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Influence of high planting densities and arrangements on yield and fruit development of *Musa* AAA Simmonds

Influencia de altas densidades de siembra y arreglo poblacional en el desarrollo y producción de fruta de *Musa* AAA Simmonds

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Abstract

Banana is one of the most abundantly consumed fruits in the world for its contribution to human nutrition, including an important content of potassium. Given the social contribution of this crop in the cropping areas of Colombia, it is necessary to develop agronomic management strategies that contribute to increasing productivity and offering alternatives that regulate the effects of climate seasonality on banana production in the Urabá region of Colombia. For this purpose, different planting densities (2,000, 2,500, 3,000 and 3,500 plants ha^{-1}) and planting arrangements (triangle, rectangle and double furrow), plus a relative control (1,700 plants ha^{-1} under triangle arrangement), were evaluated in the banana cv. Williams. The experimental design corresponded to randomized complete blocks in a 4 x 3 + 1 (densities x arrangements + control treatment at 1,700 plants ha^{-1}) factorial arrangement. During harvest, the following parameters were monitored: bunch weight, number of hands and fingers per bunch, finger length and diameter, bunch ratio and percentage of loss per bunch. Two analyses of variance were carried out, a general one including the control treatment, and an additional one excluding it. The double furrow planting arrangement favored the productivity of the crop in terms of a greater assimilation and lesser loss records at the bunch level. The strong correlation of the studied variables with the double furrow arrangement became evident.

Key words: Banana, light interception, plant competition, plant population, bunch quality.

Resumen

El banano (*Musa* AAA Simmonds) es una de las frutas más consumidas en el mundo, por su aporte nutricional y fuente de potasio para los seres humanos. Dada su contribución social en las zonas productoras de Colombia, es necesario desarrollar estrategias de manejo agronómico que contribuyan a incrementar la productividad y ofrezcan alternativas para reducir los daños derivados de la estacionalidad del clima sobre la producción de esta fruta en la zona del Urabá, Colombia. Para ello se evaluaron en una plantación de banano cv Williams diferentes densidades de plantación (2000, 2500, 3000 y 3500 plantas/ha) en diferentes arreglos poblacionales (triángular, rectangular y doble surco) más un testigo relativo (1700 plantas/ha) dispuestas en triángulo). El diseño utilizado fue de bloques completos al azar en arreglo factorial de 4 x 3 + 1 (densidades x arreglos) + el testigo de 1700 plantas). En cosecha se midieron el peso, el número de manos y dedos por racimo, largo y diámetro del dedo, radio del fruto y porcentaje de reducción o pérdida de peso por racimo. Se realizó un análisis de varianza general y un análisis de varianza excluyendo el testigo. Los resultados mostraron que, la distribución de plantas en doble surco favoreció la productividad del cultivo debido a un mayor aprovechamiento y una reducción significativa de la pérdida por racimo. En este arreglo se encontró una alta correlación entre las variables evaluadas.

Palabras clave: Banano, Interceptación de luz, competencia entre plantas, población de plantas, calidad de racimo y fruta.

Introduction

Banana contributes 107 million yearly tons of fruit to the world, where in this crop holds an outstanding place among the most important production systems (FAO, 2015). Colombia holds the fifth place at the continental level (FAO, 2017), with a planted area of 49,307 hectares distributed in two zones: Urabá, which is the most important one, with 34,789 ha; and Magdalena and La Guajira regions, which jointly cover 14,518 ha. These three regions produce 98.4 million boxes of banana per year (Augura, 2017; FAO, 2017), which are equivalent to 11.8% of the agricultural exports of the country (Augura, 2016).

However, banana production in Colombia is dominated by climate seasonality through the presence of two marked periods namely, a first dry semester and a second wet semester (Toro et al., 2016), which determine alternate moments of scarcity and oversupply, respectively. In turn, this behavior directly affects the international prices, which actually drop when there is greater supply (Augura, 2012; FAO, 2017), thus constituting a clear disadvantage for the traditional cultivation system.

