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Growth, Yield and Fruit Quality of Williams Banana as Affected by Different Planting Distances

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ABSTRACT

The present study was conducted in two successive seasons (2009/2010 and 2010/2011) on the first and second ratoons of Williams banana plants cultivated in loamy clay soil under flood irrigation at a private orchard located at Tanta, Gharbia Governorate, Egypt. Four planting densities (ranged from 933 to 1400 plants feddan^{-1}) were examined to study their effect on vegetative growth, flowering, yield and fruit quality of Williams banana. Banana plants grown at close spacing had taller pseudostem than plants grown under wide spacing. The highest yield per feddan was obtained from plants spaced at 3×2 m with two plants per hole, followed by those at 3×1 m, with one plant per hole since it was 34.07 and 30.33 tons in the first ratoon and 34.80 and 31.50 in the second ratoon for both planting distances, respectively. Earliest bunch shooting and minimum days for harvesting were recorded with planting distance 3×4 m with three plants per hole and bunch emerged earlier (12-13 days) than bunches produced from plants spaced at 3×1 m with one plants per hole in both first and second ratoons, respectively. Heaviest bunches were harvested from plants at 3×4 m spacing with three plants per hole. Increasing yield per feddan by this planting distance could be attributed mainly to the increasing number of plants in the area unit. The highest finger weight, length, Total Soluble Solids (TSS%) and total sugars% were produced from plant spaced at 3×4 m with three plants per hole.

Key words: Williams banana, planting distances, growth, yield, fruit quality

INTRODUCTION

Banana is considered as one of the most important fruit crops in tropical zones of the world as well as Egypt. High Density Planting (HDP) is one of the recent and novel concepts of most effective measures to increase productivity per unit area without affecting the quality of the fruit, efficient method of orchard system, precocious easily manageable, high yield potential with higher returns per unit area and more efficient way of harvesting radiant energy. HDP has been successfully implicated in many fruit crops. High technology banana cultivation by using HDP gives very high yield and profit. The planting distance adopted for banana varies throughout Egypt and also in the other parts of the world (Nankinga *et al*., 2005; Randhawa *et al*., 1973).

Optimum planting density for banana is derived from complex integration of many factors, all of which must be evaluated for each individual highlighted eight factors mainly cultivars, soil fertility, sucker selection, management level, weed suppression, wind speed, topography and economic consideration (Simmonds, 1966).

Wider spacing have a positively effect on all vegetative growth parameters except plant height which affected negatively throughout various stages of growth. While, the closer spacing record maximum plant height and yield (Athani *et al*., 2009).

Gross yield of banana per hectare depends on yield per plant and the number of plants per hectare. Floral ignition can occur at any time of the year and is not directly dependent on external factors such as temperature and light (Challopadhay *et al*., 1985). Moreover, productivity increases with increasing density, but yield gains from increasing density are decreasing (Daniells *et al*., 1985). On the other hand, increasing in the planting densities is not a requirement to increase yield (kg ha^{-1}) linearly (Niels, 2009).

Bunch weight, cluster and finger size directly affect by plant spacing (Odeke *et al*., 1999). Theoretically, there is less competition between plants within the optimal plant density. This could be achieved by minimizing mutual shading and overlapping of root zones. Interplant competition is increasing under higher plant densities (above 2000 plants ha^{-1}). Since, increasing of cycling time and decreasing of bunches weight than average weight influenced by increasing plant density (Niels, 2009).

This study was designed to highlight the important effect of four planting distances within row on vegetative growth, flowering, yield and fruit quality of Williams banana under Gharbia governorate conditions.

MATERIALS AND METHODS

This investigation was carried out during the two consecutive seasons of 2009/2010 (first ratoon) and 2010/2011 (second ratoon) in a private orchard at Tanta, Gharbia governorate, Egypt on Williams banana plants.

Williams banana plants were planted at an inter-row spacing of 3 m and four different spacing of 1, 2, 3 and 4 m within row. One sucker per hole was left for the 3×1 m with plant density 1400 plants per feddan; while it was two suckers per hole for both 3×2 m and 3×3 m with plant density 1400 and 933 plants per feddan in both spacing, respectively. The number of suckers for the 3×4 m was three suckers per hole with 1050 plants per feddan as plant density.

