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Spacing between plants and cultivar affect the production components of Italian zucchini

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ABSTRACT: The italian zucchini is a vegetable of national importance, much appreciated, which requires techniques that aim to increase production in less space. Plant spacing can influence the development of plants and the fruit production. The objective of this study was to evaluate the performance of Italian zucchini cultivars as a function of plant spacing. The experimental design was a randomized blocks in a 2 x 4 factorial scheme with four repetitions. The treatments consisted of a combination of two cultivars of zucchini (Alícia and Caserta) and four spacings between plants (0.4, 0.5, 0.6 and 0.7 m). The evaluated characteristics were: total number of fruits plant^{-1}, number of commercial fruits plant^{-1}, total productivity, commercial and non commercial, fresh mass of commercial fruits and dry mass of the plant. The cultivars responded differently to spacings between plants. The Alicia hybrid showed higher commercial yield, 28,490.5 kg ha^{-1} at spacing of 0.64 m between plants and Caserta cultivar, 26,398.8 kg ha^{-1} at spacing of 0.4 m.

Key words: *Cucurbita pepo* L., density, productivity

Espaçamento entre plantas e cultivar afetam os componentes de produção de abobrinha italiana

RESUMO: A abobrinha italiana é uma hortaliça de importância nacional, bastante apreciada, o que exige técnicas que visem aumento de produção em menor espaço. O espaçamento de plantio pode influenciar o desenvolvimento das plantas e a produção dos frutos. Objetivou-se avaliar o desempenho de cultivares de abobrinha italiana em função do espaçamento entre plantas. O delineamento experimental utilizado foi em blocos casualizados em esquema fatorial 2 x 4 com quatro repetições. Os tratamentos foram constituídos da combinação de duas cultivares de abobrinha (Alícia e Caserta) e quatro espaçamentos entre plantas (0,4; 0,5; 0,6 e 0,7 m). As características avaliadas foram: número total de frutos planta^{-1}, número de frutos comerciais planta^{-1}, produtividade total, comercial e não comercial, massa fresca de frutos comerciais e massa seca da planta. As cultivares responderam de modo distinto aos espaçamentos entre plantas. O híbrido Alícia expressou maior produtividade comercial, 28.490,5 kg ha^{-1} no espaçamento de 0,64 m entre plantas e a cultivar Caserta, 26.398,8 kg ha^{-1} no espaçamento de 0,4 m.

Palavras-chave: *Cucurbita pepo* L., densidade, produtividade

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Introduction

Italian zucchini (*Cucurbita pepo* L.), also known in Portuguese as 'abóbora de moita' and 'abobrinha de tronco', is one of the most consumed vegetables, standing among the ten vegetables of greatest economic importance for Brazil (Matos et al., 2017). Brazilian production in 2016 was 376,268 t, cultivated in an area of 20,904 ha, providing an average yield of 18 t ha^{-1} (CNA, 2017), with highest production and consumption and in the Midwest and Southeast regions (Filgueira, 2013).

Planting density is an important factor that mainly affects yield (Latifi et al., 2012). Adequate spacing enables the plant to develop better, promoting sufficient absorption of water, light and nutrients for carbon assimilation and plant growth, allowing higher yield and better quality (Abdel-Rahman et al., 2012).

In general, when the spacing between plants is reduced, the density of plants per unit of area increases, reaching a point at which plants compete for essential growth factors such as water, light and nutrients (Harms et al., 2015).

Planting density is a tool of great importance because it can be managed according to the demand of the consumer market, aiming to maximize production and economic return (Resende & Costa, 2003a). Another important tool is the evaluation of genotypes, since different materials may respond differently with respect to yield. Currently, several hybrids have been created and introduced in the market because they are early, with high yield and uniform production, in comparison to the cultivar Caserta.

In this context, the aim of this study was to evaluate the agronomic performance of two cultivars of Italian zucchini as a function of plant spacing.

