Article

Densification of "Apple Type" Banana Plants in Transition System for Organic Production, Rio de Janeiro, Brazil

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RESUMO

O objetivo deste trabalho foi avaliar o efeito de densidades de plantio da bananeira do tipo maçã 'BRS Princesa' sobre o desenvolvimento e a produtividade da cultura em dois ciclos de produção. A pesquisa foi realizada nos anos agrícolas de 2014 a 2016 no Departamento de Fitotecnia da Universidade Federal Rural do Rio de Janeiro (UFRRJ), no município de Seropédica, Rio de Janeiro, Brasil. Os tratamentos foram compostos por densidades de plantio, sendo 1200 (3,33 x 2,5 m); 1600 (2,5 x 2,5 m); 2000 (2,0 x 2,5 m); 2400 (1,67 x 2,5 m); 2800 (1,43 x 2,5 m) e 3200 (1,25 x 2,5 m) plantas por hectare, dispostos em delineamento de blocos completos casualizados com quatro repetições. Na fase vegetativa, a altura da planta e o diâmetro da base foram medidos periodicamente. No período de produção, foram medidos o peso do cacho, o peso do fruto, o número de folhas, o número de frutos, o peso da ráquis, as folhas ativas na colheita e o rendimento da cultura. Os dados foram submetidos à análise de variância por meio do teste F, ajustados a modelos de regressão. Não houve diferenças significativas na altura da planta, mas para a variável diâmetro da base, foram observados valores maiores na menor densidade populacional nos dois ciclos de produção. Na fase de produção, destaca-se que o adensamento das plantas prolongou o ciclo de vida e o ciclo de produção das bananeiras. Embora o adensamento tenha promovido um menor peso do cacho, uma menor quantidade e peso dos frutos, por outro lado, promoveu maior produtividade, com valores acima de 20 t.ha-1 em ambos os ciclos.

Palavras-chave: análise de crescimento, banana-maçã, adensamento, fruticultura tropical.

ABSTRACT

The objective of this work was to evaluate the effect of planting densities of apple type banana "BRS Princesa" on the development and productivity of the crop in two production cycles. The research was carried out in the agricultural years of 2014 to 2016 in the Department of Horticulture of the Federal Rural University of Rio de Janeiro (UFRRJ), municipality of Seropédica, Rio de Janeiro, Brazil. The treatments were composed of planting densities, being 1200 (3.33 x 2.5 m); 1600 (2.5 x 2.5 m); 2000 (2.0 x 2.5 m); 2400

(1.67 x 2.5 m); 2800 (1.43 x 2.5 m) and 3200 (1.25 x 2.5 m) plants per hectare, arranged in a randomized complete block design with four replicates. In the vegetative stage, plant height and base diameter were measured periodically. In the production period, bunch weight, fruit weight, number of leaves, number of fruits, weight of the stalk, leaves active at harvest and yield of the crop were measured. The data were submitted to analysis of variance through the F test, adjusted to regression models. There were no significant differences in plant height, but for the base diameter variable, higher values were observed in the lower population density in the two production cycles. In the production stage, it is highlighted that the plant densification extended the life cycle and the production cycle of banana plants. Although the densification promoted a lower bunch weight, a lower quantity and weight of fruits, fortuitously, promoted higher productivity, with values above 20 t.ha-1 in both cycles.

Keywords: growth analysis, apple banana, densification, tropical fruit growing.

Introduction

The increase in the use of inorganic products intensified the concerns of civil society and consumers regarding the quality of food products, in response increased the demand for reduction in the use of these products (Finckh et al. 2000). These observations reveal a potential market for fruit produced with less use of agrochemicals, within inspection and certification programs. The planting of varieties resistant to certain diseases, which require or dispense the use of pesticides, allow to offer the market products with a quality differential desired by consumers.