All plants under investigation had received the traditional and regular fertilization program as 500 g N/plant/ year as ammonium sulphate added on 14 equal amounts every two weeks intervals starting from 1st April until October. Potassium fertilizer (600 g K_2O/plants/year) was added as potassium sulphate in three equal amounts in April, June and August. While, phosphorus fertilizer added in December as 250 g of super phosphate/plants/year.

Randomized complete blocks design with three replicates for each treatment was used as experimental design. Table 1 identifies the planting distances, number of plants per hole and the plant density per feddan.

Table 1: Planting distances, number of plants per hole and plant density

Planting distances (m)	No. of plants $hole^{-1}$	Plants density
3×1	1	1400
3×2	2	1400
3×3	2	933
3×4	3	1050

The following parameters were determined in the two successive seasons:

Vegetative growth: Data of vegetative growth characteristics was studied as pseudostem length (cm) and circumference (cm), total number of emerged leaves/plant and number of green leaves at bunch shooting.

Flowering parameters: Flowering parameters were estimated as period to bunch emerged and period to bunch maturation (harvesting).

Yield and Bunch characteristics: Yield (ton fed^{-1}) and bunch characteristics were registered as bunch weight (kg), number of hands $bunch^{-1}$, number of finger $hand^{-1}$ and number of finger $bunch^{-1}$.

Finger physical and chemical characteristics: Physical characteristics of fingers were determined as average of finger weight (g), finger length (cm), diameter (cm) and peel to pulp ratio. Chemical characteristics of finger were determined after artificial ripening as TSS%, total acidity % (as g of malic acid/100 g of pulp), total sugars % and starch % according to AOAC (1985).

Statistical analysis: The obtained data were tabulated and statistically tested for analysis of variance using MSTAT (1998) and the significant differences among the various treatments were compared using LSD values at probability of 0.05 according to Walter and Duncan (1969).

RESULTS AND DISCUSSION

Effect of planting distance on vegetative growth: Data of vegetative characters (pseudostem length, circumference, average number of leaves at bunch shooting and average number of leaves per plant) of Williams banana in the two successive seasons significantly varied due to four planting distances (Fig. 1). It's showed that pseudostem length ranged between 263.3 and 274.3 cm in the first ratoon, while it recorded 266 and 278.3 cm in the second ratoon. Pseudostem circumference ranged between 70.33 and 80 cm in the first ratoon and 73 and 83.67 cm in the second ratoon.

The highest values of pseudostem length were recorded with planting distance of 3×1 m with one plant per hole as 1400 plants fed^{-1} (274.3 and 278.3 cm in the first and second ratoons, respectively); while the plants spaced at 3×4 m with three plants in the hole and 1050 plants fed^{-1} gave the lowest pseudostem length in both ratoons by recording 263.3 and 266, respectively. On the Contrary, the obtained data showed that pseudostem circumference was higher in wider spacing 3×3 m and 3×4 m than plants in closed spacing (3×1 m) since the highest values of pseudostem circumference were recorded with plant distance 3×3 m with two plants per hole as 933 plants fed^{-1} (80 and 83.67 cm in the first and second ratoon plants, respectively) and the lowest pseudostem circumference was showed with plants spaced at 3×1 m with one plant per hole and 1400 plants fed^{-1} which recorded 70.33 cm in the first ratoon and 73 cm in the second one.

On the other hand, data cleared that plants spaced at 3×4 m with three plants per hole produced the highest number of green leaves at bunch shooting (12.33 and 13.27 leaves) and total leaves per plant (30.67 and 32 leaves) in the first and second ratoons, respectively.

