PAB
Pesquisa Agropecuária Brasileira

ISSN 1678-3921

Journal homepage: www.embrapa.br/pab

For manuscript submission and journal contents, access: www.scielo.br/pab

Pomology/ Original Article

Decreased spacing with different numbers of branches to enhance green fig production

Abstract – The objective of this work was to evaluate the effect of decreased spacing between 'Roxo de Valinhos' fig (*Ficus carica*) trees with different numbers of fruiting branches on green fig production. Fig trees, with two or four fruiting branches, were distributed in four blocks, at a standard spacing of 2.5 m between rows, three spacing between plants in a row (0.50, 0.75, and 1.00 m), and densities of 8,000, 5,333, and 4,000 plants per hectare. The experiment was conducted during two cycles (2020/2021 and 2021/2022). Green fruits were harvested twice a week, and the total number of fruits per harvest and the total harvest weight per plant were quantified. The average production per plant and the estimated yield were calculated for each evaluation cycle. Decreasing the spacing between fig trees increases their yield. The spacing of 0.50 m decreases production per plant, but increases yield in 73%. There is no difference in the production of green figs between trees with two or four fruiting branches.

Index terms: *Ficus carica*, pruning systems, training.

Adensamento com número diferente de ramos para aumentar a produção de figos verdes

Resumo – O objetivo deste trabalho foi avaliar o efeito da diminuição do espaçamento entre figueiras 'Roxo de Valinhos' (*Ficus carica*) com diferentes números de ramos produtivos na produção de figos verdes. As figueiras, com dois ou quatro ramos produtivos, foram distribuídas em quatro blocos, com espaçamento padrão de 2,5 m entre linhas, espaçamentos entre plantas na linha de 0,50, 0,75 e 1,00 m, e densidades de 8.000, 5.333 e 4.000 plantas por hectare. O experimento foi conduzido durante dois ciclos (2020/2021 e 2021/2022). Os frutos verdes foram colhidos duas vezes por semana, tendo-se quantificado o número total de frutos por colheita e o peso total de colheita por planta. A produção média por planta e a produtividade estimada foram calculadas para cada ciclo de avaliação. A diminuição do espaçamento entre as figueiras aumenta a sua produtividade. O espaçamento de 0,50 m diminui a produção por planta, mas aumenta a produtividade em 73%. Não há diferença na produção de figos verdes entre as figueiras com dois ou quatro ramos produtivos.

Termos para indexação: *Ficus carica*, sistemas de podas, condução.

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Received
September 23, 2022

Accepted
November 25, 2022

How to cite
PIO, R.; SANCHEZ, O.M.P.; RIBEIRO, C.H.M.; FAZENDA, L.H.V.; SILVA, A.D. da; PECHE, P.M. Decreased spacing with different numbers of branches to enhance green fig production. **Pesquisa Agropecuária Brasileira**, v.58, e03135, 2023. DOI: https://doi.org/10.1590/S1678-3921.pab2023.v58.03135.

Introduction

The fig (*Ficus carica* L.) tree has a great economic importance in worldwide fruit production (FAO, 2022). In Brazil, there are two main fig markets: the state of São Paulo, where fig trees are grown to produce in natura figs, with an average yield of 18.6 Mg ha^{-1} ripe figs; and the Southern region of the country and southwestern/southern part of the state of Minas Gerais, where green figs are produced for processing purposes, with an average yield from 5.7 to 7.4 Mg ha^{-1} (IBGE, 2022). The commercial cultivation of figs is based on a single cultivar, Roxo de Valinhos, due to its high vigor, yield, hardiness, and easy adaptation to the Brazilian management system of intensive pruning (Curi et al., 2019; Pio et al., 2019; Silva et al., 2020; Ferraz et al., 2020; Almeida et al., 2022).

In Brazil, drastic winter pruning is an agricultural technique used in fig tree orchards to manage small plants at a higher density (Souza et al., 2021) by eliminating the branches that grew and produced fruit (fruiting stems) in the previous cycle (Gonçalves et al., 2006). According to Dalastra et al. (2009, 2011), in this cultivation system, fig trees are spaced 1.5–2.0 m apart, with 2.5x3.0 m between planting rows, and their structure consists of a crown, obtained during pruning, and a main stem, at 40 cm from the soil level, with three primary lateral branches of 15–20 cm in length, each containing two secondary lateral branches of 10–15 cm, totaling six branches, each with two fruiting branches.