Although widely adapted to tropical conditions, banana plants are increasingly being cultivated through unsustainable practices, with widespread use of chemical pesticides, and their consequent impacts on workers health and the environment (Blazy et al. 2011). In parallel, we can observe the increase in the areas destined to organic and agroecological production, being currently the banana, the most cultivated fruit tree in the world within these principles. It occupies approximately 86,000 hectares, corresponding to 45% of the area planted with tropical fruits in organic systems, or slightly more than 27% of all organic fruit production worldwide.

Banana participates more and more in the fruit markets of the whole world, with emphasis on those from production that aim at the sustainable management of the crop and the inputs used, as well as the integrated pest, disease and weed management. In parallel, we highlight the optimization of soil use through the management of productive arrangements that seek greater productivity in smaller spaces (Donato et al. 2013).

In most of the areas of irrigated banana production in Brazil, the same planting spacings and population densities defined for dryland conditions have been used, which are very varied. Considering that irrigated banana has better conditions for development and production, it is necessary to establish planting spacings and adequate population densities for irrigated crops (Pereira 1997).

Productive arrangements should allow good use of light and soil, protect soil against erosion, promote cultural control of spontaneous plants (Lanza 2016) and result in substantial improvement in productivity, product quality and farmers' net income (Pereira et al. 2000). In the various banana producing regions of the world, planting spacings ranged from 2.0 x 1.0 m to 9.0 x 3.0 m, with population densities of 370 to 5.000 pl.ha-1 respectively, predominantly 1,000 to 2,000 pl.ha^{-1} (Borges et al. 2004; Stover e Simmonds 1987).

Among the genotypes made available to producers by the breeding program of the Brazilian Agricultural Research Company (EMBRAPA) is the 'Princesa' (YB42-07), a tetraploid hybrid of the AAAB group, resulting from crossing the cultivar Yangambi n° 2 with the diploid hybrid (AA) M53, marketed in the 'Maçã' subgroup (Silva et al. 2006). The recommended spacing for this cultivar is 3.0 mx 2.0 m, but with potential for further densification.

In the Brazilian market, the bananas of the Cavendish, Prata and 'Maçã' subgroups are the most commercialized (Saraiva et al. 2013). It is known that the latter, currently, reaches higher prices in the Brazilian markets, reaching R $ 4.00 / kg or about U$ 1.30 / kg, while the other two prices are below U $ 1,00 / kg (CEAGESP 2017), reiterating the importance of conducting research with these subgroups. This price

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differential is due to the lower supply of real Apple banana in the Brazilian market due mainly to the occurrence of the severe Evil Panama and Sigatoka, together with the low technological adoption, culminated in low productivity. In this sense, the objective of this study was to evaluate the effect of densities of banana plantation "BRS Princesa" on vegetative and reproductive aspects for the first and second production cycle.

Materials and Methods

This work was carried out in the experimental field of the Department of Phytotechnology of the Federal Rural University of Rio de Janeiro (UFRRJ), in the city of Seropédica, Rio de Janeiro, Brazil, being implemented in July 2014 and evaluated until December 2016, about 17 months of cultivation until two production cycles are completed. The experimental area is located at 22° 45 '08.62"S and 43 ° 40 '28.50"O, at an altitude of 27 m, where Köpen Aw weather is predominant, with wet summers and dry winters. The average annual temperature is about 24.5 °C and the average precipitation is 1,200 mm. The area was occupied previously, mainly by grass colonization (*Panicum maximum*), being used in the last decades for experiments of the Institute of Agronomy of the UFRRJ.

The seedlings used in the experiment were obtained from in vitro cultivation, produced by Campo Biotechnology and Embrapa Manioc and Tropical Fruits, in Cruz das Almas, Bahia, Brazil. A total of 350 seedlings of the "BRS Princesa" apple variety (YB42-07), a tetraploid hybrid (AAAB), produced in Embrapa Manioc and Tropical Fruits, were obtained from micro-propagated banana trees (*Musa spp*). The experiment occupied an area with dimensions of 30 x 50 m, totaling 1500 m². Initially the soil was prepared through a plowing, two harrows, subsoiling at 50 cm depth and grooving of the area. Twelve planting lines were arranged in the area, with a fixed spacing of 2,50 m between them. Based on the results found in the soil fertility analysis, liming was performed 30 days before planting, as well as planting fertilization with 80g of Yoorin® phosphate fertilizer and 10 L of bovine manure per pit.