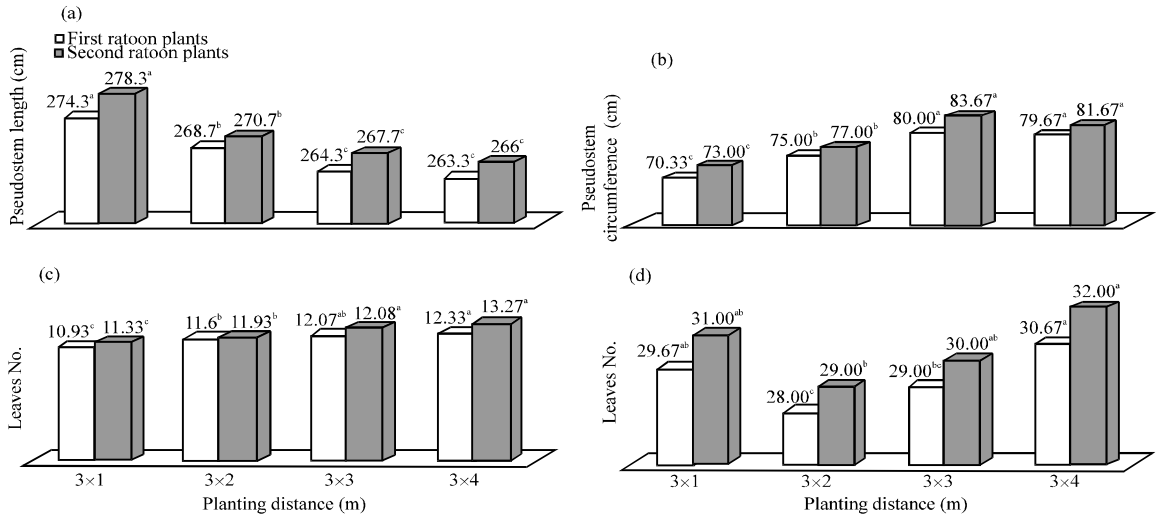

Fig. 1(a-d): Effect of planting distances on vegetative growth of cv. Williams banana, (a) Pseudostem length, (b) Pseudostem circumference, (c) Average No. of green leaves at bunch shooting and (d) Average No. of leaves plant^{-1}. Column with different letters shows significant difference at p = 0.05 using LSD

The present results are agreement with those obtained by Ahmed and Mannan (1970) and Robinson and Nel (1988). Khodaer (1999) and Abdallah *et al.* (2010) who found that the highest pseudostem was occurred under decreasing planting distances. On the other hand, Saleh (1988) reported that planting distances had no effect on pseudostem length. Moreover, Athani *et al.* (2009) reported that all the vegetative growth parameters were higher in the wider spacing and lower in the closer spacing. The closer spacing recorded maximum plant higher; while, the wider spacing recorded minimum plant height.

Saleh (1988) and Khodaer (1999) found that number of green leaves at bunch shooting was not affected by planting distance, but Robinson and Nel (1988) reported that highest density increased total leaves per plants.

Period to bunch shooting and harvesting: It's evident from data presented in Fig. 2 that the period from sucker emergence to bunch shooting and the period from bunch shooting to bunch harvest were differed significantly among the different plant density treatments.

Bunches were emerged earlier under wider space and took shorter periods to harvest during first and second ratoon plants. The plants spaced at 3×4 m with three plants in the hole emerged their bunches about 12-13 days significantly earlier than plants spaced at 3×1 m with one plant per hole in the two ratoon plants, respectively. At the same trend, bunches of plants under closed spacing (3×1 m, with one plant per hole) were harvested later than the other plants under wider spacing. They harvested after about 141 and 144 days from bunches emergence in the first and second ratoon plants, respectively. Plants spaced at 3×3 m with three plants at hole had the earliest harvested bunch (about 130 and 131 days from bunch emergence to bunch harvest in the two ratoon plants, respectively). The obtained results are in accordance with those reported by Ahmed and Mannan (1970), Chundawat *et al.* (1983) and Abdallah *et al.* (2010), who found that plants with close space took the longest time for the emergence of their inflorescences and the period from flowering to harvest compared to plants cultivated at wide space. The results may be related to the interplant competition under close spacing; that is accepted with Niels (2009), who suggested