Plantation density increase in banana crops generates significant plant heigh and higher productivity (Shaikh et al., 1986; Athani et al., 2009) without affecting the organoleptic quality parameters of the fruit, although bunches have certainly exhibited low weight (Palkar et al., 2012; El- Khawaga, 2013). In this regard, Mustaffa and Kumar (2012) indicate that Israeli banana plantations have reached productions of 120 t ha^{-1} under a planting density of 4,091 plants ha^{-1}. However, these authors reported low bunch weight. On the other hand, in Colombia, Belalcázar et al. (2003) have observed plantain production increases ranging from 270% to 345% under planting densities between 3,000 and 5,000 plants ha^{-1}.

The establishment of banana crops under High Density Planting (HDP) is a novel management practice that not only optimizes the use of natural resources, but also allows increasing productivity without affecting fruit quality (Gogoi, 2015; Hanuman et al., 2016). HDP is even more favorable in double furrow systems, wherein a higher number of plants leads to a greater leaf area index (LAI) and an increase in interception of photosynthetically active radiation (PAR), with a positive impact on yield (Rodríguez et al., 2007). In contrast, Benson (2013) states that densities greater than 2,000 plants ha^{-1} have an adverse effect on growth and development as a consequence of root superposition, while self-shading (the result of leaf overlapping) promotes the formation of low-weight bunches (Israeli et al., 1995; Daniells et al. 1984). In addition, a positive effect of HDP on finger size, has been observed by Sarrwy et al. (2012). As, for the Urabá Antioqueño región, it is essential to increase productivity for the first half of the year, due to the best international prices in response to the low supply of fruit, it is estimated the HDP alternative may be viable to achieve this purpose.

Despite inconsist results, HDP has been adopted in plantain production systems of the Colombian regions (Cárdenas et al., 2017) and the coffee zone (Cayón et al., 2004); in Venezuela (Delgado et al., 2008); in Ecuador (Toapanta et al., 2002); and Costa Rica (Smith et al., 2010; Gonçalves and Kernaghan, 2014). Just as well, HDP has been implemented in banana plantations in India (Chaudhuri and Baruah, 2010) and Bangladesh (Khalequzzaman et al., 2009). Thus, this crop management alternative, which has proved successful in plantain, currently needs to be evaluated in banana. Therefore, the objective of this study was to determine the effect of HDP and arrangements on finger yield and quality in *Musa* AAA clone Williams, as a contribution for the Urabá growers to reach greater profits.

Materials and methods

Research was conducted from 2015 to 2016 at La Tagua farm, which belongs to the company Bananeras de Urabá, located in the municipality of Turbo, Antioquia (Colombia). The experimental site was located at 07°53′N 76°41′O, 28 m a.s.l., with an average of maximum and minimum temperatures of 32.39 °C and 22.37 °C respectively, relative humidity of 86.94%, average annual rainfall of 3246.42 mm and average annual solar brightness of 4.2 daylight hours. All these features correspond to a very humid tropical forest climate (Guarin, 2011). The soil exhibited clay loamy texture, pH (5.8), organic matter (OM) content (1.73%), respective Ca and Mg levels (8.9 and 4.11 $cmol_c kg^{-1}$), K (0.41 $cmol_c$ kg^{-1};), P (21.4 mg kg^{-1}), S (5.67 mg kg^{-1}), Zn (2.0 mg kg^{-1}), B (0.54 mg kg^{-1}), Cation Exchange Capacity (CEC) (13.6 $cmol_c$ kg^{-1}), and an adequate relation between bases. This information allowed defining the nutrition plan to meet the needs of the plantation, which was set up with in vitro propagated seedlings of the clone cv. Williams, distributed according to the treatment plan (Table 1). Initial soil organic matter and P supplies conformed to crop requirements and soil analysis. The subsequent agronomic management was done according to the technical recommendations for each particular case.