We chose the conventional sub-sprinkler irrigation system, activated by an electric pump, with nominal power of 5HP, whose water was collected from a pond near the experimental area.

The treatments were composed of planting densities, being 1200 (3.33 x 2.5 m); 1600 (2.5 x 2.5 m); 2000 (2.0 x 2.5 m); 2400 (1.67 x 2.5 m); 2800 (1.43 x 2.5 m) and 3200 (1.25 x 2.5 m) plants per hectare, arranged in a randomized complete block design with four replicates. The seedlings were transplanted, when they had an average of 20 cm in height, in pits of 0,5 x 0,5 m. After transplanting, the cultural treatments were carried out according to a technical recommendation for the cultivar (Borges et al., 2004), including weed control, cover fertilization, shoot removal and cleaning of clumps.

The vegetative behavior of the plants began to be evaluated from 30 days after transplanting (DAT), on August 29, 2014, being performed monthly until the end of the experiment. The banana production stage began to be evaluated from the beginning of the flowering to the closing of the harvest of the 2nd cycle.

At the time of harvesting the first and second cycles were measured the height of the plant, from the soil level to the leaf rosette; the diameter of the pseudostem, 10 cm above ground level, the number of photosynthetically active leaves present per plant and the date of harvesting of said plant. From the date of harvesting, the period from the transplanting of the seedlings to the harvesting of the first and second production cycles was computed, and with these temporal data, the productive cycle was calculated for each planting density adopted, by the time difference, in days, between the second and the first harvest.

Post-harvest values were recorded: Bunch Weight, Fruit Weight, Number of Fruits, Number of Courses, Weight of Second Courses. With the fruit weight data per plant, productivity (ton ha^{-1}) was estimated by multiplying by the number of plants in each planting density under study.

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The data were submitted to analysis of variance by the F test at 5% probability. The means were submitted to regression analysis and adjusted models based on the biological phenomenon, the regression coefficient and the significance of the parameters.

Results and Discussion

The results show that in the vegetative stage in both production cycles, only the plant height variable does not suffer from the densification effect, with no significant differences between the treatments. The average value for plant height at the time of harvest for the 1st cycle was 294,6 cm and for the 2nd cycle 295,6 cm (Table 1).

Table 1 - Mean values of the vegetative parameters and the production stage of the 1st and 2nd cycles that did not present significant differences at 5% probability by the Test F, UFRRJ, Seropédica / RJ.

DESCRIPTORS	First Cycle		Second Cycle	
	Y	CV%	Y	CV%
Height of Plant (cm)	294,6	5,4	295,6	6,3
Leaves Active in Harvest (qtd)	9,6	11,6	6,4	16,9
Bunch Weight (kg)	7,9	16,6	7,8	24,5
Fruit Weight Per Bunch (kg)	7,3	17,0	7,2	25,2
Number of Courses (qtd)	6,4	8,8	7,5	10,0
Second Pence Weight (kg)	1,3	10,6	1,1	33,3

Source: by the authors.

In the same way, in the production stage of the crop, some parameters did not suffer from the effect of plant densities, and did not show significant differences between the treatments in both production cycles, being it possible to mention Active Harvest Leaves, Curd Weight, Fruit Weight, Number of Courses and Weight of Second Course.

Regarding the Active leaves in Harvest parameter, it is possible to observe that the average between treatments was higher for the 1st cycle with 9.6 leaves and for the 2nd cycle 6,4 for bunch weight, the means between the treatments practically did not differentiate between the cycles, being 7,9 kg in the 1st cycle and 7,8 kg in the 2nd cycle, as well as Fruit Weight where average values of 7.3 kg were found in the 1st cycle and 7.2 kg in the 2nd cycle of production. Regarding the number of courses, there was a slight increase in the second cycle, from 6.4 to 7.5 pence per bunch respectively, however with a decrease in the average value of Second course Weight from 1.3 kg to 1.1 kg between the 1st and 2nd cycle of production.