Material and Methods

The experiment was conducted from August to October 2015 at Rafael Fernandes Experimental Farm, belonging to Universidade Federal Rural do Semi-Árido, Mossoró, Rio Grande do Norte, Brazil (5° 12' S, 37°19' W, 18.5 m altitude) in a soil classified as Ultisol.

Chemical analyses in soil samples from the 0-20 cm layer revealed the following results: pH (H_2O) = 6.4; EC = 0.03 dS m^{-1}; P = 4.37 mg dm^{-3}; K^+ = 51.9 mg dm^{-3}; Na^+ = 2.2 mg dm^{-3}; Ca^{2+} = 0.72 $cmol_c$ dm^{-3}; Mg^{2+} = 0.15 mol_c dm^{-3}; Al^{+3} = 0 $cmol_c$ dm^{-3} (Tedesco et al., 1995).

The climatic conditions along the experiment were characterized by an average temperature of 23.9 °C with minimum of 18.1 °C and maximum of 29.6 °C, average air relative humidity of 62.9% and accumulated precipitation of 27.8 mm in the period.

The experimental design used was randomized blocks, in a 2 x 4 factorial scheme, with 4 repetitions, corresponding to two zucchini cultivars (Alícia and Caserta) and four spacings between plants (0.4; 0.5; 0.6 and 0.7 m). The spacing between rows was 1.0 m. The experimental plots consisted of three 4.2-m-long plant rows, considering the central row as usable area, disregarding one plant on each end.

Caserta is an open pollination cultivar, with vigorous plant, fruit with cylindrical shape and light green color with stripes, and cycle from 45 to 55 days. Alícia is a hybrid, with vigorous plant, cylindrical fruit with light green color and darker, brighter green stripes.

Soil preparation consisted of plowing and harrowing. Basal fertilization was performed according to soil analysis and to the recommendation of Carrijo et al. (1999), using: 24 kg ha^{-1} of N, 120 kg ha^{-1} of P_2O_5, 42 kg ha^{-1} of K_2O, 25 kg ha^{-1} of S, 20 kg ha^{-1} of Mg and 1.0 kg ha^{-1} of B, incorporated in the planting furrow. Topdressing fertilization consisted of: 96 kg ha^{-1} of N and 98 kg ha^{-1} of K_2O, split into two applications, at 15 and 30 days after transplanting (DAT).

Irrigation was applied using a drip system, composed of one line per plant row with pressure-compensating drippers, with an average flow rate of 1.5 L h^{-1}, spaced by 0.30 m. Irrigation was performed daily, according to the need of the crop, and a water depth of 390 mm was applied throughout the cycle.

Zucchini seedlings were produced in 128-cell polystyrene trays using commercial substrate. Transplantation was carried out 13 days after sowing, when the plants had three true leaves. Then, plants were covered for 22 days with a white polypropylene fabric (agrotextile), 15 g m^{-2} weight, forming a tunnel, in order to prevent the attack of pea leaf miner and silverleaf whitefly. Phytosanitary control was performed preventively, applying insecticides of the Neonicotinoid chemical group, acaricide and insecticide of contact and ingestion of the Avermectin chemical group.

Harvest began at 27 DAT, when the fruits reached 16 to 22 cm in length. The characteristics evaluated were: number of marketable fruits per $plant^{-1}$ (fruits free of injuries and 16 to 22 cm long), total number of fruits $plant^{-1}$, average fruit weight, marketable yield (sum of the weight of fruits free of injuries and 16 to 22 cm long), unmarketable yield (sum of the weight of fruits with length < 16 cm and/or with injuries) and total fruits (sum of marketable and unmarketable yields) and plant dry mass (vegetative part and fruits were dried in forced air circulation oven at 65 °C, until reaching constant weight).

The data were subjected to analysis of variance and, when there was a significant effect for the qualitative factor (cultivars), the means were compared by Tukey test at $p \leq 0.05$, while regression analysis was applied for the spacing factor, using the program Sisvar version 5.6 (Ferreira, 2014).