In this scenario, Brazilian fig yield is still considered low, with values of 3.8 Mg ha^{-1} in the northern part of state of Minas Gerais (Gonçalves et al., 2006) and < 3.8 g ha^{-1} green figs in the west of the state of Paraná (Dalastra et al., 2011). However, there are reports of increased yields of 5.07 Mg ha^{-1} in Paraná (Campagnolo et al., 2010) and 7.86 Mg ha^{-1} in Minas Gerais (Norberto et al., 2001) due to modifications in the plant management system. Campagnolo et al. (2010), for example, pruned shoot tips once after the emission of the sixteenth leaf and then after the emission of every sixth leaf, when the apical bud was removed and two sprouts per fruiting branch were selected.

Combined with modifications to the canopy management system, an alternative for growers to increase green fig yield, even in a small planting site, and to reach a higher profitability is decreasing the spacing between trees (Souza et al., 2019). Although production per plant is reduced in this case, yield per area is increased, especially in perennial fruit tree orchards (Azevedo et al., 2015; Pasa et al., 2015).

The objective of this work was to evaluate the effect of decreased spacing between 'Roxo de Valinhos' fig trees with different numbers of fruiting branches on green fig production.

Materials and Methods

The experiment was conducted in the experimental area of the Department of Agriculture of Universidade Federal de Lavras, located in the municipality of Lavras, in the state of Minas Gerais, Brazil (21°14'S, 45°00'W, at 918 m above sea level). According to Köppen’s classification, the climate of the region is of the Cwb type, i.e., tropical high altitude (mesothermal), with dry winters and concentrated rains from October to March (Alvares et al., 2013).

'Roxo de Valinhos' fig tree seedlings were produced from cuttings obtained from the apical portion of branches pruned during winter (Bisi et al., 2016) and standardized at a length of 15 cm and a diameter of 7.0 mm. The base of the cuttings was treated with a concentration of 2,000 mg L^{-1} IBA for 10 s, following the methodology of Ohland et al. (2009). Then, the cuttings were buried to 2/3 of their length in 2.5 L plastic bags containing pine bark substrate, being grown under nursery conditions with 50% brightness. The experimental area was established in October 2017 when the seedlings were four months old.

The soil of area was classified as a Cambissolo Háplico (Guimarães et al., 2021), corresponding to an Inceptisol (Soil Survey Staff, 2014). To prepare the site, 2.0 Mg ha^{-1} dolomitic limestone were applied, as well as a foundation fertilizer containing 15 L organic matter from composting and mineral sources of phosphorus (300 g simple superphosphate) and potassium (150 g potassium chloride). Soil analysis was conducted in the 0–20 cm layer, showing: pH_{water} 5.7, 46.3 g dm^{-3} organic matter, 136.9 mg dm^{-3} phosphorus, 122.0 mg dm^{-3} potassium, 10.1 $cmol_c$ dm^{-3} calcium, 3.1 $cmol_c$ dm^{-3} magnesium, 14.2 $cmol_c$ dm^{-3} sum of bases, and 15.5 $cmol_c$ dm^{-3} cation exchange capacity (CEC). The fig trees were distributed in four blocks, with a standard spacing of 2.5 m between rows and three different spacing (0.50, 0.75, and 1.00 m) between plants in the planting row.

After planted, the seedlings were trimmed and reduced to a height of 40 cm above the soil. After 30 days, sprouting occurred, and two shoots were left per plant, being allowed to grow freely until June 2018, when they were reduced to 15 cm, forming the two primary lateral branches. After 45 days, budding occurred, and three shoots by a primary lateral branch (one in one part of a plant and two in another) were left, being allowed to grow freely until June 2019 when winter pruning was carried out and they were shortened to 10 cm, forming the secondary lateral branches. At this time, the crown structures of the plants in the experimental area were formed with two or four secondary lateral branches. For the secondary lateral branches to increase in size, the plants were kept in the experimental area for a year before the beginning of the trial.