The results found for plant height and number of active leaves, corroborate with works developed by Pereira et al. (1999), Roque et al. (2014), Moura et al. (2002) and Nomura et al. (2013) where no significant differences were found in the first production cycle of the "BRS Princesa" banana for these parameters.

Nomura et al. (2013) detected values of banana height "BRS Princesa" similar to those found in the present study, being 3,05 m in height. Similar results were found by Lédo et al. (2008) with the plants presenting an average height of 3,03 m, when they carried out the first experiments with this cultivar at the Embrapa Coastal Trails in the Northeast of Brazil. Roque et al. (2014) comparing different banana genotypes in the Bahian Recôncavo, found higher values in height for the cultivar BRS Princesa, with 3,33 m. Daniells et al. (1985) and Silva et al. (2006) found lower mean values, being 2,78 m in height. (Pereira et al. 2000), compared different planting densities of "Prata-Anã" banana and verified that there were no differences for the evaluated

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parameters. In the literature are found pioneer works in this type of study with banana, such as Lichtemberg et al. (1998) who observed a small increment of plant height with increasing density and reduction of plant spacing.

In relation to the parameters of the vegetative stage that presented significant differences between the treatments, only diameter suffered from the densification effect. As can be observed in Figure 1, plant densification had its most significant effect in the 2nd cycle of production than in the 1st cycle. The difference between the treatment of lower (1200 pl ha⁻¹) and that of larger (3200 pl.ha⁻¹) plant density in the 1st cycle of production was approximately 1,64 cm, and for the 2nd cycle 4,3 cm. These results associated to the decrease in the angular coefficient of the straight line from -0.0006 to -0.0026 show how the effect of the densification becomes more expressive after the total establishment of the plant stand.
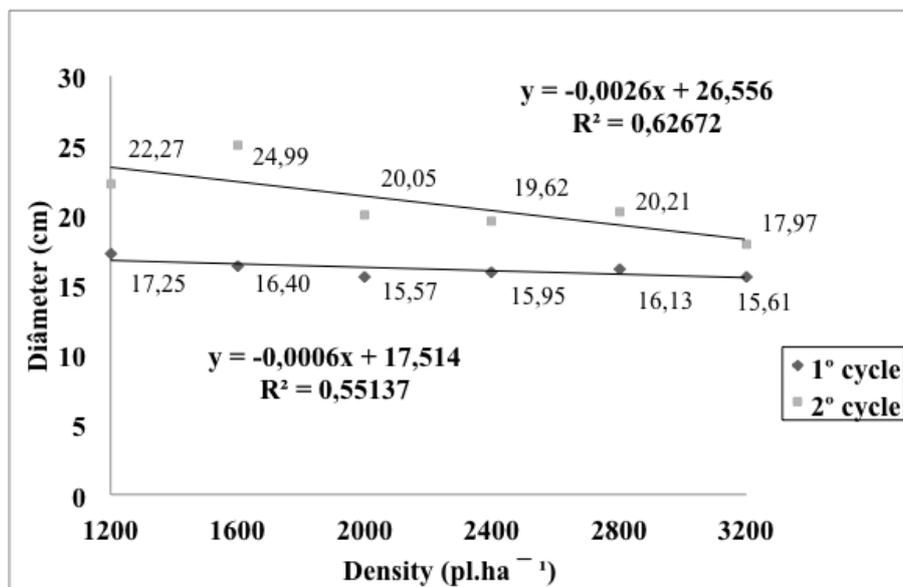

Figure 1 - Diameter of the pseudostem for the 1st and 2nd cycle of production as a function of the density of banana cultivar "BRS Princesa", UFRRJ, Seropédica / RJ. 2017. Source: by the authors.

