters of the plant crop of banana

Planting method	Pseudostem height (cm)	Pseudostem girth (cm)	Number of leaves/ plant
Furrow	177 a	70 a	14.4
Flat	163 b	64 b	13.6
Bed	155 c	63 b	13.4
Sig. level	*	*	NS

Means in columns followed by the same letter(s) are not significantly different at P≥0.05 level according to Duncan's Multiple Range Test.
* and NS indicate significance at 0.05 and not significant, respectively.

Table 3 shows significant interaction effects between banana clones and planting methods on all vegetative growth parameters of the plant crop. The tallest pseudostems, the thickest girths, the greatest number of leaves and the highest leaf area were associated with the introduced clone WH grown in furrows, whereas the lowest values of these parameters were recorded by the local clone DC grown in beds. Under all planting methods, the introduced clone WH resulted in the best vegetative growth. On the other hand, regardless of clones, the furrow planting method produced the most vigorous vegetative growth.

Crop earliness

Table 4 shows significant interaction effects between banana clones and planting methods on the number of days required from planting to shooting and from shooting to harvesting of the plant crop. The clone WH planted in furrows resulted in the longest duration from planting to shooting and DC planted in beds resulted in the shortest. Generally, the local clone DC had the shortest duration from planting to shooting and from shooting to harvesting, which indicated that it was an early clone as compared to the introduced clones. However, the bed planting method resulted in the longest duration from shooting to harvesting. This might be

due to the water stress caused by the bed planting method. The number of days from planting to shooting ranged from 253 to 288 and from shooting to harvesting ranged from 90 to 104 in all tested clones. The clone WH exhibited late flowering compared to DC but was comparable with GN clone. Furrow planting increased the number of days from planting to shooting but it decreased the number of days from shooting to harvesting.

Table 3. Interaction effects between banana clones and planting methods on vegetative growth parameters of the plant crop of banana

Banana clones	Planting methods	Pseudostem height (cm)	Pseudostem girth (cm)	Number of leaves at shooting	Leaf area (m^2)
DC	Furrow	153d	66c	13.9c	0.839c
	Flat	141e	54d	12.1d	0.791d
	Bed	139e	53d	12.6d	0.821b
GN	Furrow	181b	69b	15.1a	0.961b
	Flat	169c	67bc	14.2b	0.892c
	Bed	159d	68bc	13.9c	0.842c
WH	Furrow	198a	76a	15.7a	1.030a
	Flat	179b	71b	14.6b	0.921b
	Bed	168c	69b	13.7c	0.820c
Sig. level		**	*	*	*

DC = Dwarf Cavendish, GN = Grand Nain and WH = William Hybrid.
Means in columns followed by the same letter(s) are not significantly different at $P \geq 0.05$ level according to Duncan's Multiple Range Test.
*, ** and NS indicate significance at 0.05, 0.01 and not significant, respectively.

Table 4. Interaction effects between banana clones and planting methods on the earliness of the plant crop of banana

Banana clones	Planting method	Days from planting to shooting	Days from shooting to harvesting
DC	Furrow	276.1c	90.0d
	Flat	269.4d	92.0c
	Bed	253.8f	95.0bc
GN	Furrow	281.4b	96.6bc
	Flat	277.1bc	99.8ab
	Bed	264.3e	102.1a
WH	Furrow	288.4a	98.3ab
	Flat	279.9bc	102.3a
	Bed	268.3de	104.1a
Sig. level		**	*

DC = Dwarf Cavendish, GN = Grand Nain and WH = William Hybrid.
Means in columns followed by the same letter(s) are not significantly different at P≥0.05 level according to Duncan's Multiple Range Test.
* and ** indicate significance at 0.05 and 0.01, respectively.

Yield and yield components

Table 5 shows the main effects of banana clones on yield and yield components of the plant crop. Results showed significant differences in all yield components among the banana clones. The introduced clones WH and GN produced significantly higher yields and yield components than the local clone DC which produced the lowest values. These results are supported by the vigorous vegetative growth of the introduced clones shown in Tables 1 and 3. There were no significant differences in yield components between the two introduced clones. These results supported the findings of Elsiddig *et al*. (2009).

Table 6 shows the main effects of planting methods on yield and yield components of banana clones. The furrow planting method was superior in all yield parameters, followed by planting in flat and then bed planting method. This was most probably due to the fact that the furrow planting

method provided sufficient irrigation water for plants which resulted in larger bunches and higher yields. These results are also consistent with the data presented in Table 2 which shows that the furrow planting method resulted in the most vigorous vegetative growth as compared to the other two methods.

Table 5. Main effect of banana clones on yield and yield components of the plant crop of banana

Banana clone	Bunch wt. (kg)	No. of hands/bunch	No. of fingers/bunch	Yield (ton/ha)
DC	14.0b	7.6b	85.7b	23.4b
GN	18.3a	8.2a	112.1a	30.5a
WH	18.7a	8.4a	119.4a	31.1a
Sig. level	**	*	**	**

DC = Dwarf Cavendish, GN = Grand Nain and WH = William Hybrid.
Means in columns followed by the same letter(s) are not significantly different at P≥0.05 level according to Duncan's Multiple Range Test.
* and ** indicate significance at 0.05 and 0.01, respectively.