Experimental design. The study was conducted under a randomized complete block design with 4 x 3 + 1 (four planting densities x three population arrangements plus a control treatment) bifactorial arrangement with four planting densities (2,000;

Table 1. Treatments, planting densities and spatial arrangements in a banana plantation of the clone Williams (*Musa* AAA Simmonds). Urabá region, Colombia.

Treatment No.	Planting density (plants ha^{-1})	Spatial arrangements (m)
1	1,700	Control (2.7 x 2.7)
2	2,000	Triangle (2.3 x 2.3)
4	2,500	Triangle (2.15 x 2.15)
5	3,000	Triangle (1.95 x 1.95)
6	3,500	Triangle (1.8 x 1.8)
7	2,000	Rectangle (3.2 x 1.57)
8	2,500	Rectangle (2.8 x 1.30)
9	3,000	Rectangle (2.6 x 1.20)
10	3,500	Rectangle (2.4 x 1.15)
11	2,000	Double row (dp * 1.0 x dr ** 3.3)
11	2,500	Double row (dp * 1.2 x dr ** 3.3)
12	3,000	Double row (dp 1.0 x dr 3.0)
13	3,500	Double row (dp 1.0 x dr 2.8)

* dp: distance between plants (m) ** dr: distance between rows (m).

2,500; 3,000 and 3,500 plants ha^{-1}) and the three arrangements (triangle, rectangle and double furrow), plus the relative control (1,700 plants ha^{-1} under a triangular arrangement) and three replicates. Each experimental unit contained a population of 26 plants, at the center of which the 'useful plot' (made up of 10 plants) was established.

Harvest. The finger bunches were harvested according to their state of commercial maturity (10-12 weeks), based on the quality protocols established by the trader Uniban. In each treatment, four bunches were selected from the plants located in the useful plot, delimited for the data collection planned in the study.

Bunch weight (kg). The gross weight of 10 bunches per treatment was determined on a scale at the time of harvest.

Hands and fingers per bunch (No). They were established by directly counting the units.

Finger length (cm). It was measured from the base of the pedicel to the apex of the finger with a metric tape measure.

Finger diameter (cm). It was estimated with a caliper at the middle part of the three central fingers of the second and last hands of the bunch.

Ratio. Average number of boxes filled with one bunch.

Loss (%). It was evaluated in 10 bunches from each useful plot. For this purpose, the quality defects of the finger (exclusively related to physiological aspects) as identified during the post-harvest process were taken into account.

Data analysis. A SAS 9.13 software was employed to assess the general effect of the treatments on the variables. An analysis of variance only including the two factors under study (planting densities and arrangements) was used to determine their effects on the variables and their interactions. Orthogonal polynomial contrasts were applied to estimate the linear and quadratic effects of the planting density factor. In addition, polynomial regression models were fitted to the data, including the control treatment. A Tukey test at 5% allowed assessing the spatial arrangements. A Pearson correlation analysis was also performed between the variables of production and fruit quality.

Results and discussion

Production. The analysis of variance (excluding the control) showed that the yield variables bunch weight, number of hands and number of fingers were not influenced by the effects of planting arrangement or planting density, although the number of fingers per bunch responded significantly to their interaction. However, when the control treatment was included, these variables showed no response to the effects of these factors, and no differences were detected between the control and the average of the treatments. The absence of effect of the treatments on the variables of production, allows to confirm that the HDP crop system studied for Urabá antioqueño, can be viable because the objective is to obtain a greater production per unit of area, therefore when increasing density is achieved this purpose. These results coincide with those reported by Pujari et al. (2010) and Smith et al. (2010), in the sense of the little influence of spacing on banana yield variables. Still, they contrast with a report by Lanza et al. (2017), who recorded yield increments under increased planting densities of 'BRS Princess' banana in Brazil.

