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Effects of Banana Clones and Spacing on Growth, Yield and Fruit Quality of Some Banana Cultivars

Dr. AbdElgadir D.A. Mohammed
Assistant Professor, Department of Horticulture, Faculty of Agriculture, University of Sinnar, Abu Naama, Sudan
Email: abdelgadir-ahmed@hotmail.com

Abstract

Afield experiment was carried out at the National Institute for the Promotion of Horticultural Exports (NIPHE) research farm, University of Gezira, Wad Medani, Sudan, to study the effects of banana clones and spacing on vegetative growth, crop earliness, yield and yield components, fruit green life and fruit quality of some introduced banana clones under Gezira state conditions. Treatments consisted of six new banana clones, namely, Williams hybrid clone 1 (WH1), Williams hybrid clone 2 (WH2), Grand Nain clone 1 (GN1), Grand Nain clone 2 (GN2), Zelig and Bio, which were introduced from South Africa by NIPHE. The introduced clones were compared with the local cultivar Dwarf Cavendish (DC). All clones were grown at spacings of 2x2 m and 3x3 m. These treatments were arranged in a split plot design with three replications and four plants each. Results showed that vegetative growth parameters, crop earliness, yield and yield components, fruit green life and fruit quality were significantly affected by spacing and banana clones. WH1 and Zelig obtained the best vegetative growth, whereas DC obtained the worst growth. Zelig and Bio scored the highest yield and yield components, while DC scored the lowest yield in the three ratoons. WH1 took the largest number of days from shooting to harvesting, whereas Zelig recorded the highest exportable yield in the three ratoons. Generally, the spacing of 2 x 2m resulted in an increase in pseudostem height and total yield (t/ha), but it resulted in a small pseudostem girth and low exportable yield in all banana clones as compared to the wider spacing (3 x 3 m). Banana clones grown at 3x3m had significantly longer fruit green lives than those grown at 2x2m.

Keywords: Effects, Banana clones, Spacing, growth, Yield, Yield component, Fruit quality, Exportable hands.

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تأثير سلالات الموز ومسافات الزراعة على النمو، الإنتاج وجودة الثمار لبعض أصناف الموز

إعداد الدكتور/ عبد القادر دفع الله أحمد محمد

أستاذ مساعد بقسم البساتين، كلية الزراعة، جامعة سنار، أبو نعامة، السودان

Email: abdelgadir-ahmed@hotmail.com

المستخلص:

أجريت تجربة حقلية بحقل بحوث المعهد القومي لتنمية الصادرات البستانية، جامعة الجزيرة، ود مدني، السودان، لدراسة تأثير سلالات الموز ومسافات الزراعة على النمو الخضري، التبكير في الإنتاج، الإنتاج ومكونات الإنتاج، مدة بقاء الثمار خضراء وجودة الثمار لبعض سلالات الموز المستجلبة تحت مناخ ولاية الجزيرة. تضمنت المعاملات ست سلالات موز جديدة هي (هجين وليامز سلالة 1، هجين وليامز سلالة 2، جرانين سلالة 1، جرانين سلالة 2، زلج وبايو)، والتي استجلبت من جنوب أفريقيا بواسطة المعهد القومي لتنمية الصادرات البستانية. تمت مقارنة السلالات المستجلبة مع الصنف المحلي كافندش القزم. تمت زراعة جميع السلالات على مسافات (3 × 3 و2 × 2 متر). نظمت المعاملات باستخدام تصميم القطع المنشقة بثلاثة تكرارات وأربعة نباتات لكل تكرار. أوضحت النتائج أن النمو الخضري، التبكير في الإنتاج، الإنتاج ومكونات الإنتاج، مدة بقاء الثمار خضراء وجودة الثمار تأثرت معنوياً بسلالات الموز ومسافات الزراعة. تحصلت السلالتان هجين الوليامز سلالة 1 والزلج على أفضل صفات نمو خضري، بينما تحصل كافندش القزم على أسوأ نمو. أحرزت السلالتان زلج وبايو أعلى إنتاجية ومكونات الإنتاجية، بينما أحرز كافندش القزم أقل محصول. استغرق هجين الوليامز سلالة 1 أكبر عدد من الأيام من الإزهار الى نضج الثمار، بينما سجلت السلالة زلج أعلى نسبة صادر من الثمار. عموماً أدت مسافات الزراعة 2 × 2 متر الى زيادة في ارتفاع النبات والإنتاج الكلي (طن/هكتار) في كل السلالات المستخدمة في هذه الدراسة ولكنها أدت الى انخفاض في محيط الساق وانخفاض في نسبة المحصول الصالح للصادر مقارنةً بالمسافات الأوسع (3 × 3 م). سلالات الموز المزروعة على مسافة 3 × 3 م بقيت خضراء مدة أطول من تلك المزروعة على مسافة 2 × 2 م. لم تؤثر سلالات الموز ومسافات الزراعة معنوياً على عدد أيام النضج وتغير اللون والصلابة أثناء النضج. كان للسلالتين زلج وبايو أعلى قيمة في نسبة المواد السكرية الذائبة ومذاق الثمار، بينما نتج عن كافندش القزم أقل محتوى من المواد الصلبة الذائبة وأسوأ طعم مقارنةً بالسلالات المستجلبة. أدت مسافات الزراعة الأوسع (3×3م) الى أنتاج ثمار ذات محتوى عالي من المواد الصلبة الذائبة وطعم أفضل مقارنةً بمسافات (2×2 م).

