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Effect of Plant Density on Growth, Yield and Quality of Banana (*Musa AAA*) Cavendish cv. Grand Nain under Kassala conditions

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Abstract

The experiment was established in a private farm at Alqurashi village near Atbara River, Aroma locality, Kassala State, Sudan. Three months old plants of banana cv. "Grand Nain", propagated by tissue culture, were transplanted in the field on first of January 2022 at nine spacing of 2×2m, 2×2.5m, 2×3m, 2×3.5m, 2×4m, 3×2.5m, 3×3m, 3×3.5m and 3×4m. The treatments were replicated 3 times in randomized complete block design (RCBD) and each plot encompassed 12 plants. Results showed that, higher growth parameters were recorded under spacing of 3×2.5m. Least time from planting to flowering and from flowering to harvesting were observed on plants under spacing of 3×2.5m for the mother plant and first ratoon crops. The highest bunch weight and total yield were obtained on plants spaced at 3×2.5m. The highest marginal rate of return (26.18) was recorded at this treatment.

Key words: Plant density, pseudo stem, banana, grand Nain, bunch.

اثر الكثافة النباتية علي النمو والانتاجية و جودة الموز صنف قراندنين تحت ظروف ولاية كسلا

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المستخلص:

أجريت التجربة في مزرعة خاصة بقرية القرشي بالقرب من نهر عطبرة، محلية أروما، ولاية كسلا، السودان. نبتات موز نسيجية عمرها ثلاثة أشهر من صنف قراندنين تمت زراعتها في الحقل في الأول من يناير 2022 على تسع مسافات 2×2م، 2×2.5م، 2×3م، 2×3.5م، 2×4م، 3×2.5 م، 3 × 3 م، 3 × 3.5 م و 3 × 4 م. تم تكرار المعاملات 3 مرات في تصميم القطاعات العشوائية الكاملة وتضمنت كل قطعة 12 نباتًا. أظهرت النتائج أنه تم تسجيل أعلى معاملات نمو تحت مسافات 3×2.5م. ولوحظ أقل وقت من الزراعة إلى الازهار ومن الازهار إلى الحصاد عند مسافة 3×2.5م للنبات الأم المحصول الاول. تم الحصول على أعلى وزن للسبيطة وأعلى إنتاجية على مسافة 3×2.5م بين النباتات. وقد تم تسجيل أعلى معدل عائد هامشي (26.18) في هذه المعاملة.

الكلمات مفتاحية: كثافة نباتية, الساق الكاذبة, الموز, قراند نين, سبيطة.

Introduction

Bananas and plantains are the fourth most important food crop in the world after rice, wheat and maize (Salvador *et al*., 2007).

In Sudan banana is the most important fruit crop. It is very delicious and popular fruit and also grown successfully in many part of Sudan (Khiry, 2006). The harvested banana area in Sudan in 2020 was about 47000 ha, and the production was estimated to be 923938 tones (FAO, 2021).

Banana plant density is an important cultural practice because it determines production, net returns and also quantity of nutrients and water per unit area (Behera *et al*., 2014). Plant density is depending on cultivar, soil type and management (Elsiddig *et al*., 2009). Litzenberger (1974) reported that wide plant spacing results in vigorous vegetative growth, large bunches and fingers, high exportable yield but low total yield. Moreover, Robinson, (1996) found that banana plant spacing also affects the time from planting to harvesting and hence crop duration.

Banana cultivar Grand Nain was released to farmers and became a popular variety grown mostly for local consumption and export. The plant of this cultivar is taller than the traditionally grown dwarf Cavendish variety and that necessitates determining the optimum plant density to obtain high yield and its components. Therefore, the objective of this study is to examine the effect of plant density on growth, yield and quality of banana cultivar Grand Nain under Kassala conditions.

Materials and Methods

The experiment was conducted in a private farm at Alqurashi village near Atbara river Aroma locality, Kassala State, Sudan (latitude 15° 13´ N, longitude 35° 93´ E, altitude 421 m above sea level) during the period of January 2022 to June 2023. The climate of the study area is characterized by being dry and hot in summer.