In relation to the mean diameter, Nomura et al. (2013), Lédo et al. (2008) and Roque et al. (2014) in studies also with BRS Princesa banana, found average values of 22.21 cm, similar to that verified in this study, mainly in the 2nd cycle. Similar work performed by Moura et al. (2002) with "Long Real" banana were also found significant differences for pseudostem diameter, as well as Lichtemberg et al. (1998) observed an increase in the circumference of the pseudostem with the reduction of plant densities.

In a study using different spacings of a triploid cultivar, Hotsonyame (1991) also detected that there was no change in the vegetative growth of the plants. Similar results with different banana varieties were obtained by Irizarry et al. (1969), Daniells et al. (1985), Robinson and Nel (2015), and Pedrotti et al. (2015).

As for the production cycle of the crop (Figure 2), it is possible to perceive through the results a pattern similar to that found for other evaluated parameters, where the effect of the densification becomes more significant in the 2nd cycle compared to the 1st cycle of production. Observing the data of the 1st cycle, it was verified that the densification promoted a delay in the harvest of approximately 40 days, and that this delay added to the effect of the treatment in the 2nd cycle of production and better establishment of the plant stand, increased even more the difference between the treatments with higher and lower population densities, reaching the difference of 134 days between them.

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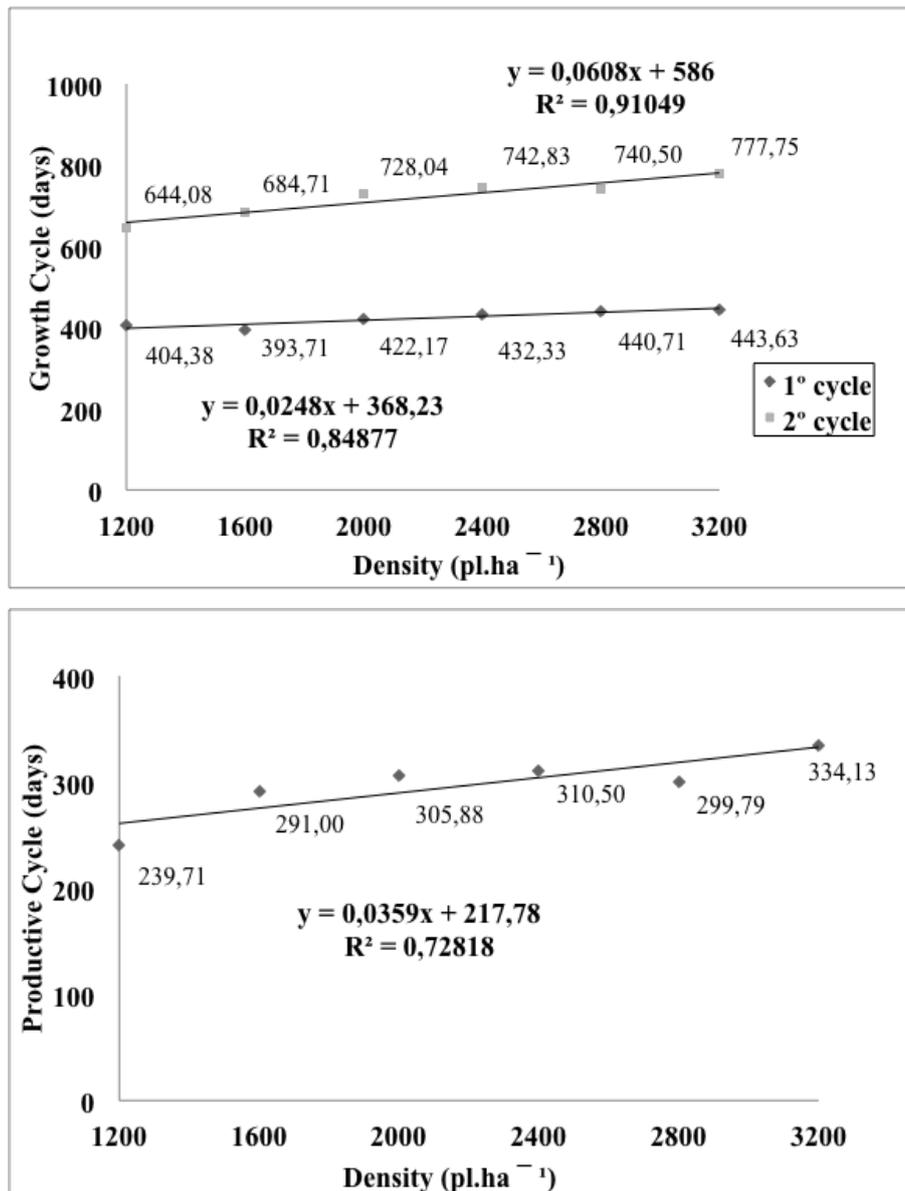Maria de Souza, Luiz Fernando de Sousa Antunes