الكلمات المفتاحية: تأثير، سلالات الموز، مسافات الزراعة، النمو، الإنتاج، مكونات الإنتاج، جودة الثمار، كفوف قابلة للتصدير.

1. Introduction

Banana is one of the most popular and cheapest fruits in the Sudan and is available all the year round. The harvested banana area in Sudan in 2020 was about 47000 ha, and the production was estimated to be 923938 tones (FAO, 2021). It plays an important role in the diet of the people due to its high nutritive value. It has a high carbohydrate content and is a good source of vitamins A, B and C (Hamid, 1992). It is also rich in important minerals like Ca, K, P and Fe and contains little amounts of proteins and fats (Litzenberger, 1974).

The predominant banana clone grown in Sudan is the Dwarf Cavendish (DC), which is a low yielder, has small-sized fingers, short green life and does not meet international market standards (Hamed, 1992). Banana market trade requirements include a finger length of not less than 20 cm, firm, dark-green fingers and a green life of at least three weeks at 14^0 C and 90% relative humidity (Robinson, 1996). Therefore, some of the most internationally popular clones, which possess these desirable characters, such as Williams Hybrid and Grand Nain, have been introduced by the National Institute for the Promotion of Horticultural Exports and evaluated compared to the local clone DC (Mahmoud and Elkashif, 2003;Elkashif and Mahmoud, 2005; Elkashif *et al*., 2005; 2010; Elsiddig *et al*., 2009).

Mahmoud *et al.* (2011) evaluated some introduced irradiated clones of Grand Nain (GN) and Williams Hybrid (WH) and found that they had significantly higher bunch weight, total and exportable yields and longer fruit green life, but slightly lower total soluble solids (TSS) content than the local clone DC. Similarly, Elsiddig *et al*. (2009) reported that introduced clones of GN and WH had the best vegetative growth and the highest exportable and total yields. However, the local clone DC resulted in the least parameters of vegetative growth and yield components but recorded the highest TSS content.

Banana spacing is one of the most important cultural practices because it determines plant population, number of bunches per unit area and, hence, total yield (Wills *et al*., 1981). Therefore, the most appropriate plant spacing should be chosen, depending on cultivar, soil type and management of the plantation (Black and Peacock, 1971). Generally, wide plant spacing results in vigorous vegetative growth, large bunches and fingers, high exportable yield but low total yield (Litzberger, 1974).

However, close spacing results in taller and slender plants, low exportable yield due to small-sized fingers and high total yield due to the large number of bunches per unit area. Also, wide plant spacing resulted in an early crop and *vice versa* (Elsiddig *et al*., 2009).

Mahmoud *et al*. (2011) studied the effects of plant spacing and number of suckers on growth and yield of bananas. They found that plant spacing of 3x3 m (1111 plants/ha) with two suckers resulted in the best vegetative growth, the largest fingers and the highest exportable yield. However, it produced the lowest total yield. The close spacing of 2x2 m (2500 plants/ha) produced the highest total yield, but the smallest fingers and the lowest exportable yield. Hence, there is a need to find out the optimum plant spacing of these introduced banana clones that would give high exportable yield of fruit with a long green life and good quality. Therefore, the objective of this study was to evaluate the effects of banana clones and spacing on vegetative growth, crop earliness, yield and yield components, fruit green life and fruit quality of the first three ratoons of these introduced clones.

2. Materials and Methods

This study was conducted at the national Institute for the Promotion of Horticultural Exports (NIPHE) research farm at Hantoub area along the east bank of the Blue Nile, lat. 14.5^0N, and long. 33.4^oE. The area lies within an arid climate of summer rains and relatively warm winter. The mean minimum temperature is 14^0C in January and the mean maximum is 43^0C in May. Average annual rainfall is 320 mm; however, the total annual varies from year to year. The rainy season lasts from June to October, with a well-defined peak in August. Humidity is generally low with a peak of 60% in August and decreases to a lowest of about 12% in April. The soil at the experimental site is classified as vertic, ustifluvents, fine loamy, mixed, isohyprthermic (SSAS, 1999). Six banana clones were introduced at the plantlet stage from tissue culture laboratories in South Africa by the NIPHE, University of Gezira. They were William's hybrid clone 1 (WH1), William's hybrid clone 2 (WH2), Grand Nain clone 1 (GN1), Grand Nain clone 2 (GN2), Zelig and Bio. The clones were compared with the local Dwarf Cavendish (DC). The clones were raised in the nursery for 7 months and then transplanted in the field. The introduced clones and the local clone Dwarf Cavendish (DC) were transplanted in the field at the spacing of 2x2m and 3x3m. Treatments were arranged in a split plot design with spacing as the main plots and clones as subplots and replicated three times.

Plot size was 5x5 m and each plot consisted of four plants. Uniform, vigorous suckers were selected and planted in pits 30x30x30 cm. The plots were irrigated every 5-to7 days according to weather conditions. Roundup herbicide was used for weed control one month after planting at the rate of 750 ml/ha. Nitrogen in the form of urea was applied at the rate of 400g per mat/year in split doses every four months. Two plants from each plot were randomly selected, tagged and used for data collection. Data were collected for the first, second and third ratoons and consisted of the following:

Growth parameters:

Growth parameters data consisted of the measurement of pseudostem height and girth (cm) at shooting. Pseudostem height was measured from the soil surface up to the point of intersection of petioles of the two youngest leaves. Pseudostem girth was measured at 10 cm above the soil surface. Number of days from shooting to harvesting was determined.