Other studies have revealed yield drops under increasing planting density, and one of the reasons is the competition for radiation. In analyzing the incidence of shading on banana, Israeli et al. (1995) detected bunch weight reductions of 7% for the medium-to-low shading level and of 32% for abundant shade during the first production cycle. In the second cycle, said reductions were 8%, 21% and 55% under the light, medium and heavy shade levels, respectively.

In studies carried out by Athani et al. (2009), bunch weight was observed to drop under increasing planting densities, from 3,086 to 6,250 plants ha^{-1}, although the productivity per ha certainly increased through an augmented number of bunches. According to Gogoi et al.

(2015) bunch weight reduction is due to a higher solar radiation intersection, in turn resulting from increased leaf area. This situation certainly affects the translocation of assimilates (Thippesha et al., 2008), which does not enhance bunch weight, but productivity. In the opinion of Rodríguez et al. (2007) this effect can be dissipated by modifying planting arrangement, which, in their experiment, allowed achieving greater yield through a double furrow system, which facilitated better PAR interception as a result from LAI modifications. However, Hanuman et al. (2016) state that reduced bunch weight is a frequent result of HDP in the *Musaceae*.

In this regard, the average bunch weight values found in the present study ranged from 17.22 to 23.77 kg; the number of hands from 6.11 to 6.89, and the number of fingers from 85.34 to 107.89. These values approximately match those indicated by Rodríguez et al. (2012) for the Urabá region of Antioquia (Colombia).

The number of fingers slightly increased at low planting densities, as observed in the triangle and rectangle arrangements. This result is the likely effect of a higher incidence of solar radiation per unit of leaf area at these planting densities (Table 2). In this sense, Israeli et al. (1995) point out that shading can negatively affect banana yield by up to 55%. On the other hand, the largest numbers of fingers were recorded at 2,500 plants ha^{-1} arranged in triangle and at 3,000 plants ha^{-1} established in double furrow. The remaining densities did not determine any difference between planting arrangements. These results coincide with those of Andrade et al. (2015) regarding the scarce influence of competition between plants on the finger characteristics of banana cv. Angola.

Finger development. The analysis of variance that included the control treatment revealed that only the bunch ratio (number of busches/box) and the percentage of loss (finger not meeting quality standards) were altered by planting arrangement and planting density. For its part, the analysis of variance that excluded the control treatment indicated that the finger length of the last hand and the finger ripeness of the second hand were not affected by planting density, planting arrangement or their interactions. On the other hand, bunch ratio and last hand finger ripeness were influenced by planting arrangement. Likewise, loss was observed to be the result of planting density and arrangement and their interaction.

Table 2. Response of the number of fingers to planting arrangement and density in banana cv. Williams. Urabá region, Colombia.

Planting arrangement	Planting density (plants ha^{-1})			
	2,000	2,500	3,000	3,500
Triangle	108.00 A a*	88.22 B b	89.56 AB b	88.11 A b
Rectangle	95.00 A ab	107.89 A a	85.33 B b	99.37 A ab
Double furrow	91.33 A a	93.00 AB a	105.11 A a	91.33 A a

*Mean values accompanied by similar lower case letters along the same line or capital letter along the same column do not differ significantly according to orthogonal contrasts (F, P ≤ 0.05).

These data allow inferring that HDP had a negative effect on finger development, specifically associated to low radiation interception, higher loss levels and smaller bunch ratios under the triangle, rectangle and row arrangements. However, the double furrow planting arrangement increased the bunch ratio and decreased the percentage of loss (Table3), which is in agreement with prior research. Firstly, Rodríguez et al. (2007) attribute observed productivity rises and optimal bunch disposition on the plant to the double furrow arrangement. Secondly, Andrade et al. (2015) state that the double furrow arrangement probably minimizes the influence of interspecific competition on the characteristics of the finger. According to Kesevan (2002) said effect is only evident at densities higher than 5,000 plants ha^{-1}. Regarding plantain, Prata et al. (2018) have found an association between HDP and productivity increases, which, however, excludes finger quality, as also reported by Cayón et al. (2004), Delgado et al. (2008) and Cortázar et al. (2017).