Results and Discussion

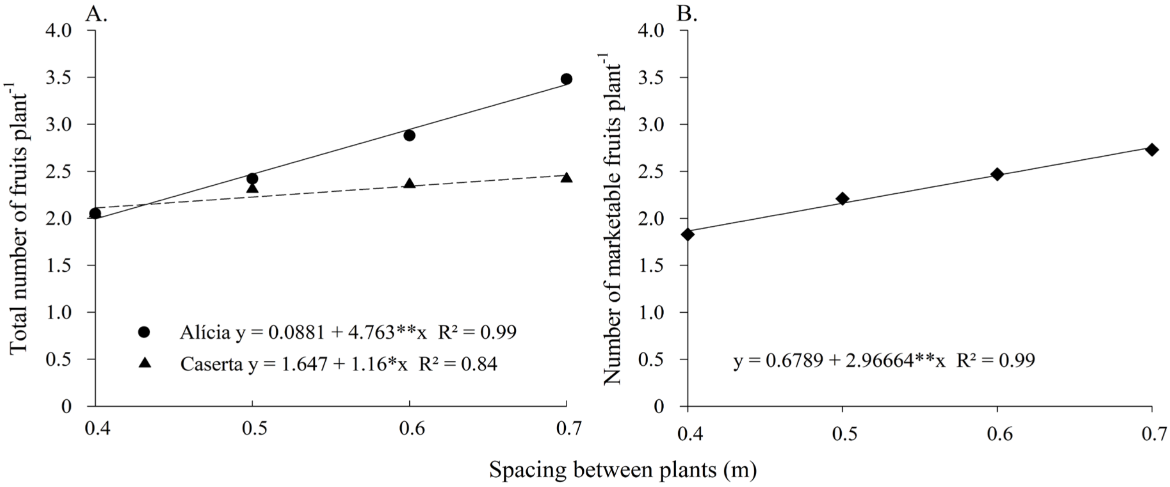
The analysis of variance revealed significant effect of the interaction between cultivars and plant spacing on the total number of fruits $plant^{-1}$ (TNFP), marketable yield (MY) and total yield (TY). For the number of marketable fruits $plant^{-1}$ (NMFP) and plant dry mass (PDM), there was a significant effect of the single factors. For the other characteristics none of the factors was significant (Table 1).

The total number of fruits $plant^{-1}$ as a function of spacing increased linearly for both cultivars (Figure 1A). The estimated maximums were 3.42 and 2.45 fruits $plant^{-1}$ at the spacing of 0.7 m, respectively, for the cultivars Alícia and Caserta. In

Table 1. Summary of analysis of variance for total number of fruits plant-1 (TNFP), number of marketable fruits plant-1 (NMFP), total yield (TY), marketable yield (MY), unmarketable yield (UY), fresh weight of marketable fruits (FWMF) and plant dry mass (PDM) of Italian zucchini cultivars under different spacings between plants

F.V.	G.L.	TNFP	NMFP	TY	MY	UY	FWMF	PDM
		F						
Blocks	3	3.47*	3.56ns	3.27*	3.71*	0.60ns	3.63*	4.78*
Cultivar (C)	1	9.53**	12.04**	9.62**	13.40**	0.46ns	0.65ns	15.78**
Spacing (S)	3	7.88**	9.08**	1.17ns	1.00ns	1.42ns	2.10ns	18.77**
C x S	3	3.12*	2.97ns	4.30*	4.62*	0.20ns	1.50ns	1.40ns
CV (%)		15.44	15.63	14.45	14.03	63.52	9.13	13.74

nsNot significant; *, ** - Significant at $p \leq 0.05$ and $p \leq 0.01$ by F test, respectively



* and ** - Significant at $p \leq 0.05$ and $p \leq 0.01$, respectively

Figure 1. Total number of fruits plant-1 (A) and number of marketable fruits plant-1 (B) in the Italian zucchini cultivars Alícia and Caserta, as a function of the spacing between plants

relation to the cultivars, Alícia was significantly superior to Caserta only at the spacing of 0.7 m (Table 2).