Three months old plants of banana cv. “Grand Nain”, propagated by tissue culture, were transplanted in the field on the first of January 2022, at nine spacing of 2×2m, 2×2.5m, 2×3m, 2×3.5m, 2×4m, 3×2.5m, 3×3m, 3×3.5m and 3×4m. This population give 2500, 2000, 1666, 1429, 1250, 1333, 1111, 952 and 833 mother plant/ha, respectively. Three months after planting, two suckers were left and this plant population was maintained thereafter. Irrigation was applied immediately after planting.

The special horticultural practices, *viz*; fertilization, weed control, leaf removal, mulching, desuckering, bunch propping, removal of male bud, wind breaks, etc. were carried out as recommended. Irrigation was applied every 5-7 days according to farmers practice by surface irrigation from Atbara River.

The nine treatments were replicated 3 times in randomized complete block design (RCBD) and each plot encompassed 12 plants. Growth parameters measured included seasonal increases in pseudostem height 5 cm above soil surface to the point of intersection of the petioles of the two youngest leaves. Pseudostem diameter was measured 5 cm above the ground level. The number of green leaves was counted and recorded at shooting. The numbers of days from planting to flowering and from flowering to harvest were also determined.

Mature bunches were harvested when they reached the full three-quarter shape. Yield and yield components were taken, with 10cm of the stalk left with the bunch to facilitate handling. The second hand of freshly harvested bunch was used to measure the fruit characteristics according to Dadzie and Orchard (1997).

Marginal rate of return analyses, as described by CIMMYT (1988), were used to evaluate the profitability of the different plant density based on the field information and data collected.

CropStat statistical program was used for data analysis and the least significant difference test was used for mean separation at the probability level of 0.05.

Results and Discussion

Effect of plant density on growth parameters:

The differences observed on pseudostem height, pseudostem diameter and number of green leaves for both mother plant and first ratoon of banana cv. Grand Nain were highly significant (Table 1). Taller plant for mother plant and first ratoon of banana were observed under close pant spacing compared to wide spacing. The highest pseudostem diameter and number of green leaves were recorded under wide plant spacing compared to close spacing of mother plant and first ratoon (Table 1). This might be due to the effect of high density on banana pseudostem through high completion for sun light. These results are in agreement with those of Kesavan *et al* (2001) who reported that banana plants grown on close spacing were taller with thinner pseudostem than those grown under wide spacing. Moreover, Elsiddig (2003) stated that banana plants grown at a close spacing were taller with thinner pseudostems than those grown under wide spacing.

Table 1. Effect of plant density on pseudostem height (cm), pseudostem diameter (cm) and number of leaves of banana.

Plant density	Pseudostem height (cm)		Pseudostem diameter (cm)		Number of green leaves	
	MP	FR	MP	FR	MP	FR
2m×2m	192b	205a	53c	58c	11e	16b
2m×2.5m	194b	205a	58b	62b	13c	17b
2m×3m	200ab	204ab	60b	64ab	13c	15c
2m×3.5m	201ab	202ab	60b	64ab	14bc	19a
2m×4m	202a	201b	61ab	65ab	15ab	20a
3m×2.5m	197ab	197bc	63a	67a	16a	20a
3m×3m	197ab	196c	64a	67a	16a	20a
3m×3.5m	196b	195c	64a	68a	15ab	20a
3m×4m	193b	192c	63a	67a	15ab	20a
Sig. level	**	***	**	**	***	***
$SE^{\pm}$	1.83	1.63	1.51	1.40	0.46	0.14
CV%	1.60	1.40	4.30	3.70	5.60	3.80
LSD	5.4	4.90	4.52	4.19	1.39	1.23

MP= Mother plant. FR= First ratoon crops

****and **: indicated significance at P≤0.001and P≤0.05, respectively.*

Effect of plant density on crop duration:

Highly significant differences were observed in the number of days from planting to flowering and number of days from flowering to harvest on mother plant and first ratoon (Table 2). Fewer days from planting to flowering and from flowering to harvesting were observed under treatment of 3m×2.5m followed by 3m×3m (Table 2). This may be due the large plant population encountered at the closer spacing resulted in a significant competition between plants which suppressed growth, delayed shooting and hence resulted in longer crop cycles as compared to the wider spacing. These results are in conformity with the findings of Ahmed (2003) who reported that the narrow spacing significantly increased the number of days from shooting to harvest.

Table 2. Effect of plant density on number of days from planting to flowering and number of days from flowering to harvest of banana.