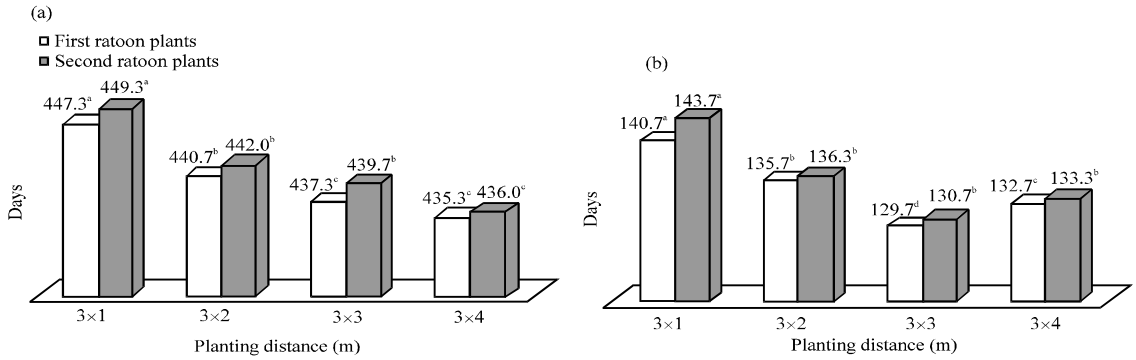

Fig. 2(a-b): Effect of planting distances on duration to bunch shooting and harvesting of cv. Williams banana, (a) Days to bunch emerged and (b) Days from bunch emerged to bunch harvest, Column with different letters shows significant difference at p = 0.05 using LSD

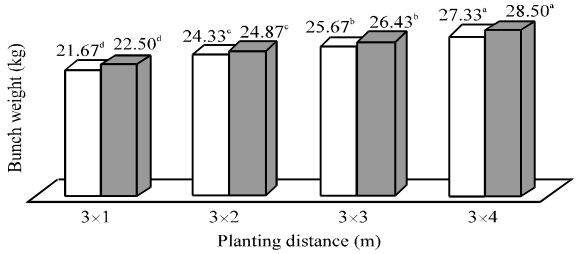

Fig. 3: Effect of planting distances on bunch weight of cv. Williams banana, Column with different letters shows significant difference at p = 0.05 using LSD

that at higher plant densities (above 2000 plants ha^{-1}) there is an increasing interplant competition. From here on additional plants increase cycling time and produce bunches.

Bunch characteristics and yield: Bunch weight is the most important economic character, differed significantly among the treatments (Fig. 3). All HDP treatments registered a reduction in bunch weight compared with the normal density of plants per feddan. This reduction in bunch weight with increment in plant density may be due to excessive interception of light by enhanced canopy under HDP, which might have helped to increase in vegetative characters but probably not the bunch characters. Bunch weight was increased significantly with increasing plant distances, this true in both first and second ratoon plants.

Heavy bunches (27.33 and 28.50 kg) were recorded when plant spaced at 3×4 m with three plants in the hole in both two ratoon plants, respectively. However, the lowest bunches were registered under closed planting (3×1 m, with one plant per hole), since it recorded 21.67 and 22.50 kg in the first and second ratoon plants, respectively.

These results are in line with those obtained by Ahmed and Mannan (1970), Azouz *et al.* (1971), Robinson and Singh (1974), Kesavan *et al.* (2002), Nalina *et al.* (2003) and Abdallah *et al.* (2010). They found that average bunch weight was increased by increasing planting distances. As cleared in Fig. 4, the highest yield per feddan (34.07 and 34.80 tons) was recorded by plant spaced at 3×2 m with two plants per hole in the first and second ratoon plants, respectively. While the lowest yield per feddan (23.90 and 24.63 ton) recorded by plants spaced at 3×3 m with two plants per hole in both ratoon plants, respectively.

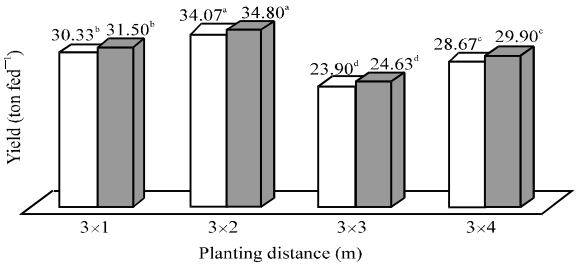

Fig. 4: Effect of planting distances on yield (ton fed^{-1}) of cv. Williams banana, Column with different letters shows significance difference at p = 0.05 using LSD