At the spacing of 0.40 m between plants, the cultivars Alícia and Caserta produced virtually the same amount of fruits plant-1, on average 2.0 fruits. However, it is observed that in comparison to the spacing of 0.7 m, there were reductions of 42 and 14% in the number of fruits per plant in the cultivars Alícia and Caserta, respectively, indicating that Caserta was less susceptible to the pressures of competition between plants, with the increase in plant density (spacing of 0.4 m) compared to Alícia (Table 2).

Similar results with cucurbits confirm the effect of spacing on the number of fruits plant-1. In pumpkin, Resende et al. (2013) found that, at the spacing of 1.0 m between plants, the number of fruits was 38% lower than that observed at spacing of 3.0 m. In yellow melon, the spacing of 0.50 m between plants favored higher fruit production (3.07 fruits plant-1) compared to the spacing of 0.20 m (1.43 fruits plant-1) (Dantas et al., 2013). In zucchini, the increase in density from 2 to 3 plants m-2 reduced the number of fruits by 52% (Bahlgerdi et al., 2014).

At the largest spacings (lower planting density), the increase in the number of fruits plant-1 possibly occurs because there is a reduction in the effects of mutual shading, causing the inter- or intra-plant competition to be attenuated. Another factor that can also contribute to obtaining the largest number of fruits plant-1 at the largest spacings may be related to the higher efficiency of bees in the pollination process (Dantas et al., 2013).

The number of marketable fruits plant-1 increased linearly with the increment in spacing, with a maximum of 2.7 fruits plant-1 (Figure 1B). Resende & Costa (2003a) also observed a reduction of waste fruits (unmarketable) in melon plants as the spacing between plants increased. This fact is mainly due to the reduction in fruit size when the spacing between plants is reduced. Regarding the cultivars, Alícia had on average 2.5 marketable fruits and Caserta had 2.1 fruits plant-1.

As for the fresh weight of marketable fruits, there were no significant effects of the factors individually or in interaction (Table 1). This result differs from that reported by El-Hamed & Elwan (2011) and Bahlgerdi et al. (2014), who observed that the reduction in spacing decreased fruit weight. In the present study, contrary to the results observed by these authors, the greater competition between plants, with the reduction of spacing from 0.7 to 0.4 m between plants, did not result in lower fruit weight, whose average was 621.0 g fruit-1.

Table 2. Total number of fruits plant-1 (TNFP), total yield (TY) and marketable yield (MY) of Italian zucchini as a function of cultivars and spacing between plants

Cultivar	TNFP				TY (kg ha-1)				MY (kg ha-1)			
	0.4	0.5	0.6	0.7	0.4	0.5	0.6	0.7	0.4	0.5	0.6	0.7
Alícia	2.05a	2.42a	2.88a	3.48a	25937.36a	29469.99a	28781.30a	30233.74a	23815.67a	27684.78a	27536.12a	28570.81a
Caserta	2.05a	2.31a	2.36a	2.42b	28513.36a	26807.07a	22847.25b	19457.49b	25633.27a	24757.80a	21373.68b	17924.57b

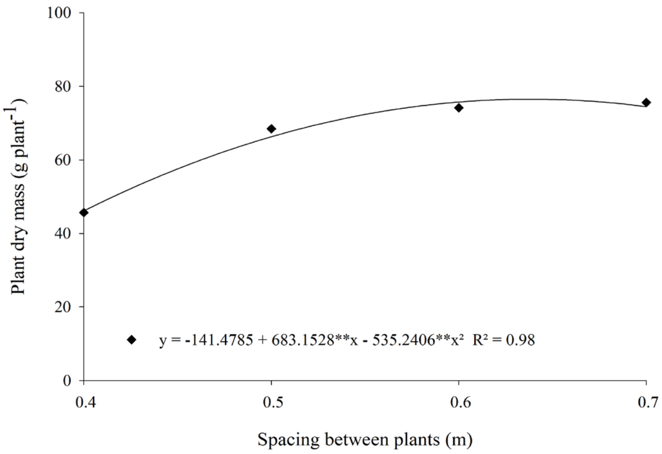
Means followed by the same letter in the column do not differ statistically by F test at $p \leq 0.05$