During the experiment, 2% copper sulfate fungicide were sprayed every 15 days on the plants, weeds were removed when necessary, and 10 L per plant of organic matter from composting were applied to the soil twice (once in October and once in June) in each cultivation year. Soil analysis was carried out in both years, showing: pH_{water} 5.6, 42.2 mg dm^{-3} organic matter, 141.8 mg dm^{-3} P (Mehlich-1 method), 10.9 $cmol_c$ dm^{-3} Ca, 3.5 $cmol_c$ dm^{-3} Mg, 16.5 $cmol_c$ dm^{-3} CEC, and 71.3% base saturation. For plant maintenance, 300 g ammonium sulfate were applied twice, once in October and once in January, and 200 g simple superphosphate and 200 g potassium chloride were applied once in September (Pio, 2018). The climatic data for the experimental period are shown in Figure 1.

In each block, the treatments were distributed in a 3x2 factorial arrangement, consisting of three spacing (0.50, 0.75, and 1.00 m) between plants in the row and two or four fruiting branches. Five plants were used per treatment, but only the three central plants were evaluated, i.e., of a total of 120 plants, 72 were used.

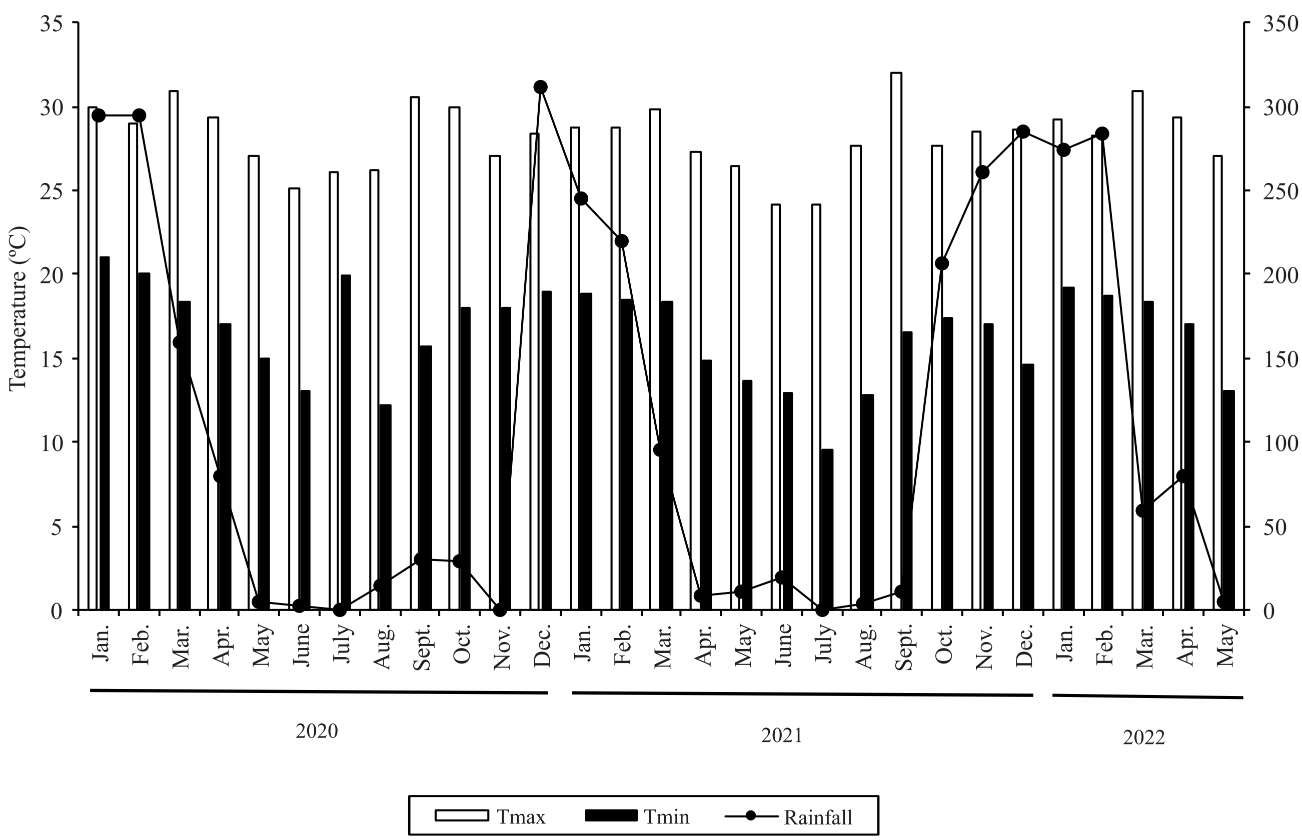

Figure 1. Mean maximum and minimum temperatures (Tmax and Tmin, respectively) and mean monthly cumulative rainfall from June 2020 to May 2022.