Figure 2 - Time elapsed from planting to harvests for the 1st and 2nd cycle of production and time elapsed between the two harvests due to the density of banana cultivation "BRS Princesa", UFRRJ, Seropédica / RJ. 2017. Source: by the authors.

These results suggest that the densification presents disadvantages in relation to harvest time, and that this disadvantage is likely to accentuate in the next production cycles, evidenced by the increase of the coefficient of angularity from 0.0248 in the 1st cycle to 0.0608 in the 2nd cycle of production. Consequently, the densification extended the period between the harvests of the different cycles. At the lowest density (1200 pl ha^{-1}), the same clump was harvested to collect the second cluster about 240 days later, while for the larger density (3200 pl ha^{-1}) an average difference of 334 days was required, a difference close to three months.

In a study carried out to evaluate the development of different banana genotypes in the city of Botucatu / SP, Ramos et al. (AAB) and Tropical Tetraploid Apple (AAAB) were similar to the results found for the "Princesa" banana in the present work. As for the banana 'Prata', cultivar Prata Anã (AAB), (Lichtemberg et al. 1998), in Siderópolis, SC, pointed out that the duration of the 1st cycle was lower at higher growing densities.

Regarding the production parameters, it was possible to observe that there were only significant differences between treatments for number of fruits and estimated productivity. It was observed that there is an expressive

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increase in the number of fruits in the 2nd cycle compared to the 1st cycle of production and this increase occurred in all treatments (Figure 3).
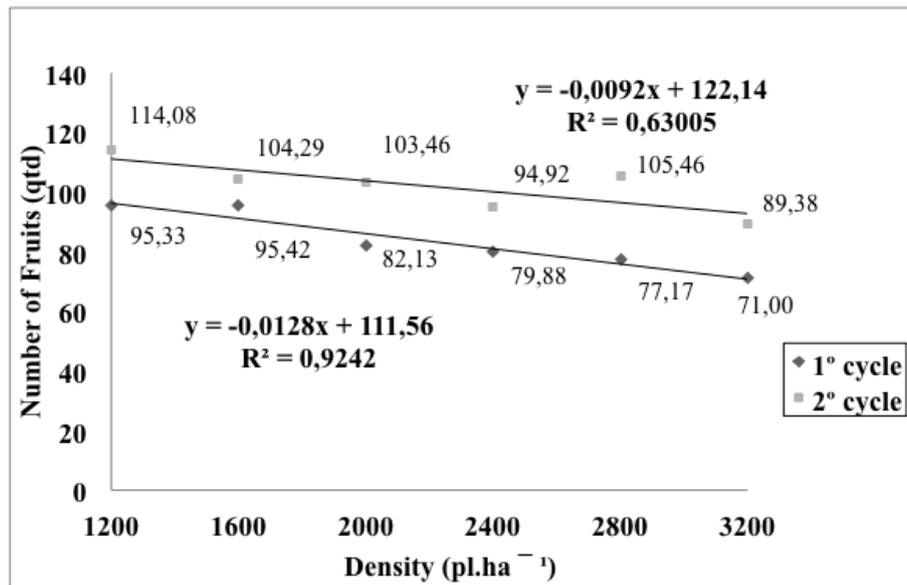

Figure 3 - Number of fruits per cluster for the 1st and 2nd cycle of production as a function of the density of banana cultivar "BRS Princesa", UFRRJ, Seropédica / RJ. 2017. Source: by the authors.