Although showing no significant differences, the length of the last hand ranged between 20.06 and 21.13 cm, while the diameter of the central finger of the second hand varied from 2.63 to 3.86 cm and the diameter of the central finger of the last hand varied from 2.19 to 2.76 cm. Although these values comply with the quality standards required by international marketers, they are lower than those reported by Díaz et al. (2003) for the Urabá Antioqueño region, and by Vargas and Valle (2011) for Costa Rica. Just as well, there were no significant differences for the degree of ripeness and the diameter of the central finger of the last hand. These results coincide with those of Gogoi et al. (2015) who compared different planting densities, with the work of Rodríguez et al. (2007) on a double furrow system, and with those obtained by Smith et al. (2010) from date banana (*Musa* AA cv. Pisang MAS) planted under HDP. Yet, contrasting results have also been found. Atahi et al. (2008) observed a decrease in finger length and diameter under increasing planting densities. This discrepancy is confirmed by Hanuman et al. (2016) in evaluating decreasing planting densities, which correlated with increased numbers of hands, fingers per bunch and finger diameter.

The bunch ratio was favored by the triangle arrangement at the 2,000 plants ha^{-1} density (Table 3). The triangle arrangement is likely

Table3. Effect of planting arrangements and planting densities on the finger quality variables of the banana clone cv. Williams. Urabá region, Colombia.

Treat. No.	Planting arrangement	Planting density (plants ha^{-1})	LL (cm)	DCFS (cm)	DCFL (cm)	Ratio	Loss (%)
1	Triangle	1,700	20.67	2.97	2.58	0.86 ab*	16.04 ab
2	Triangle	2,000	20.92	2.81	2.49	0.96 a	8.80 b
4	Triangle	2,500	21.03	3.04	2.76	0.90 ab	13.33 ab
5	Triangle	3,000	20.80	2.94	2.63	0.95 a	18.22 ab
6	Triangle	3,500	20.06	2.90	2.45	0.86 ab	15.44 ab
7	Rectangle	2,000	20.67	2.95	2.55	0.83 ab	13.33 ab
8	Rectangle	2,500	20.06	2.95	2.35	0.91 ab	14.60 ab
9	Rectangle	3,000	20.90	2.81	2.53	0.71 b	22,58 a
10	Rectangle	3,500	20.24	2.63	2.19	0.82 ab	16.44 ab
11	Double furrow	2,000	21.13	2.74	2.42	0.90 ab	15.35 ab
11	Double furrow	2,500	20.90	3.07	2.76	0.81 ab	9.49 b
12	Double furrow	3,000	21.00	3.01	2.59	0.93 ab	10.51 b
13	Double furrow	3,500	20.95	3.86	2.69	0.85 ab	9.18 b

*Means followed by the same letter are not statistically different according to the Tukey test (P = 0.05). LL: Last hand's length; DCFS: Diameter of the central finger of the second hand; DCFL: Diameter of the central finger of the last hand; Ratio: Average number of boxes filled with one bunch. Loss: Finger eliminated due to quality defects.

to allow a better leaf area distribution and a higher LAI. However, previous studies indicate that planting arrangement does not affect PAR capture, thus implying that the estimated extinction coefficient ***k*** and the average angle of inclination of the leaves do not influence yield, although it has been seen that the double furrow system allows a better location of the bunches (Rodríguez et al., 2007).