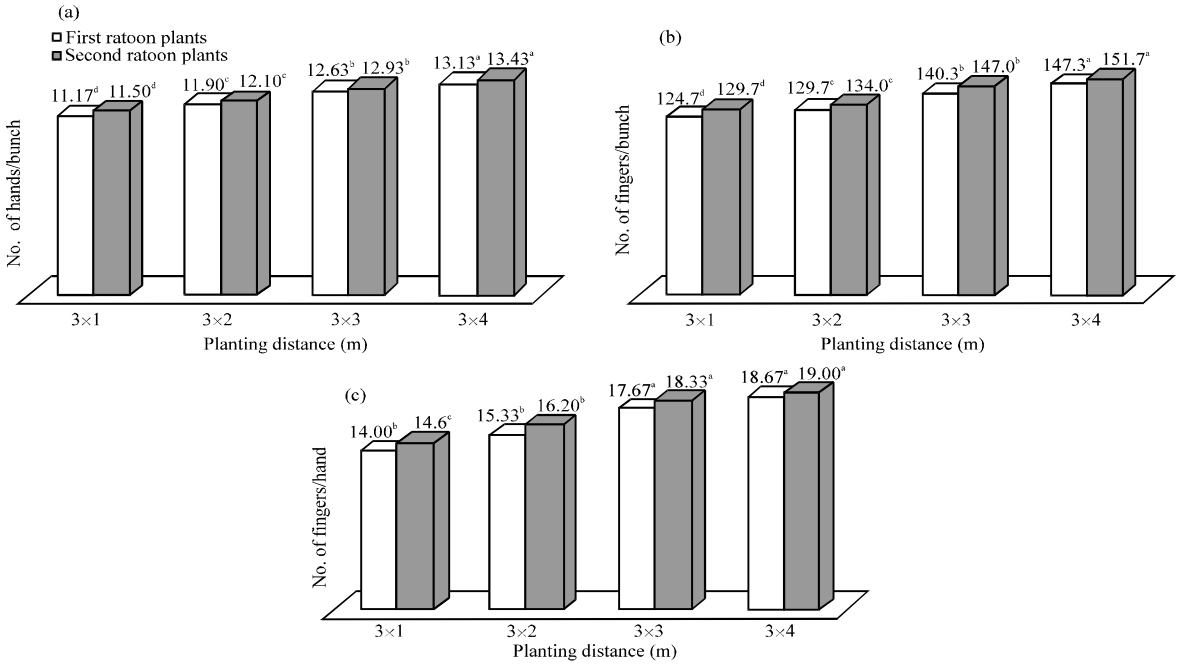

Fig. 5(a-c): Effect of planting distances on bunch characters of cv. Williams banana, (a) No. of hand bunch^{-1}, (b) No. of fingers bunch^{-1} and (c) No. of fingers hand^{-1}, Column with different letters shows significance difference at p = 0.05 using LSD

The results of yield referred that gross yield of banana depends on yield per plant and the number of plants per unit area (feddan) and that is accepted with Daniells *et al.* (1985), who reported that productivity was increased with increasing density. On the other hand, Niels (2009) suggested that yield (kg ha^{-1}) increases do not anymore increase linearly with increasing planting densities.

The registered data presented in Fig. 5 showed that increasing the number of hands per bunch, number of fingers per bunch and number of fingers per hand were related with planting distances. Thus was true in the first and second ratoon plants.

The highest number of hands bunch^{-1} (13.13 and 13.43), also the highest number of fingers/bunch (147.3 and 151.7) and the highest number of fingers hand^{-1} (18.67 and 19.00) were registered in wider plant at 3×4 m with three plants per hole in the first and second ratoon plants, respectively. Meanwhile, the lowest number of hands bunch^{-1} (11.17 and 11.50), number of

fingers/bunch (124.7 and 129.7) and number of fingers hand^{-1} (14.0 and 14.6) were recorded by closed planting space at 3×1 m with one plant per hole in the two ratoon plants, respectively.

Similar results were obtained by Abdallah *et al.* (2010) and Odeke *et al.* (1999) who reported that manipulation of plant spacing directly influences bunch weight, cluster and finger size.

Finger characteristics

Physical characteristics: It's cleared from data in Fig. 6 that finger weight of Williams banana was not affected significantly by different planting distances in the first ratoon plants. On the other hand, the plants spaced at 3×4 m with three plants per hole recorded the highest finger weight (187.80 g) in the second ratoon plants. Meanwhile, the lowest finger weight was registered in plants spaced at 3×1 m with one plant per hole (173.50 g).

Finger length and diameter was affected significantly by plant density in the two ratoon plants. The highest finger length (19.70 and 19.93 cm in the first and second ratoon plants, respectively) was recorded with wider plants (3×4 m, with three plants per hole) and the lowest finger length (18.57 and 18.87 cm in the both ratoon plants, respectively) was registered in the plants spaced at 3×2 m with two plants per hole.