Plant dry mass as a function of spacings between plants showed a quadratic behavior with the increase in spacing (Figure 2). The maximum estimated value was 76.6 g plant^{-1}, obtained at the spacing of 0.64 m.

Benz et al. (2015) state that the increase in the rates of growth of zucchini plants and their fruits is proportional to the greater availability of solar radiation. At larger spacings, the plant has more space to expand its leaves, so there is less shading. Thus, there is an increase in the amount of radiation intercepted by the plant and, consequently, greater photosynthesis and individual growth (Peil et al., 2014). The ideal plant population is the one that is enough to achieve the optimum leaf area index (LAI) in order to intercept the maximum useful solar radiation for photosynthesis and, at the same time, maximize the dry matter fraction allocated to the fruits (Resende & Flori, 2004).

The spacings between plants affected the fruit yield of the cultivars Alícia and Caserta differently. For Alícia, a quadratic regression model fitted to the means of fruit yield as a function of spacings, with a maximum of 29,971 kg ha^{-1}, obtained at the spacing of 0.40 m. For Caserta, the relationship was decreasing and linear, with a maximum of 29,075 kg ha^{-1}, obtained at the spacing of 0.40 m (Figure 3A).

Regarding the marketable yield, the response was similar to that observed for total yield, obtaining the maximum estimated values of 28,490.5 and 26,398.8 kg ha^{-1} at the spacings of 0.65 and 0.40 m for the cultivars Alícia and Caserta, respectively (Figure 3B).



* and ** - Significant at p ≤ 0.05 and p ≤ 0.01, respectively

Figure 2. Dry mass of Italian zucchini as a function of planting spacings

The hybrid Alícia was shown to be little tolerant to the increase in plant density, obtaining increments in marketable and total yields as the spacing between plants increased. Certainly such increase is related to the high production capacity that the hybrid cultivar has in smaller populations, where the stress caused by competition between plants is milder. The cultivar Caserta has a good tolerance to the reduction of spacing between plants, compared to Alícia, showing higher total and marketable yields at the smallest spacing.

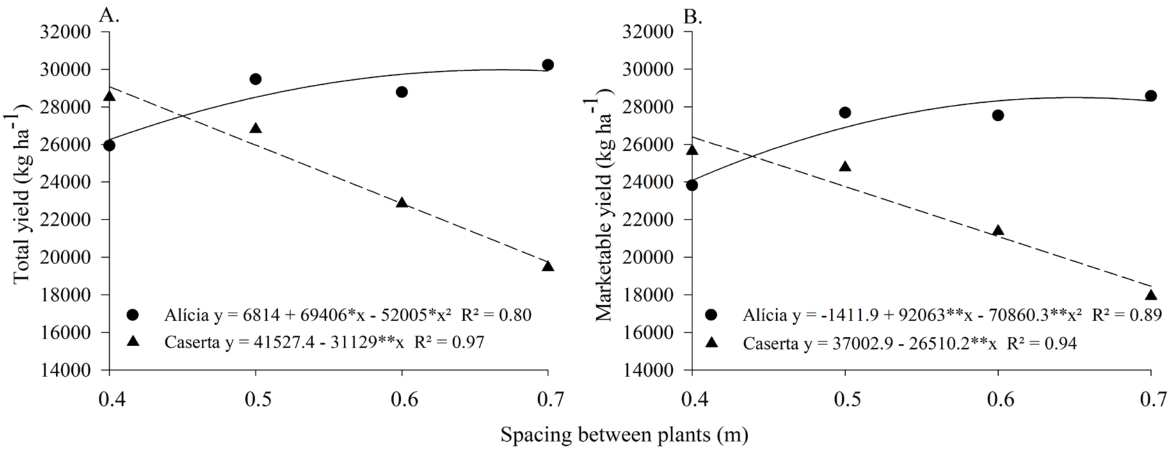
It is important to highlight that both cultivars evaluated had higher yields than the national average, 18 t ha^{-1} (CNA, 2017), which is probably due to favorable weather conditions, low variation of temperature and humidity, and the use of technologies such as drip irrigation and agrotextile.