Plant density	Number of days from planting to flowering		Number of days from flowering to harvest	
	MP	FR	MP	FR
2m×2m	301ab	410ab	112a	127a
2m×2.5m	302a	411a	111a	123b
2m×3m	300ab	409b	107b	122b
2m×3.5m	304a	408b	104b	119c
2m×4m	299a	406b	102c	117d
3m×2.5m	291c	398cd	98d	109f
3m×3m	297b	401c	102c	111f
3m×3.5m	300ab	400c	103c	112e
3m×4m	301ab	396d	105b	109e
Sig. level	**	***	**	***
$SE^{\pm}$	1.64	1.41	1.27	0.89
CV%	1.00	0.60	2.30	1.30
LSD	4.93	2.23	3.80	2.68

MP= Mother plant. FR= First ratoon crops

****and **: indicated significance at P≤0.001and P≤0.05, respectively.*

Effect of plant density on bunch weight and total yield:

Bunch weight and total yield were affected by plant density. Results showed highly significant differences in bunch weight and total yield of mother plant and first ratoon of banana (Table 3). The maximum bunch weight and total yield were recorded under plant density of 3m×2.5m compared to plant density of 2m×2m for mother plant and first ratoon of banana (Table 3). This might be due to good vigor of pseudostem diameter at wider spacing resulted in bigger bunches and high yield. These results are in conformity with the findings of Robinson and Nel (1988) who found that high density of banana induced small bunch. On the other hands, AbdElgadir (2022) found that the highest bunch weight was produced at the spacing of 3x3 m compared to 2×2 m in the three ratoons of banana.

Table 3. Effect of plant density on bunch weight (kg) and total yield (t/ha) of banana

Plant density	Bunch weight (kg)		Total yield (t/ha)
	MP	FR	
2m×2m	7.4g	8.6f	61.5d
2m×2.5m	9.1f	10.3e	59.4de
2m×3m	11.1e	12.5d	60.1d
2m×3.5m	13.4d	14.1c	59.4de
2m×4m	19.4c	21.1b	77.1b
3m×2.5m	21.2a	22.2a	87.4a
3m×3m	20.0b	21.0b	68.9c
3m×3.5m	19.5bc	20.3b	57.3e
3m×4m	19.3bc	20.4b	50.3f
Sig. level	**	***	***
$SE^{\pm}$	0.36	0.35	0.19
CV%	4.0	3.70	2.40
LSD	1.09	1.06	2.73

MP= Mother plant. FR= First ratoon crops
****and **: indicated significance at P≤0.001 and P≤0.01, respectively.*

Effect of plant density on number of hands per bunch and number of fingers per hands

There were highly significant differences in the number of hands per bunch and number of fingers per bunch of mother plant and first ratoon crops of banana (Table 4). The highest values of number of hands per bunch and number of fingers per hands were observed under plant density of 3m×2.5m followed by 3m×3m for mother plant and first ratoon of banana (Table 4). This may be due to less competition between plants grown at the wider spacing gives large fingers. These results are in conformity with the findings of Khiry (2006) who found that plant density of banana significantly affected number of hands per bunch and number of fingers per bunch of mother plant. AbdElgadir (2022) found that the largest number of hands per bunch was recorded by the spacing of 3×3 m compared to 2×2 m of banana.

Table 4. Effect of plant density on of number of hands per bunch and number of finger per hands of banana.

Plant density	Number of hands per bunch		Number of fingers per hands	
	MP	FR	MP	FR
2m×2m	5.0d	6.0d	11e	14d
2m×2.5m	5.2d	6.3d	12de	15.0cd
2m×3m	6.3c	7.0c	13cd	15.0cd
2m×3.5m	7.0c	8.3b	14bc	16.2bc
2m×4m	8.0b	9.2ab	15ab	17.0b
3m×2.5m	9.3a	10.2a	16a	19.3a
3m×3m	8.0b	9.3a	16a	18.5a
3m×3.5m	7.3c	8.2b	15ab	17.3b
3m×4m	7.0c	8.4b	14bc	17.7b
Sig. level	***	***	***	***
$SE^{\pm}$	0.31	6.34	0.69	0.59
CV%	7.8	2.40	8.60	6.10
LSD	0.94	1.03	2.06	1.76

MP= Mother plant. FR= First ratoon crops
****: indicated significance at P≤0.001.*

Effect of plant density on finger weight and finger length

Highly significant differences due to various plant densities were observed in finger weights and finger length of mother plant and first ratoon crops of banana (Table 4). The highest values of finger weight and finger length were recorded by plant of density of 3m×2.5m followed by 3m×3m for mother plant and first ratoon of banana (Table 4). These results are in conformity with the findings of Khiry (2006) who found that plant density of banana had significant affect on finger weight and finger length.