Yield and yield components:

Bunches were harvested when fruits were at the mature green stage "full three quarter" and bunch weight was recorded. Bunches were dehanded using a sharp curved knife. Hands and stalks were separately weighed. The number of hands per bunch were counted. The exportable hands were selected by measuring the length of the middle finger on the outer whorl of each hand. Any finger length equal to 203mm or more was considered to be exportable (Robinson, 1996) Exportable yield percentage was determined as follows:

$$= \frac{\text{Weight of exportable hands}}{\text{Total weight of hands}} \times 100$$

Determination of the green life of banana fruit:

Green life was calculated as the number of days from harvest till the fruits reached colour score number 3, according to Chiquita Company colour chart. Bunches of the first three ratoons were harvested when fruits were at the mature green stage "full three quarter" and cut into hands. Banana hands were washed with tap water to remove latex and dust and were disinfected in a solution of commercial bleach (Chlorox) of 5.25% sodium hypochlorite at a concentration of 5 ml/liter and then placed in intact polyethylene bags and stored at 14^0 C to determine the green life of banana fruit. Green life was terminated when fruits reached colour code number 3 according to Chiquita Company colour chart.

Fruit quality measurements:

At colour score number 3, the banana hands were treated with Ethrel (2 ml/l) by dipping for two minutes, air dried, packed in intact polyethylene bags and ripened at 20^0C and 70% relative humidity. The number of days required to reach the colour score number 6, according to Chiquita Company colour chart, was recorded. Fruit firmness was determined using thumb and forefinger pressure test, which was rated on a scale of 1 to 5 as follows: 1, very firm; 2, firm; 3, slightly soft; 4, soft and 5, very soft. Colour development was rated according to Chiquita Company colour chart as follows: 1, dark green; 2, green; 3, yellowish green; 4, more yellow than green; 5, yellow with green tips; 6, yellow and 7, yellow with brown flecks. Fruit taste was determined using a taste panel to evaluate banana fruit quality and acceptability. Ten panelists were asked to evaluate the fruit taste according to a scale ranging from 1 to 5 as follows:1, unacceptable; 2, slightly acceptable; 3, acceptable; 4, sweet and 5, very sweet. Total soluble solids were measured at the full ripe stage (colour score number 6) using a hand refractometer (Bellingham and Stanley Ltd, Tunbridge Wells, England). The data were subjected to analysis of variance (ANOVA) procedure. In the cases of significant F values, Duncan's Multiple Range Test (DMRT) at p=0.05 was used to compare treatments means.

3. Results and Discussion

The effects of banana clones and spacing on growth, yield and fruit quality of the plant crop of these introduced banana clones have already been published (Elsiddig *et al*., 2009).

Vegetative growth parameters:

Pseudostem height is a very important character, which affects many management practices. For example, tall plants are liable to wind damage and falling down, in addition to difficulty of harvest. Large pseudostem girth is an important factor to support plants against strong winds that cause plants to fall down and result in losses of mature or immature bunches.

The main effects of banana clones on pseudostem height and girth of the first, second and third ratoons at shooting are significant (Table 1). William's hybrid clone 1 resulted in the tallest pseudostem in the three ratoons, whereas DC resulted in the shortest. However, William's hybrid clone2, Grand Nain clone 2 and Zelig were comparable in pseudostem height. Zelig obtained the largest pseudostem girth, which was comparable with William's hybrid clone1 in both cycles.

William's hybrid clone 1, Grand Nain clone 1 and Bio were comparable in pseudostem girth in second and third ratoons. However, DC resulted in the smallest girth. Elsiddig et al. (2009) have reported similar results for the plant crop of these introduced clones. Ali (2000) recorded a pseudostem height and girth of 172 and 64.7 cm, respectively, for Dwarf Cavendish.

The main effects of spacing on pseudostem height and girth at shooting were significant (Table 1). Plant spacing of 2x2 m resulted in the tallest and thinnest pseudostems in the three ratoons as compared with 3x3 m. These results were consistent with the reports of Elsiddig (2003) who stated that banana plants grown at a close spacing were taller with thinner pseudostems than those grown under a wide spacing. This was due to the high competition between plants grown at a close spacing for sunlight.

The interaction effects between banana clones and spacing on pseudostem height and girth at shooting of the three ratoons were significant (Table 3). The tallest and thinnest pseudostems were produced at a spacing of 2x2 m compared to 3x 3 m in all clones. William's hybrid clone 1 in the three ratoons obtained the tallest pseudostems, whereas Bio resulted in the shortest. Zelig and William's hybrid clone 1 grown at 3 x3 m recorded the largest pseudostem girth, whereas Grand Nain clone 2 grown at 2x2 m recorded the lowest. These results were in agreement with the findings of Kesavan *et al.* (2001).

Table 1. Main effects of banana clones and spacing on the vegetative growth of the three ratoons at shooting.