In case of finger diameter, wider spaced plants (3×3 m, with two plants in a hole and 3×4 m, with three plants per hole) were significantly gave the highest finger diameter since it was 3.47 and 3.53 cm in plants spaced at 3×3 m with two plants in a hole in the two ratoon plants, respectively and 3.37, 3.47 cm with the plant spaced at 3×4 m with three plants per hole in the first and second ratoon plants, respectively. In the meantime, the lowest finger diameter was found in closed plants (3×1 m, with one plant per hole) which recorded 3.07 and 3.17 cm in the both two ratoon plants, respectively.

As data showed, the ratio between both peel and pulp was significantly differed in the two ratoon plants as affected by plant distances. The ratio was the highest in the close plants (3×1 m, with one plant per hole) since it calculated 0.49 and 0.50 in the first and second ratoon plants, respectively. Meanwhile, it calculated the lowest ratio (0.47 and 0.46 in both experimental ratoon plants, respectively) in the wider plants distances (3×4 m, with three plants per hole). From here, we can suggest that wider plants produce a thinner peel fingers as compared to pulp than closed

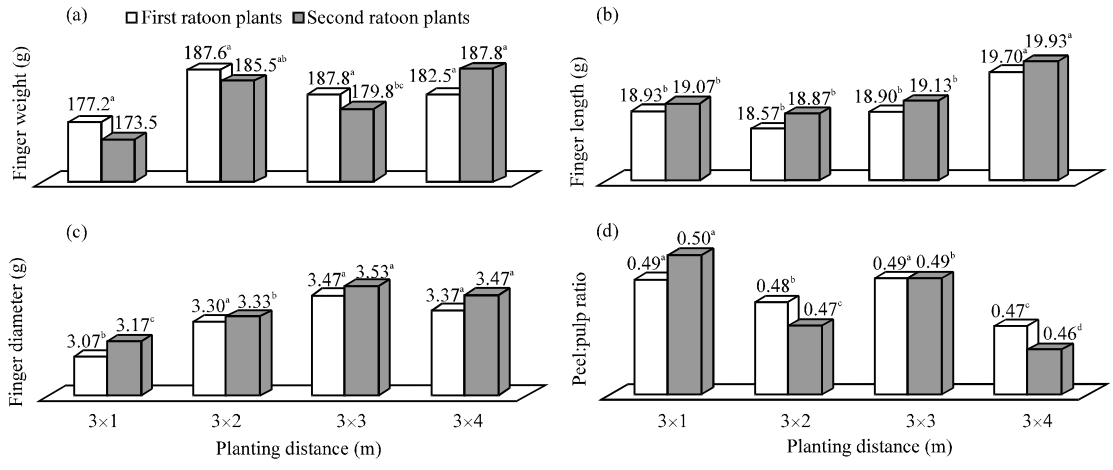

Fig. 6(a-d): Effect of planting distances on physical characters of cv. William's banana fingers, (a) Finger weight, (b) Finger length, (c) Finger diameter and (d) Peel:pulp ratio, Column with different letters shows significance difference at p = 0.05 using LSD