DOI: 10.1590/S1678-3921.pab2023.v58.03135

In the first evaluation cycle, pruning was performed in June 2020, and, after 45 days, only a single sprout of each secondary lateral branch (fruiting branch) was left, i.e., two fruiting branches for plants with two secondary lateral branches and four fruiting branches for those with four lateral branches. The second evaluation cycle began in June 2021, when the fruiting branches were removed, and, after 45 days, a single sprout of each secondary lateral branch was left.

Between October and March of each evaluation cycle, harvests were carried out biweekly. Green fruits with a diameter of approximately 3.0 cm and red and swollen ostioles were harvested for the production of figs in syrup (Dalastra et al., 2009). The total number of fruits per harvest and the total harvest weight per plant were quantified; the fruits were weighed on a digital scale with a 20 kg capacity. At the end of the cumulative harvests, the average number of fruits per fruiting branch, the average production per plant (kg), and the estimated yield (Mg ha^{-1}) were calculated for each evaluation cycle by multiplying the average production per plant by the population densities of the fig trees (8,000, 5,333, and 4,000 plants per hectare).

In each evaluation cycle, a sample of ten fruits per plant was separated during harvest in December. Fruit length (cm) and diameter (cm) were measured using a digital caliper, and average fresh fruit weight (g) was quantified with the aid of a digital scale with a 2.0 kg capacity.

In the beginning of June, during winter pruning in each evaluation cycle, the average length of the fruiting branches was measured from the tips to the insertion point of the branches using a graduated tape. Then, the average length of the fruiting branches of each plot was calculated, and the fresh weight of the fruiting branches was quantified using a digital scale with a 20 kg capacity.

Means were compared by Tukey's test, and all analyses were performed using the Sisvar, version 5.6, software (Ferreira, 2011).

Results and Discussion

There was no interaction between the number of fruiting branches and plant spacing for all variables analyzed in the two evaluation cycles.

However, in both cycles, the average length and, consequently, the fresh weight of the branches were greater for plants with two fruiting branches (Table 1) due to the source and drain relationship (Larcher, 2000). This result was expected because there is a tendency for the average length of branches to decrease with the increase in the number of branches per plant, as observed by Dalastra et al. (2011), who found an average branch length of 148.7 cm for fig trees with six fruiting branches but of 138.5 cm for those with 21 fruiting branches. In the present study, the decrease in the average length of the branches was proportional to the increase in the number of fruiting branches. In addition, the plants with two fruiting branches showed a lower production of photoassimilates, which is an indicative that the higher the number of branches, the greater the competition for these compounds and other resources, such as water and nutrients (Espindula et al., 2021).

Table 1. Length and fresh weight of fruiting branches, mean number of fruits per branch, and average fresh weight of green figs (*Ficus carica*) of trees with different numbers of fruiting branches and planted at different spacing in the row[(1)].

Number of branches	Length of branches (cm)		Fresh weight of branches (g)		Number of fruits per branch		Average fresh weight of fruits (g)	
	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022
Two	199.81a	233.01a	636.13a	786.51a	63.75a	67.10a	12.21a	12.23a
Four	164.92b	210.13b	526.74b	629.81b	29.87b	29.52b	12.51a	12.41a
CV (%)	8.52	4.79	8.08	10.33	16.01	13.92	2.27	3.29
Spacing (m)								
0.50	168.07b	212.86b	538.31b	644.50b	38.92c	44.23b	12.42a	12.41a
0.75	181.13ab	221.62ab	584.46ab	706.50ab	46.57b	46.13b	12.34a	12.31a
1.00	202.77a	233.14a	636.80a	794.00a	54.59a	55.10a	12.36a	12.38a
CV (%)	10.98	6.47	11.29	13.29	6.87	10.02	2.31	2.99

[(1)]Means followed by equal letters, lowercase in the columns, do not differ by Tukey's test, at 5% probability.