Clones	Pseudostem height (cm)			Pseudostem girth (cm)		
	R_1	R_2	R_3	R_1	R_2	R_3
WH1	234.7 a	243.8 a	250.0 a	61.8 b	66.2 ab	70.2 ab
WH2	197.2 b	218.7 b	229.2 b	58.8 c	63.3 bc	65.8 bc
GN1	189.8 cd	191.3 c	228.3 b	59.2 c	63.2 bc	67.8 bc
GN2	191.2bc	202.2bc	213.3 c	60.7 b	62.2 c	68.8 abc
Zelig	198.3 b	210.0 bc	222.8 b	64.7 a	68.2 a	71.7 a
Bio	183.5 d	192.2 c	201.2 d	60.3 b	65.7 ab	67.2 bc
DC	163.2 e	172.5 d	180.6 e	56.3 d	58.7 d	60.4 d
CV (%)	2.9	7.9	2.3	6.1	4.0	3.9
Sig. level	***	***	***	*	**	**

Spacing (m)						
3x3	195.7	207.9	218.1	62.8	67.2	72.3
2x2	202.5	211.4	230.2	59.1	62.3	64.8
CV (%)	7.0	8.0	3.3	7.3	6.9	5.8
Sig. level	*	*	*	NS	*	**

WH1= Williams hybrid clone 1, WH2= Williams hybrid clone 2, GN1= Grand Nain clone 1, GN2= Grand Nain clone 2, DC= Dwarf Cavendish.

*, **, *** and NS indicate significance at 5%, 1%, 0.1% levels and not significant, respectively.

R_1, R_2 and R_3 indicate first ratoon, second ratoon and third ratoon, respectively.

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

Table 2. Interaction effects of banana clones and spacing on vegetative growth of the three ratoons at shooting.

Clones	Spacing	Pseudostem height (cm)			Pseudostem girth (cm)		
		R_1	R_2	R_3	R_1	R_2	R_3
WH1	3 x3	230.0 a	343.3a	248.3a	64.3 b	70.0 ab	76.7 a
	2x2	239.3 a	244.3a	251.7a	59.3 c	62.3 cd	63.7 e
WH2	3x3	195.0 bcd	216.7ab	228.3b	59.7 c	65.0 cd	66.7 cde
	2x2	199.3 bc	220.7ab	230.0b	58.0 c	61.7 cd	65.0 de
GN1	3x3	187.7 de	193.3b	203.3de	59.7 c	64.3 cd	69.0 bcd
	2x2	192.0 cde	189.3b	253.3a	58.7 c	62.0 cd	66.7 cde
GN2	3x3	188.3 de	201.7b	211.7cd	61.7 c	63.3 cd	71.0 bc
	2x2	194.0 cd	202.7b	215.0c	59.7 c	61.0 d	66.7 cde
Zelig	3x3	191.7 cde	201.7b	216.7c	68.0 a	74.0 a	79.0 a
	2x2	205.0 b	218.3ab	229.0b	61.3 c	62.3 cd	64.3 de
Bio	3x3	181.7 e	191.0b	200.3e	63.3 b	66.7 bc	71.7 b
	2x2	185.3 de	193.3b	202.0e	57.3 d	64.7 cd	62.7 e
DC	3x3	169.5 g	170.2 d	172.6 g	53.2	55.4 e	58.7 e
	2x2	172.7 f	173.3 c	174.5	49.1	52.6 f	55.4 f

		f					
CV (%)		2.9	7.9	2.3	6.1	4.0	3.9
Sig. leve		***	***	***	NS	*	***

WH1= Williams hybrid clone 1, WH2= Williams hybrid clone 2, GN1= Grand Nain clone 1, GN2= Grand Nain clone 2, DC= Dwarf Cavendish.

*, *** and NS indicate significance at 5%, 0.1% levels and not significant, respectively.

R_1, R_2 and R_3 indicate first ratoon, second ratoon and third ratoon, respectively.

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

Crop earliness:

The main effects of banana clones and spacing on number of days from shooting to harvesting of the three ratoons are shown in Table 3. Results indicated highly significant differences between banana clones in number of days from shooting to harvesting in the three ratoons.

The longest duration for bunch maturation was taken by William's hybrid clone 1 and 2 in the three ratoons, while the shortest was taken by Grand Nain clone 1, Zelig and DC in all ratoon crops.

However, the local clone DC was the earliest clone as compared to the introduced clones. Spacing had highly significant effects on number of days from shooting to harvesting in the three ratoons (Table 3). The largest numbers of days from shooting to harvesting were obtained at the spacing of 2x2 m compared to 3x3 m in all clones. Elsiddig *et al.* (2009) reported the same results for the plant crop of these clones. Robinson and Nel (1989) reported that the crop cycle duration was extended under close spacing.

The interaction effects of banana clones and spacing on number of days from shooting to harvesting are presented in Table 4. Results showed significant differences in the first ratoon and highly significant differences in the second and third ratoons. Generally, in all clones, plants grown at the closer spacing took more time for bunch maturation for the three ratoons, as compared to the wider spacing. This was because, plants grown at the closer were week and had poor vegetative growth and hence took more time for bunch growth and maturation. Kesavan *et al*. (2001) reported similar results.

William's hybrid clone 1 at both spacings took a longer duration from shooting to harvesting in the three ratoons, while Grand Nain clone 1 and DC at the spacing of 3x3 m took the shortest. These findings were in conformity with the reports of Robinson and Nel (1988) who stated that the duration from flowering to harvest of Cavendish subgroup ranged between 100 to 240 days in subtropical areas.