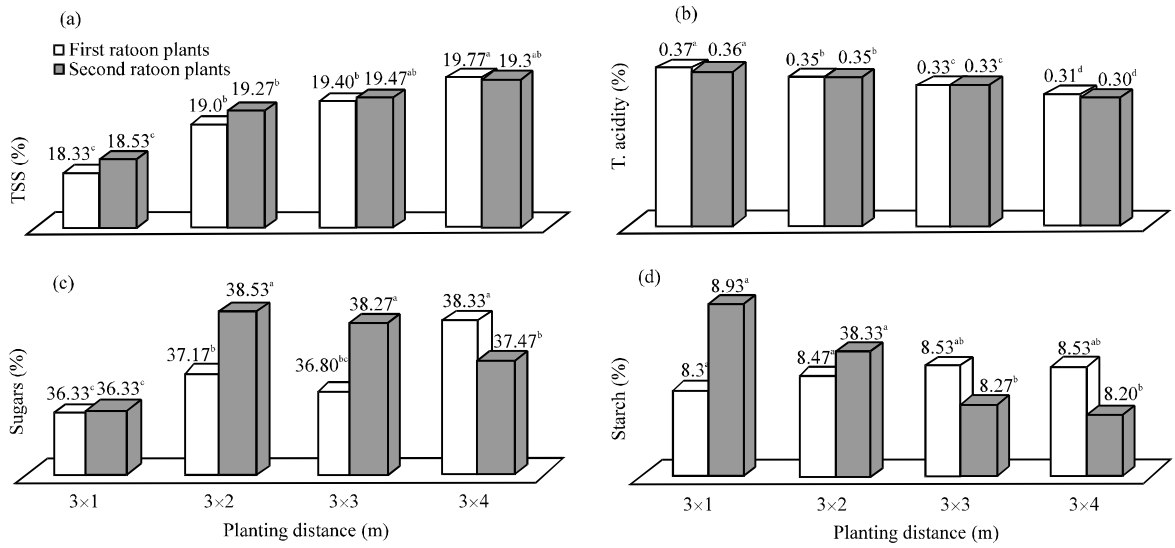

Fig. 7(a-d): Effect of planting distances on chemical characters of cv. Williams banana fingers, (a) TSS%, (b) Titratable acidity%, (c) Sugars% and (d) Starch, Column with different letters shows significance difference at p = 0.05 using LSD

plants which produce the thickest peel as compared to pulp. Our results were in agreement with those reported by Chundawat *et al.* (1983), Maharana and Das (1996), Khodaer (1999) and Abdallah *et al.* (2010). Also, Odeke *et al.* (1999) stated that "manipulation of plant spacing directly influences finger size".

Chemical characteristics: Figure 7 represents the effect of different plant density on chemical characteristics of Williams banana fingers. It's evident that total soluble solids % (TSS%) were affected significantly by differ in plant density, while it determined the highest value in plants spaced at 3×4 m with three plants in a hole (19.77 and 19.73 in the two ratoon plants, respectively) and the lowest TSS% were measured at closed plants which spaced at 3×1 m since it recorded 18.33 and 18.53 in the first and second ratoon plants, respectively.

Titratable acidity percentage was affected by different plant density, the highest percentage of acidity was determined at closed plant (3×1 m, with one plant per hole). It measured 0.37 and 0.36 % in both experimental ratoon plants, respectively. In contrast, the lowest percentage of acidity (0.31% in the first ratoon plants and 0.30%, in the second ratoon plants) was determined in wider plants (3×4 m, with three plants per hole).

HDP affected significantly in sugars% of the finger since it recorded the lowest value in closed plant spaced at 3×1 m with one plant in the hole (36.33 and 36.37% in the first and second ratoon plants, respectively). Meanwhile, the other planting spacing had no trend in sugars % which it gave the highest value in the plant spaced at 3×4 m with three plants per hole in the first ratoon plants (38.33%). Whereas, the highest significant value of sugars (%) was measured in the second ratoon plants in both plants spaced at 3×2 m with two plants in a hole (38.53%) and 3×3 m with two plants per hole (38.27%).

No significant differences are shown in the percentage of starch (%) in the first ratoon plants, but the highest percentage was measured at closed plants (3×1 m, with one plant in a hole) since it recorded 8.73%. In contrast, it's evident a significant differences between both the closed and

wider plants in the second ratoon plants. HDP (3×1 m, with one plant per hole and 3×2 m, with two plant per hole) was recorded the highest percentage of starch (8.93 and 8.63% in both planting spacing, respectively); while the lowest value of starch was determined in normal density plants (3×3 m, with two plants per hole and 3×4 m, with three plants in a hole) since it measured 8.27 and 8.20% in the two plant distances, respectively.

These results are harmony with those obtained by Chundawat *et al.* (1983) who found that TSS was reduced with decreasing planting distances. On the other hand, Saleh (1988) showed that TSS was not affected by planting distance. Nalina *et al.* (2003) stated that "all HDP recorded a reduction in TSS and total sugars; whereas, acidity had no significant differences among all HDP treatments". Reduction of fruit quality was observed in earlier HDP studies on banana with an increase in planting density (Irizarry *et al.*, 1978). Regarding the effect of HDP as affected on starch percentage, it's hard to find research work dealings with this point.

CONCLUSION

High technology banana cultivation by using HDP gives very high yield and profit. The planting distance adopted for banana varies throughout Egypt and also in the other parts of the world. From the results of this study we conclude that cultivation of banana plants grown at close spacing (3×2 m), with two plants/hole is the best planting distances to obtain the highest yield/fed. Meanwhile, earliness of harvesting and to improve quality of fingers we conclude to cultivate plants at wide space (3×4 m), with three plants per hole.

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