Resende et al. (2013), evaluating cultivars and accessions of *Cucurbita moschata* as a function of spacing between plants, observed higher yield (18.2 t ha^{-1}) at the smallest spacing between plants (4 × 1 m). Mamnoie & Dolatkhahi (2013), evaluating *Lycopersicon esculentum* at different spacings between plants, obtained higher yields at the smallest spacings.

The cultivar Alícia was superior to Caserta at the spacings 0.6 and 0.7 m, but the two did not differ at the smallest spacings for total and marketable yields (Table 2). This increase was on the order of 32.25% between the largest and smallest spacings. This demonstrates that hybrid cultivars tend to increase production when under adequate conditions, such as the availability of water, radiation and nutrients, reaching high levels of production.

On the other hand, the increase of spacing may favor the work of pollinating insects, and the results may also be related to the increase in the total number of fruits plant^{-1} and number of marketable fruits plant^{-1} (Figure 1). Dantas et al. (2013), evaluating different spacings between plants (20, 30, 40, 50 cm) in *Cucumis melo* L., obtained linear growth as the spacing increased, corroborating the results obtained in this study.

The open pollination cultivar, Caserta, obtained higher plant dry mass than the hybrid Alícia (Table 3). This same



* and ** - Significant at p ≤ 0.05 and p ≤ 0.01, respectively

Figure 3. Total yield (A) and marketable yield (B) of the Italian zucchini cultivars Alícia and Caserta as a function of the spacing between plants

Table 3. Number of marketable fruits plant^{-1} (NMFP), plant dry mass (PDM), fresh weight of marketable fruits (FWMF) and unmarketable yield (UY) of Italian zucchini as a function of cultivars and spacing between plants

Cultivar	NMFP	PDM (g)	FWMF (g)	UY (kg ha^{-1})
Alícia	2.53 a	59.61 b	574.13 a	1703.7 a
Caserta	2.09 b	72.33 a	589.26 a	1984.10 a

Means followed by the same letter in the column do not differ statistically by F test at $p \leq 0.05$

response was observed by Santos et al. (2018), when evaluating an open pollination cultivar and hybrids of onion as a function of spacing between plants.

For the fresh weight of marketable fruits, there was no significant difference. The mean values obtained were 574.13 and 589.26 g fruit^{-1} for Alícia and Caserta, respectively (Table 3). This result was already expected because the fruits were harvested when unripe and followed a pattern of length and diameter.

No significant difference was observed for unmarketable yield. The mean values obtained were 1703.7 and 1984.10 g fruit^{-1} for Alícia and Caserta, respectively (Table 3). Resende & Costa (2003b), evaluating watermelon at different spacings, also found no significant difference for unmarketable yield at spacings of 0.60 and 0.80 m between plants. However, Grangeiro et al. (1999) observed that spacing influences the production of waste melon fruits and that increased density leads to higher production of unmarketable fruits.

Conclusions

1. The cultivars responded differently to the spacings between plants.
2. The hybrid Alícia expressed highest marketable yield, 28,490.5 kg ha^{-1}, at the spacing of 0.64 m between plants.
3. The cultivar Caserta showed highest marketable yield, 26,398.8 kg ha^{-1}, at the spacing of 0.40 m between plants.

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