Table 3. Main effects of banana clones and spacing on number of days from shooting to harvesting of the three ratoons

Clones	R_1	R_2	R_3
WH1	115.5 a	116.3 a	116.8 a
WH2	108.7 b	113.7 a	115.3 a
GN1	98.8 c	101.2 d	102.8 c
GN2	107.5 b	109.3 b	111.2b
Zelig	100.0 c	103.0 cd	104.0 c
Bio	105.2 b	106.3 bc	108.2 b
DC	104.6 b	105.2 c	104.7 c
CV (%)	3.8	3.0	2.3
Sig. level	***	***	***
Spacing (m)			
3x3	102.5	105.4	107.3
2x2	109.4	111.2	112.1
CV (%)	4.5	3.7	2.9
Sig. level	**	**	**

WH1= Williams hybrid clone 1, WH2= Williams hybrid clone 2, GN1= Grand Nain clone 1, GN2= Grand Nain clone 2, DC= Dwarf Cavendish.

** and *** indicate significance at 1% and 0.1% levels, respectively.

R_1, R_2 and R_3 indicate first ratoon, second ratoon and third ratoon, respectively.

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

Table 4. Interactions effects of banana clones and spacing on number of days from shooting to harvesting of the three ratoons.

Clones	Spacing	R_1	R_2	R_3
WH1	3x3	115.3 a	116.0 a	116.3 a
	2x2	115.7 a	116.7 a	117.3 a
WH2	3x3	104.0 cd	112.0 abc	114.3 ab
	2x2	113.3 ab	115.3 ab	116.3 a
GN1	3x3	92.0 e	92.7 f	95.3 f
	2x2	105.7 cd	109.7 bcd	110.3 bc
GN2	3x3	101.7 cd	105.3 de	108.0 cd
	2x2	113.3 ab	113.3 abc	114.3 ab
Zelig	3x3	99.0 d	102.0 e	103.3 e
	2x2	101.0 cd	104.0 de	104.7 de
Bio	3x3	103.0 cd	104.3 de	106.7 cde
	2x2	107.3 bc	108.3 cd	109.7 c
DC	3x3	94.6 e	95.7 f	95.8 f
	2x2	98.8 d	99.2 e	99.1 e
CV (%)		3.8	3.0	2.3
Sig. level		*	**	***

WH1= Williams hybrid clone 1, WH2=Williams hybrid clone 2, GN1= Grand Nain clone 1, GN2= Grand Nain clone 2, DC= Dwarf Cavendish.

*,**and *** indicate significance at 5% , 1% and 0.1% levels, respectively.

R_1, R_2 and R_3 indicate first ratoon, second ratoon and third ratoon, respectively. Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

Yield and yield components:

The main effects of banana clones and plant spacing on yield components of the three ratoons were highly significant (Table 5). The clones Zelig and Bio resulted in the highest bunch weight, the largest number of hands per bunch and the highest yield of all crops, whereas Grand Nain clone I and DC resulted in the lowest yield parameters.

Elkashif *et al.* (2005) reported that DC clone produced the smallest bunches as compared to introduced WH clones, which were evaluated in Kassala State. Yield increased slowly as the number of ratoons increased. Mahmoud and Elkashif (2003) recorded a bunch weight of 15.1 kg for Dwarf Cavendish cultivar. Robinson (1996) reported that the weight of a Cavendish bunch could vary from 15 kg to 50 kg depending on cultural practices and soil fertility.

The main effects of plant spacing on yield parameters are significant (Table 5). The highest bunch weight and the largest number of hands per bunch were produced at the spacing of 3x3 m compared to 2x2 m in the three ratoons. However, the spacing of 2x2 m resulted in higher yield due to the large plant population per unit area and hence a large number of bunches, irrespective of their small size. Similar results have been reported by Elsiddig *et al.* (2009) for the plant crop of these introduced clones. Robinson and Nel (1988) stated that high plant density induced smaller bunches.

Exportable yield:

Banana clones had no significant effects on exportable yield of the three ratoons. The effects of spacing on exportable yield of the three ratoons are highly significant (table 6). The highest exportable yield was obtained at the spacing of 3 x 3 m.

The interaction effects of banana clones and spacing on exportable yield of the three ratoons are highly significat (Table 7). Zelig clone grown at the spacing of 3 x 3 m obtained the highest exportable yield, whereas DC grown at the spacing of 2 x 2m resulted in the lowest in the three ratoons. Generally, in all clones, exportable yield was higher at the spacing of 3 x 3m as compared to 2 x 2m. This was because there was less competition between plants grown at the wider spacing that resulted in bigger bunches with large fingers suitable for export.

On the other hand, plants grown at the closer spacing suffered from competition and hence produced small bunches with small fingers that were not acceptable in international markets. Elsiddig *et al.* (2009) reported the same results for the plant crop of these clones.

Table 5. Main effects of banana clones and spacing on yield and yield components of the three ratoons.