As already observed in the 1st cycle of production, the increase of the density of plants decreases the number of total fruits per cluster, which also occurred in the 2nd cycle. However, in this parameter, the observed pattern differs from that found in the others, where the best establishment of the plant stand influences in a more significant way the treatments of higher density.

The difference in the number of fruits in the 1st cycle of production between treatments of lower (1200 pl ha^{-1}) and higher (3200 pl ha^{-1}) population densities is 25 fruits, and in the 2nd cycle of production 24 fruits per cluster. These data suggest that the effect of densification on the number of fruits is practically the same, but tends to decrease with time. These results can be evidenced with the decrease of the coefficient of the straight line from 0.9242 in the 1st cycle to 0.63005 in the 2nd cycle, suggesting that in the next cycles the number of fruits per bunch of banana "BRS Princesa" will equal within the range studied. As the lower banana density favors the larger diameter of the pseudostem, which indicates a larger size of the rhizome or more reserve, as previously seen, it can be inferred that, this allows the development of plagues with greater number of fruits, since the number was not influenced by the density.

Works such as Scarpare Filho and Kluge (2001) and Moura et al. (2002) found that when increasing the densities of banana plants, there is a decrease in the number of fruits per bunch, as was observed in the present work for apple banana.

As for banana productivity, it was found that treatments with lower plant density (1200, 1600 and 2000 pl ha^{-1}) did not reach 15 t ha^{-1} in both cycles of (2400, 2800 and 3200 pl ha) higher yields were observed, exceeding 22 t ha^{-1} (Table 2).

Using the density of 1600 pl ha^{-1} as a standard for "BRS Princesa" apple banana cultivation in Brazil, productivity increases were evaluated with increasing and decreasing plant density. It was observed that the use of smaller planting densities, such as 1200 pl ha^{-1}, favored some productive parameters, such as Number of Fruits, but evidences a productivity loss of 16.4% in the 1st cycle and 8.4% in the 2nd cycle, when compared to the standard density.

Table 2 - Productivity estimated for the 1st and 2nd cycle of production, with respective times from transplanting to harvesting, as a function of the growing density of the "BRS Princesa" banana, UFRRJ, Seropédica / RJ. 2017.

	Density of cultivation (plant/hectare)					
	1200	1600	2000	2400	2800	3200
	First Cicle					
Yield (t.ha⁻¹)	10,1	12,1	14,7	16,5	18,9	22,3
Efect (%)*	-16,4	--	21,4	36,1	56,3	84,3
Time (Days)	404,4	393,7	422,2	432,3	440,7	443,6
Efect (%)	2,7	--	7,2	9,8	11,9	12,7
	Second Cicle					
Yield (t.ha⁻¹)	10,5	11,6	13,3	16,4	20,9	20,1
Efect (%)	-8,7	--	14,8	41,8	80,5	74,1
Time (Days)	644,1	684,7	728,1	742,8	740,5	777,8
Efect (%)	-5,9	--	6,3	8,5	8,1	13,6
	SUM (First more Second cicle)					
Yield (t.ha⁻¹)	20,6	23,7	28	32,9	39,8	42,4
Efect (%)	-13,1	--	18,1	38,8	67,9	78,9

Effect of the other treatments compared to the culture density standard of 1600 pl ha⁻¹. Source: by the authors.

On the other hand, with plant densities, it can be observed that increasing the planting density by 30% in the treatment of 2000 pl ha⁻¹ yields an increase of 21.4% in the 1st cycle and 14.8 % in the 2nd cycle. Similarly, comparing the standard with the following densities of 2400, 2800 and 3200 pl ha⁻¹, there was an increase in productivity, respectively, of 36.1%, 56.3% and 84.3% in the 1st cycle and 41.8%, 80.5% and 74.1% in the 2nd cycle. It can be noticed that the production cycle extended (time in days) with the increase in crop density, however, in percentage values much lower than the gains in productivity.