Interaction arrays x densities. The interaction between planting arrangement and planting density indicates that loss was greater under the triangle arrangement (18.22%) for the 3,000 plants ha^{-1} density, followed by the records of the 1,700, 2,000 and 2,500 plants ha^{-1} densities for the same parameter (Table 4). For the rectangle arrangement, the highest yield reduction count (22.58%) was recorded under the 3,000 plants ha^{-1} density, overcoming by 69.39% the record of the 2,000 plants ha^{-1} density. Finally, no loss differences were observed under the double furrow arrangement, which registered an average count of 10.84% (Table 4). The aforementioned resonates with a previous analysis by Rodríguez et al. (2007) who point out that yield is more favored by planting density than by spatial arrangement. However, the double groove arrangement under HDP offers better bunch filling advantages.

It can be inferred that the 2,000 plants ha^{-1} density under the triangle arrangement favors productivity by contributing to a better assimilation on the part of the finger, as also observed for the double furrow arrangement at the 2,500 and 3,000 plants ha^{-1} densities. These results correspond with those of Mahmoud (2013) which allows concluding that spacing plants favors larger and heavier bunches, these attributes being beneficial to the finger. In the opinion of Rodríguez et al. (2007) this is due to a better leaf area distribution, which optimizes the use of PAR. Finger length showed no significant differences in response to planting arrangements, thus contrasting with the bunch ratio results (Figure 1).

Table 4. Percentage of loss in banana cv. Williams as a function of planting density and planting arrangement. Urabá region, Colombia.

Planting arrange-ment	Planting density (plants ha^{-1})				
	1.700	2.000	2.500	3.000	3.500
Triangle	12.90 b	7.85 c B*	13.33 b A	18.22 a A	15.44 ab A
Rectangle		13.33 b A	14.60 ab A	22.58 a A	14.11 ab AB
Double furrow		14.19 a A	9.49 a B	10.51 a B	9.18 a B

*Mean values with similar lowercase letters on the same line do not differ statistically according to orthogonal contrasts (F, P ≤ 0.05).

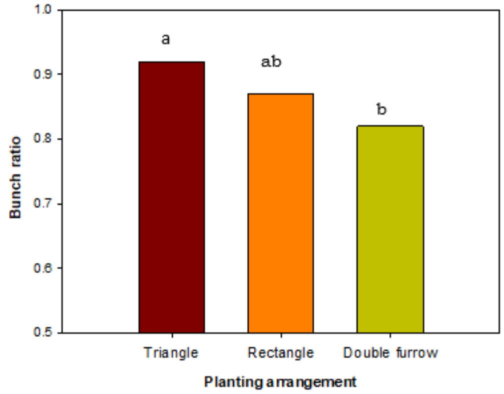

Figure 1. Bunch ratio of banana cv. Williams as a function of planting arrangement. Urabá Antioqueño región, Colombia.

*Mean values with similar lowercase letters on the same column do not differ statistically according to the Tukey test (P=0.05).

In general, from these observations, it can be speculated that low densities combined with the double furrow arrangement allow greater light penetration. This is likely to provide greater availability of assimilates for the bunch filling process, thus increasing finger diameter and favoring bunch ratio.

Contrastingly, Eckstein and Robinson (1995) and Delgado et al. (2008) indicate that, from flowering to harvest, banana plants can fill the finger using a limited amount of leaves because this favors light penetration and air circulation. The latter, in turn, improves CO_2 diffusion and photosynthetic compensation by young and more exposed leaves. These considerations are consistent with those of Rodríguez et al. (2007) and Smith et al. (2010), who state that an increase in planting density linearly reduces bunch weight.

Correlation between yield and finger development. The number of hands per bunch correlated negatively with loss and the diameter of the last hand, while the number of fingers per hand negatively correlated with the diameter of the central finger of the last hand and the percentage of loss (Table 5). These results corroborate the strong association existing between yield and development variables, since assimilation by the last hand is determining to increase productivity and decrease the percentage of loss, which is largely due to the source-sink relationship. In this sense, larger numbers of exposed leaves guarantee a greater source of photoassimilates for the bunch. However, the numbers of hands per bunch and of fingers per hand (i.e., the size of the sink) determine the redistribution of said assimilates. In this way, those bunches that received the most amounts of photoassimilates due to better leaf exposure were favored with the increase of the length and diameter of the fingers and, ultimately, with a better development of the whole bunch. In general, high planting densities were found to negatively affect assimilation by the last hand (Rodríguez et al., 2007).