	Bunch weight (kg)			No. of hands / bunch			Yield (ton / ha.)		
Clones	R1	R2	R3	R1	R2	R3	R1	R2	R3
WH1	16.4 c	17.5 b	18.3 c	9.3 a	9.2 bc	9.8 a	26.5 c	28.8 b	30.2 c

WH2	16.1 c	17.o b	17.5 c	9.2 a	9.3 bc	10.2 a	27.1 c	28.2 b	29.3 c
GN1	11.9 e	13.7 c	14.8 d	7.8 b	8.5 c	8.7 b	20.3 d	24.3 c	26.4 d
GN2	13.5 d	17.1 b	19.8 b	8.2 b	9.0 bc	9.8 a	22.0 d	27.7 b	33.6 b
Zelig	20.9 a	21.5 a	22.4 a	9.8 a	10.5 a	10.7 a	32.7 a	33.8 a	36.0 a
Bio	19.7 b	21.1 a	22.5 a	9.3 a	9.8 ab	10.5 a	29.5 b	32.3 a	35.5 ab
DC	12.6 e	12.5 d	13.2 e	7.6 b	8.3 c	8.7 b	17.1 e	18.5 d	18.9 e
CV (%)	5.3	4.5	4.7	8.2	6.9	6.6	5.5	5.8	5.1
Sig. level	***	***	***	***	***	***	***	***	***
Spacing (m)									
3x3	21.2	22.7	23.2	10.3	10.4	10.6	23.6	25.2	25.7
2x2	11.6	13.3	15.2	7.6	8.4	9.3	29.1	33.2	38.0
CV (%)	24.1	20.1	18.4	4.2	5.0	7.3	26.4	22.2	18.0
Sig. level	**	**	**	***	***	***	NS	*	**

WH1= Williams hybrid clone 1, WH2= Williams hybrid clone 2, GN1= Grand Nain clone 1, GN2= Grand Nain clone 2, DC= Dwarf Cavendish.

*, **, *** and NS indicate significance at 5%, 1%, 0.1% levels and not significant, respectively.

R_1, R_2 and R_3 indicate first ratoon, second ratoon and third ratoon, respectively.

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

Table 6: Effects of spacing on exportable yield (Percentage) of the first, second and third ratoons.

Spacing	**R_1**	**R_2**	**R_3**
3 x 3	66.4	68.2	66.8
2 x 2	38.6	44.5	42.3
CV %	20.3	18.1	12.8
Sig. level	***	**	***

** and *** indicate significance at 1% and 0.1% levels, respectively.

R_1, R_2 and R_3 indicate first, second and third ratoons, respectively.

Green life (days):

There were significant differences in the green life among the different banana clones in the three ratoons (table 8). The clones Bio, Zelig, GN1 and GN2 had the longest green lives in all the ratoon crops, as compared to the other clones. The locally grown clone, Dwarf Cavendish, had the shortest green life in all ratoon crops. These results indicate the superiority of the introduced clones as compared to the local cultivar DC and their suitability for export due to their longer green lives. Mahmoud and Elkashif (2003) and Elsiddig *et al.* (2009) have reported similar results for the plant crop of these introduced clones. These results confirm the findings of Black and Peacock (1971) who reported that variations in the green lives of the different banana clones were mainly due to genetically factors.

Banana clones grown at the spacing of 3x3m had a significantly longer green life than those grown at 2x2m in all ratoon crops (table 8).

This was probably because bananas grown at a wider spacing produced larger, well developed fruits which stayed firm and green for a longer period of time than those produced by plants grown at a closer spacing (Robinson, 1996). These results are in agreement with those reported by Elsiddig *et al.* (2009) and Elkashif *et al.* (2010).

Number of days to ripen:

There were no significant differences among clones and spacing with respect to the number of days required for ripening after treatment with ethylene at 20^0C for all ratoons.

This indicates that all clones responded similarly to exogenous ethylene and they required about 5 days to full ripening (Table 9). These results are in conformity with those reported by Elkashif *et al.* (2005) and Seymour *et al*, (1987).

Banana fruit colour:

There were no significant differences among clones and spacing on colour development during ripening with Ethrel treatment at 20^0C of the first, second and third ratoons. All fruits of different banana clones reached colour 6 (full yellow) after 5 to 6 days (table 10). This indicated that all introduced clones responded similarly and positively to Ethrel and reached high fruit quality standards. Our findings were consistent with those reported by Seymour *et al.* (1989) who mentioned that banana fruit treated with ethylene at 20^0C resulted in good colour development which is an important characteristic trait required in international trade.

Table 7. Interaction effects of banana clones and spacing on exportable yield (percentage) of the three ratoons.

Clones	Spacing	R_1	R_2	R_3
WH1	3x3	57.7 bc	59.9 ab	58.0 ab
	2x2	39.2 cd	42.5 c	53.4 bc
WH2	3x3	54.6 bc	60.9 ab	51.6 bc
	2x2	34.5 d	36.8 d	44.6 bcd
GN1	3x3	71.8 ab	73.8 a	72.5 a
	2x2	20.5 d	30.7 cd	37.2 cd
GN2	3x3	66.1 ab	68.0 a	72.3 a
	2x2	52.2 bc	47.9 bc	46.8 bc
Zelig	3 x3	79.6 a	73.0 a	73.5 a
	2x2	42.8 c	47.6 bc	43.8 bcd
Bio	3x3	68.3 ab	73.7 a	73.2 a
	2x2	22.3 d	19.2 e	27.8 d
DC	3x3	43.7	45.2	48.5
	2x2	19.3	22.4	25.8
CV (%)		20.7	18.5	17.6
Sig. level		**	***	**

WH1= Williams hybrid clone 1, WH2= Williams hybrid clone 2, GN1= Grand Nain clone 1, GN2= Grand Nain clone 2, DC= Dwarf Cavendish.

and * indicate significance at 1% and 0.1% levels, respectively.

R_1, R_2 and R_3 indicate first ratoon, second ratoon and third ratoon, respectively.