While the production cycle extended by only 13.6% of the control (from 685 to 778 days), even though it was about three months, compared with the higher density the gain in productivity reached about 79% more bananas in the same area. Considering that the banana of the subgroup 'Maçã' is marketed by weight, this results in a very significant gain, especially for the small family producer that has little land for cultivation.

It was possible to observe a significant increase with plant densification in both cycles of production. It should be noted that total productivity did not differ significantly between the two cycles (Figure 4). It is observed that the plant densities were more advantageous in terms of productivity, compensating for the negative effect observed in the other parameters that showed significant differences among treatments, such as pseudostem diameter, productive cycle and number of fruits.

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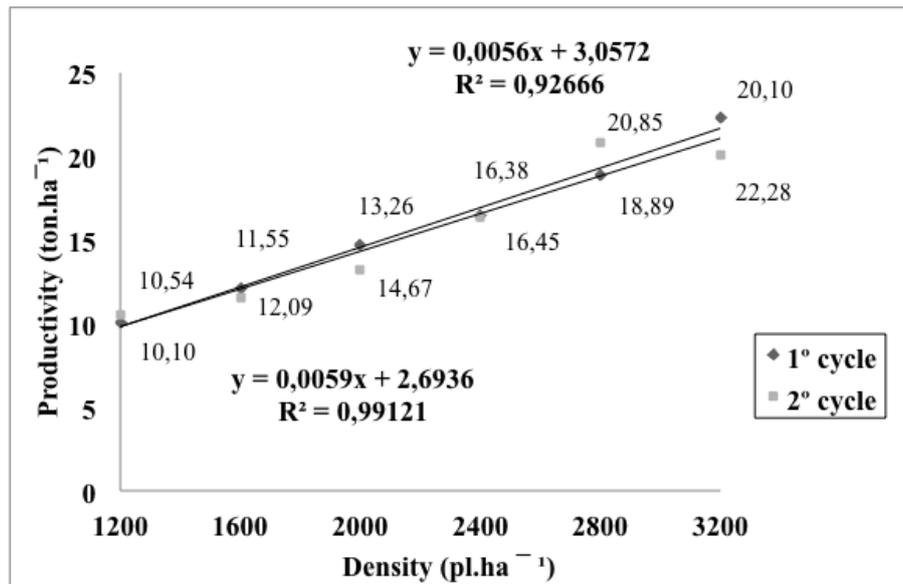Maria de Souza, Luiz Fernando de Sousa Antunes

Figure 4 - Productivity for the 1st and 2nd cycle of production as a function of the density of banana crop "BRS Princesa", UFRRJ, Seropédica / RJ. 2017.

Source: by the authors.

Comparing the productivity results verified in the present work, it is possible to infer that they follow the standards of other works with the "BRS Princesa" and true apple (AAB) cultivars found in the literature. The results of productivity, as well as the majority of their characteristics, were similar and / or superior to cultivating Apple, especially in terms of development and productivity, reaching between 15 and 25 t ha^{-1} (Lédo et al. 2008). In the same way, in several studies with irrigated apple banana, the average productivity of 18 t ha^{-1} (Borges et al. 2014) is similar to those found in the present study.

Conclusions

Increasing planting density of 'BRS Princesa' banana in the transition system for organic production promoted changes in the production cycle and in the vegetative and reproductive traits of the crop. Although higher densities reduced pseudostem diameter, number of fruits per bunch, and extended the production cycle, they resulted in significant yield gains, exceeding 20 t ha^{-1} in both cycles. These findings indicate that crop densification is a viable alternative to optimize land use, enhance production sustainability, and improve the profitability of smallholders. Therefore, the adoption of higher planting densities is recommended as a strategy to strengthen organic banana production in tropical regions, meeting the growing demand for high-quality and sustainably produced food.

Acknowledgments

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