Table 6. Main effects of planting method on yield and yield components of the plant crop of banana

Planting method	Bunch wt. (kg)	No. of hands/bunch	No. of fingers/bunch	Yield (ton/ha)
Furrow	18.4a	8.6a	122.7a	30.6a
Flat	17.2b	8.0b	108.0b	28.2b
Bed	15.5c	7.5c	86.4c	24.8c
Sig. level	*	*	*	*

Means in columns followed by the same letter(s) are not significantly different at P≥0.05 level according to Duncan's Multiple Range Test.
* indicates significance at 0.05.

The interaction effects between planting methods and banana clones on yield and yield components are shown in Table 7. The highest yields were obtained by WH and GN clones grown in furrows whereas the lowest yield was obtained by DC clone planted in beds. Regardless of clones, the furrow planting method produced the highest yields and yield components and the bed method produced the lowest.

Table 7. Interaction effects of banana clones and planting method on yield and yield components.

Banana clones	Planting method	Bunch wt. (kg)	No. of hands/bunch	No. of fingers/hand	No. of fingers/ bunch	Yield (ton/ha)
DC	Furrow	15.3e	8.0bc	12.1b	96.8c	24.4d
	Flat	14.7e	7.5d	11.6b	87.0c	23.5d
	Bed	12.1f	7.4d	9.9c	73.3d	19.4e
GN	Furrow	19.8a	8.9a	14.7a	130.8a	31.7a
	Flat	18.1c	8.1b	14.2a	115.0b	28.9bc
	Bed	17.1d	7.6cd	11.9b	90.4c	27.4c
WH	Furrow	20.1a	9.0a	15.6a	140.4a	32.2a
	Flat	18.9b	8.5ab	14.4a	122.4b	30.2b
	Bed	17.3d	7.7cd	12.4 b	95.5c	27.6c
Sig. level		**	**	*	**	**

DC = Dwarf Cavendish, GN = Grand Nain and WH = William Hybrid.
Means in columns followed by the same letter(s) are not significantly different at P≥0.05 level according to Duncan's Multiple Range Test.
* and ** indicate significance at 0.05 and 0.01, respectively.

Fruit quality

The interaction effects of the banana clones and planting methods on total soluble solids (TSS) and colour of fruits are shown in Table 8. Results indicated significant interaction effects on both parameters. Regardless of the planting method used, DC resulted in the best colour and highest TSS compared with the other two clones. However, GN and WH clones

planted in beds resulted in TSS values comparable to those obtained by DC. Generally, there was a direct relationship between banana fruit colour and total soluble solids content. This was because colour development was an indication of advanced ripening and hence high TSS content of fruits. Similar results were reported for bananas by Elkashif *et al.* (2005).

Table 8. Interaction effects between banana clones and planting method on fruit colour and total soluble solids (TSS) of the plant crop

Banana clones	Planting method	Colour	TSS
DC	Furrow	4.10a	21.63a
	Flat	3.73c	20.40ab
	Bed	3.97b	21.47a
GN	Furrow	4.10a	19.27bc
	Flat	3.87c	17.90c
	Bed	3.97b	20.23ab
WH	Furrow	3.73c	18.27c
	Flat	4.07a	19.40bc
	Bed	3.79b	20.60ab
Sig. level		*	*

DC = Dwarf Cavendish, GN = Grand Nain and WH = William Hybrid.
Means in columns followed by the same letter(s) are not significantly different at $P \geq 0.05$ level according to Duncan's Multiple Range Test.
* indicate significance at 0.05.

In conclusion, the introduced banana clones WH and GN grown in furrows had the most vigorous vegetative growth and the highest yields and yield components as compared to the local clone DC.

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تأثير طرق الزراعة على نمو وإنتاجية بعض أصناف الموز

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المستخلص: أجريت التجارب بحقل بحوث المعهد القومي لتنمية الصادرات البستانية ، جامعة الجزيرة بهدف معرفة تأثير طرق الزراعة على نمو وإنتاجية ثلاثة أصناف من الموز . طرق الزراعة كانت زراعة الموز في أحواض أو مصاطب أو جداول . مسافات الزراعة كانت ثلاثة أمتار بين الصفوف ومتران بين النباتات . أصناف الموز هي وليامز وقراندنين (مستجلبة من خارج السودان) والصنف المحلي كافندش القزم . أستخدم تصميم القطع المنشقة بثلاثة مكررات K ، حيث كانت طرق الزراعة القطع الأساسية والأصناف القطع الثانوية .

أظهرت النتائج أن زراعة الموز في الجداول أعطت أفضل نمو خضري متمثلاً في طول النبات وسمك الساق وكذلك أعلى إنتاجية ، يلي ذلك الزراعة في أحواض ، بينما أعطت الزراعة في مصاطب أقل نمو خضري وأقل إنتاجية . الأصناف المستجلبة وليامز وقراندنين كانت أطول وذات ساق أكثر سمكاً وأعلى إنتاجية من الصنف المحلي كافندش القزم الذي أعطى أقل معدلات في النمو الخضري والإنتاج . الصنف وليامز المزروع في جداول استغرق أطول مدة من الزراعة وحتى الإزهار ولكنه استغرق وقتاً أقل من الإزهار وحتى الحصاد بالمقارنة مع الأصناف الأخرى . زراعة الموز في مصاطب أعطت أعلى معدل للمواد الصلبة الذائبة بالمقارنة مع طرق الزراعة الأخرى .