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

Table 8: Effect of banana clones and spacing on fruit green life (days).

Clone	R_1	R_2	R_3
WH1	15.3 c	16.7 b	19.5 b
WH2	16.5 bc	16.2 b	20.2 a

GN1	19.0 a	19.2 a	20.5 a
GN2	17.7 ab	19.2 a	20.2 a
Zelig	19.3 a	19.8 a	20.7 a
Bio	19.0 a	19.5 a	20.5 a
DC	15.6 c	16.2 c	16.8 c
CV (%)	7.9	6.9	3.5
Sig. level	***	***	*
Spacing (m)			
3x3	21.2	21.8	21.7
2x2	17.5	18.7	18.9
Sig. level	*	*	*

WH1=Williams hybrid clone 1, WH2=Williams hybrid clone 2, GN1= Grand Nian clone 1, GN2=GrandNain clone 2, DC=Dwarf Cavendish.

* and*** indicate significance at 5%, and 0.1% level, respectively.

R_1, R_2 and R_3 indicate first, second and third ratoons, respectively.

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

Table 9. Number of days to ripen with Ethrel at 20^0C.

Banana clones	**Days**		
	R1	**R2**	**R3**
WH1	5.3	5.2	5.0
WH2	5.2	5.3	5.0
GN1	5.0	5.0	5.0
GN2	4.8	5.0	5.0
Zelig	5.0	4.8	5.0
Bio	4.8	4.8	4.8
DC	4.5	4.7	4.6
CV (%)	8.0	6.6	3.4

Sig. level	NS	NS	NS

WH1= Williams hybrid clone 1, WH2= Williams hybrid clone 2, GN1= Grand Nain clone 1, GN2= Grand Nain clone 2, DC= Dwarf Cavendish.

NS indicates not significant.

R_1, R_2 and R_3 indicate first, second and third ratoons, respectively.

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

Table 10. Colour score of fruits of banana clones at the ripe stage.

Banana clones	Colour score		
	R1	R2	R3
WH1	6.3	6.2	6.1
WH2	6.2	6.3	6.2
GN1	6.0	6.0	6.0
GN2	5.8	6.0	6.1
Zelig	6.0	5.8	6.0
Bio	5.8	5.8	5.8
DC	5.5	5.7	5.6
CV (%)	7.2	5.6	4.4
Sig. level	NS	NS	NS

WH1= Williams hybrid clone 1, WH2= Williams hybrid clone 2, GN1= Grand Nain clone 1, GN2= Grand Nain clone 2, DC= Dwarf Cavendish.

NS indicates not significant.

R_1, R_2 and R_3 indicate first, second and third ratoons, respectively.

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

Banana fruit firmness during ripening:

There were no significant differences among banana clones and spacing on fruit firmness during ripening of the first, second and third ratoons with Ethrel treatment at 20^0 C. There was a gradual decrease in fruit firmness with the progress of ripening.

All fruits of the different banana clones became soft 5 to 6 days after Ethrel treatment (Table 11). These findings were in conformity with those of Elkashif *et al.* (2005) who reported that for a firm pulp texture, good colour and flavor development, the fruit must be ripened at a temperature of 20 – 22 ^{0}C.

Fruit total soluble solids (TSS):

The effects of banana clones on fruit total soluble solids were highly significant (Table 12). The clones Zelig and Bio significantly resulted in higher TSS contents as compared to the locally grown DC, which significantly resulted in the lowest TSS contents in the three ratoons. Elsiddig *et al*. (2009) reported similar results for the plant crop of these introduced banana clones.

The effects of plant spacing on TSS content were significant (Table 12). The wider spacing (3x3m) resulted in significantly higher TSS content than the closer spacing (2x2m) in all ratoons. This was because the wider spacing resulted in the production of heavy bunches with large sized fingers, which were more likely to ripen with excellent quality standards (Robinson, 1996; Mahmoud *et al.*, 2011).

The interaction effects of banana clones and spacing on total soluble solids were highly significant (Table 13). Regardless of clones, the wider spacing always resulted in significantly higher TSS contents than the closer one. The clones Zelig and Bio planted at the wider spacing resulted in the highest TSS values than the other clones.

Fruit taste:

Results showed highly significant differences between the different banana clones in the fruit taste of all three ratoons. Generally, the clones Zelig and Bio scored the best taste values as compared to the others (Table 14).

Plant spacing had significant effects on the fruit taste of all three ratoon crops (Table 14). The wider spacing (3x3m) resulted in significantly better taste than the closer one (2x2m).

Table 11. Firmness of fruits of banana clones at the ripe stage.

Banana clones	Fruit firmness		
	R1	R2	R3
WH1	4.3	4.2	4.1
WH2	4.2	4.3	4.2

GN1	4.0	4.0	4.0
GN2	4.8	4.0	4.3
Zelig	4.0	4.8	4.2
Bio	4.8	4.4	4.1
DC	4.3	4.7	4.6
CV (%)	5.2	5.6	4.7
Sig. level	NS	NS	NS

WH1= Williams hybrid clone 1, WH2= Williams hybrid clone 2, GN1= Grand Nain clone 1, GN2= Grand Nain clone 2, DC= Dwarf Cavendish.

NS indicates not significant.

R_1, R_2 and R_3 indicate first, second and third ratoons, respectively.

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

Table 12. Main effects of banana clones and spacing on fruit total soluble solids (%).