Table 5. Pearson correlation between yield and finger quality variables in banana cv. Williams under the triangle planting arrangement. Urabá region, Colombia.

Characteristics	LL (cm)	DCFS (cm)	DCFL (cm)	Ratio	Loss (%)
Bunch weight	0.49	0.34	0.36	-0.23	-0.09
Number of hands	-0.19	-0.24	-0.62*	0.33	-0.68**
Number of fingers	0.36	-0.36	-0.50	0.29	-0.66**

*: Significant differences at 5% ($P \leq 0.05$); **: Significant differences at 1% ($P \leq 0.01$).

LL: Last hand's length; DCFS: Diameter of the central finger of the second hand; DCFL: Diameter s of the central finger of the last hand; Ratio: Average number of boxes filled with one bunch. Loss: Discarded finger due to quality defects.

Under the rectangle arrangement there was only a correlation between bunch weight and the length of the last hand (Table 6). That is, as the length of the last hand rises, bunch weight and the number of usable fingers per bunch are also increased.

Table 6. Pearson correlation between yield and finger quality variables in banana cv. Williams under the double furrow planting arrangement. Urabá region, Colombia.

Characteristics	LL (cm)	DCFS (cm)	DCFL (cm)	Ratio	Loss (%)
Bunch weight	-0.29	0.47	0.02	0.76**	-0.46
Number of hands	-0.78**	-0.18	-0.50	0.50	-0.53
Number of fingers	-0.74**	-0.27	-0.72**	0.68*	-0.54

*: Significant differences at 5% ($P \leq 0.05$); **: Significant differences at 1% $P \leq 0.01$).

LL: Last hand's length; TCFS: Diameter of the central finger of the second hand; TCFL: Diameter of the central finger of the last hand; Ratio: Average number of boxes filled with one bunch. Loss: Discarded finger due to quality defects

In the double furrow arrangement there was a positive correlation between bunch weight and bunch ratio. The number of hands correlated negatively with loss and the length. The number of fingers correlated negatively with all the finger quality variables, except for the diameter of the second hand (Table 6). The treatments that favored bunch weight contributed to increase energy assimilation, thus allowing the production of more boxes per bunch. Contrastingly, the rectangle planting arrangement at 3,000 plants ha^{-1} remarkably had the most negative impact on both loss and bunch ratio when compared to the other evaluated arrangements and densities.

HDP showed statistical similarity to the control treatment. These results are in agreement with those reported by Rodríguez et al. (2007), by stating that the double furrow arrangement combined with low densities favor banana yield. Just as well, the findings of El-Khawaga (2013) utter that bunch weight reduction resulting from HDP somehow contributes to increasing the percentage of loss.

Conclusions

The spatial distribution of HDP did not have a significant influence on the quality of the fruit required in international marketing, which allowed for greater use of the bunch (ratio), particularly under the triangle distribution. In addition, it was observed that the arrangement in double furrow, contributed to decrease the losses due to reductions in the bunch, as the density of the plantation was higher, an aspect that favors the productivity of the crop.

None of the studied combinations between HDP and planting arrangements affected bunch weight or the number of hands and fingers per bunch, while finger development, bunch ratio and the percentage of loss increase under the rectangle and triangle arrangements at the 3,000 and 3,500 plants ha^{-1} densities.

The arrangement of plants in double furrow improve the use of solar radiation a benefit that was reflected in a greater length of the fruit, in particular when combined with higher than 3,000 plants ha^{-1} densities. This same arrangement favored crop yield and influenced a lower percentage of loss by the bunch.

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