Table 5. Effect of plant density on finger weight (g) and finger length (cm) of banana.

Plant density	Finger weight (g)		Finger length (cm)	
	MP	FR	MP	FR
2m×2m	142d	154f	16c	17.0d
2m×2.5m	144d	156ef	16c	17.5d
2m×3m	146d	157e	16c	17.8d
2m×3.5m	150c	163d	17b	18.3cd
2m×4m	155bc	166c	17b	18.4cd
3m×2.5m	163a	174a	19a	22.1a
3m×3m	161ab	173ab	18ab	20.9ab
3m×3.5m	159ab	172b	18ab	19.6bc
3m×4m	156b	172b	18ab	19.3bc
Sig. level	***	***	***	***
$SE^{\pm}$	1.89	0.75	0.49	0.56
CV%	2.10	0.80	4.90	5.10
LSD	5.68	2.25	1.48	1.69

MP= Mother plant. FR= First ratoon crops
****: indicated significance at P≤0.001.*

Economic evaluation

Results of the economic analysis showed that treatment of spacing of 3×2.5m resulted in the highest return of investment. Return to investment in this treatment was estimated in the form of marginal rate of return (MRR), which came out to be 26.18 (Tables 6, 7 and 8). Therefore, the economic evaluation based on partial budget and marginal analysis indicated that the plant of banana transplanted under spacing of 3×2.5m was the most stable and economically feasible treatment under Kassala State conditions.

Table 6. Effect of plant density on partial and dominance of banana

Plant density	(Plants/ha)	Cost of plants (SDG/ha)	Cost of practices (SDG/ha)	Cost of fertilizers (SDG/ha)	Total cost (SDG/ha)
3m×4m	833	83333	83333	250000	416667
3m×3.5m	952	95238	95238	285714	476190
3m×3m	1111	111111	111111	333333	555556
2m×4m	1250	125000	125000	375000	625000
3m×2.5m	1333	133333	133333	400000	666667
2m×3.5m	1429	142857	142857	428571	714286
2m×3m	1667	166667	166667	500000	833333
2m×2.5m	2000	200000	200000	600000	1000000
2m×2m	2500	250000	250000	750000	1250000

Table 7. Partial and dominance for banana yield data (t/ha) in Kassala state

Plant density	Yield (t/ha)	Gross return SDG/ha	Total variable cost (SDG/ha)	Net returns (SDG/ha)	Dominance
3m×4m	50.3	5533611	416667	5116944	
3m×3.5m	57.3	6306667	476190	5830477	
3m×3m	68.9	7581852	555556	7026296	
2m×4m	77.1	8483750	625000	7858750	
3m×2.5m	87.4	9616444	666667	8949777	
2m×3.5m	59.4	6537143	714286	5822857	D
2m×3m	60.1	6612222	833333	5778889	D
2m×2.5m	59.4	6534000	1000000	5534000	D
2m×2m	61.5	6765000	1250000	5515000	D

Table 8. Marginal analysis or banana yield data (t/ha) in Kassala state

Plant density	Yield (t/ha)	Gross return SDG/ha	Total variable cost (SDG/ha)	Net returns (SDG/ha)	MR	MC	MRR
3m×4m	50.3	5533611	416667	5116944			
3m×3.5m	57.3	6306667	476190	5830477	713533	59523	11.99
3m×3m	68.9	7581852	555556	7026296	1195819	79366	15.07
2m×4m	77.1	8483750	625000	7858750	832454	69444	11.99
3m×2.5m	87.4	9616444	666667	8949777	1091027	41667	26.18

The price of one ton of banana=110000 SDG and one US=850SDG.

Recommendation

Based on the findings growing banana cv. Grand Nain at spacing of 3×2.5m is recommended under Kassala conditions.

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