Clone	**Total soluble solids (%)**		
	R_1	**R_2**	**R_3**
WH1	20.8 b	21.0 a	20.5 b
WH2	19.0 c	18.5 b	19.8 c
GN1	19.5 c	20.3 a	20.3 b
GN2	20.3 b	20.8 a	20.2 b
Zelig	22.2 a	21.0 a	21.2 a
Bio	21.7 a	20.5 a	21.7 a
DC	19.5 c	19.7 b	19.8 c
CV%	3.4	3.3	3.1
Sig. level	***	***	***
Spacing (m)			
3x3	22.7	22.9	22.9
2x2	21.4	21.6	21.8
Sig. level	*	*	*

WH1= Williams hybrid clone 1, WH2= Williams hybrid clone 2, GN1= Grand Nain clone 1, GN2= Grand Nain clone 2, DC= Dwarf Cavendish.

*and*** indicate significance at 5% and 0.1% level, respectively.

R_1, R_2 and R_3 indicate first, second and third ratoons, respectively.

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

Table 13. Interaction effects of banana clones and spacing on fruit total soluble solids (%).

Clone	Spacing (m)	R_1	R_2	R_3
WH1	3x3	21.0 b	22.6 a	21.3 b
	2x2	20.7 c	20.0 c	19.7 d
WH2	3x3	20.1 c	19.2 d	20.6 c
	2x2	19.0 d	18.3 e	19.4 d
GN1	3x3	19.7 d	21.5 b	20.8 c
	2x2	19.3 d	20.1 c	19.2 d
GN2	3x3	20.3 c	21.7 b	21.8 b
	2x2	20.2 c	20.4 c	20.5 c
Zelig	3x3	21.8 b	22.2 a	22.6 a
	2x2	20.7 c	20.0 c	20.1 c
Bio	3x3	22.7 a	21.8 b	21.9 b
	2x2	20.6 c	20.3 c	20.5 c
DC	3x3	19.3 d	19.6 d	19.3 d
	2x2	19.2 d	19.2 d	19.0 d
Sig. level		**	**	**

WH1= Williams hybrid clone 1, WH2= Williams hybrid clone 2, GN1= Grand Nain clone 1, GN2= Grand Nain clone 2, DC= Dwarf Cavendish.

** indicates significance at 1% level.

R_1, R_2 and R_3 indicate first, second and third ratoons, respectively.

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

Table 14. Main effects of banana clones and spacing on fruit taste.

Clone	R_1	R_2	R_3
WH1	4.7 a	5.0 a	4.5 b
WH2	4.2 b	4.2 b	4.3 b
GN1	4.0 b	5.0 a	4.3 b
GN2	4.7 a	5.0 a	4.5 b
Zelig	5.0 a	5.0 a	5.0 a
Bio	5.0 a	5.0 a	5.0 a
DC	3.3 c	3.2 c	3.4 c
CV (%)	7.1	3.4	7.2
Sig. level	***	**	***
Spacing (m)			
3x3	4.8	4.9	4.6
2x2	3.8	3.7	3.2
Sig. level	*	*	*

WH1= Williams hybrid clone 1, WH2= Williams hybrid clone 2, GN1= Grand Nain clone 1, GN2= Grand Nain clone 2, DC= Dwarf Cavendish.

*, ** and *** indicate significance at 5%, 1% and 0.1% level, respectively.

R_1, R_2 and R_3 indicate first, second and third ratoons, respectively.

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

The interaction effects of banana clone and spacing on fruit taste were highly significant (Table 15). The best taste scores were recorded for the clones Bio and Zelig grown at the wider spacing. Generally, there was a direct relationship between TSS and taste. Banana clones which scored high TSS values had the best taste and *vice versa*. Similar results were reported by Seymour *et al*, (1987) and Mahmoud and Elkashif (2003).

In conclusion, the introduced banana clones Bio and Zelig grown at the spacing of 3x3m showed an outstanding performance with respect to vegetative growth, total and exportable yields, fruit green life and quality, which makes them good candidates to replace the local clone DC.

Table 15. Interaction effects of banana clones and spacing on fruit taste.

Clone	Spacing(m)	R_1	R_2	R_3
WH1	3x3	4.7 b	5.0 a	4.7 b
	2x2	4.5 c	4.3 c	4.2 d
WH2	3x3	4.3 c	4.0 d	4.4 c
	2x2	4.0 d	3.8 e	4.1 d
GN1	3x3	4.2 d	4.8 b	4.5 c
	2x2	4.1 d	4.3 c	4.0 d
GN2	3x3	4.4 c	4.8 b	4.8 b
	2x2	4.4 c	4.3 c	4.4 c
Zelig	3x3	4.8 b	5.0 a	5.0 a
	2x2	4.5 c	4.3 c	4.3 c
Bio	3x3	5.0 a	4.9 a	4.9 a
	2x2	4.4 c	4.4 c	4.4 c
DC	3x3	4.1 d	4.4 c	4.2 d
	2x2	4.0 d	4.3 c	4.0 d
Sig. level		**	**	**

WH1= Williams hybrid clone 1, WH2= Williams hybrid clone 2, GN1= Grand Nain clone 1, GN2= Grand Nain clone 2, DC= Dwarf Cavendish.

** indicates significance at 1% level.

R_1, R_2 and R_3 indicate first, second and third ratoons, respectively.

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

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