Likewise, in both evaluation cycles, there was a proportional increase in the average length and, consequently, average fresh weight of the fruiting branches as the space between plants in the row increased. At a lower density, the average fruit yield per fruiting branch was also higher due to the greater growth of the branches, i.e., the longer the branch, the higher fig yield. Moreover, the plants with only two fruiting branches showed a higher average number of fruits per branch that was more than two-fold that of the plants with four fruiting branches. Although Dalastra et al. (2011) reported that the number of green figs per branch decreased linearly with the increase in the number of fruiting branches per plant, in the present study, there was no significant difference in production per plant due to the number of branches during the two evaluation cycles (Table 2).

Still regarding plant spacing, the highest production was recorded for plants with a greater distance between them (Table 2), i.e., at a lower planting density (Pasa et al., 2015). According to Souza et al. (2019), the lower the number of plants per hectare, the higher the number of fruits per plant. For perennial fruit trees, such as citrus [*Citrus sinensis* (L.) Osbeck], Azevedo et al. (2015) concluded that planting density reduced individual production but increased yield per area.

Regarding yield per hectare, there was no difference between plants with two or four fruiting branches (Table 2). However, higher values were obtained for plants at the highest planting density: 11.63 Mg ha^{-1} in the first evaluation cycle, representing an increase of 3.09 and 4.12 Mg ha^{-1} compared with the average for plants spaced at 0.75 and 1.0 m, respectively; and 13.57 Mg ha^{-1} in the second cycle, representing an increase of 73% compared with the average of the plants at the lowest density. In the literature, higher yields at higher densities were also reported for peach [*Prunus persica* (L.) Batsch] (Giacobbo et al., 2003), pear (*Pyrus communis* L.) (Policarpo et al., 2006; Robinson, 2011), and apple (*Malus* x *domestica* Borkh) (Pramanick et al., 2012) trees. When comparing the present study with that of Norberto et al. (2001), there was an increase in yield of 5.71 Mg ha^{-1} at the density of 8,000 plants per hectare.

According to Espindula et al. (2021), however, yield only increases up to a certain value with an increased planting density. In this context, Pramanick et al. (2012) added that maximizing the yield of the area should be the most relevant criteria for increasing orchard density, i.e., the number of plants per unit area, without compromising the physiological aspects of the produced species. Furthermore, Mayer et al. (2012) found that increasing planting density significantly increased yield, but did not reduce pear fruit size, as also observed in the present work. Souza et al. (2019) concluded that the increase in planting density in a 'BRS Rubimel' peach tree orchard increased yield without decreasing fruit quality.

The average fresh weight and dimensions (length and mean diameter) of the fruits did not differ during the two evaluation cycles regardless of the number of fruiting branches and different spacing (Tables 1 and 2).

Table 2. Production per plant, estimated yield, and length and mean diameter of green figs (*Ficus carica*) of trees with different numbers of fruiting branches and planted at different spacing in the row[(1)].

Number of branches	Production per plant (kg)		Estimated yield (Mg ha^{-1})		Fruit length (cm)		Fruit diameter (cm)	
	2021	2022	2021	2022	2021	2022	2021	2022
Two	1.59a	1.75a	8.91a	9.71a	3.96a	3.89a	2.88a	2.81a
Four	1.70a	1.95a	9.72a	11.40a	4.00a	3.97a	2.89a	2.93a
CV (%)	9.38	9.74	15.36	12.25	5.32	5.34	2.99	3.51
Spacing (m)								
0.50	1.45b	1.72b	11.63a	13.57a	3.93a	3.98a	2.89a	2.84a
0.75	1.60ab	1.86ab	8.54b	9.95b	4.06a	4.10a	2.81a	2.98a
1.00	1.87a	1.96a	7.51b	7.86c	4.12a	3.93a	2.92a	2.92a
CV (%)	13.24	10.03	15.10	11.91	5.26	5.93	3.06	3.84

[(1)]Means followed by equal letters, lowercase in the columns, do not differ by Tukey's test, at 5% probability.

Conclusions

1. The spacing of 0.50 cm between 'Roxo de Valinhos' fig (*Ficus carica*) trees in a row increases green figs yield.
2. The production of green figs does not differ between trees with two or four fruiting branches.

Acknowledgments

To Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), for financing, in part, this study (Finance Code 001); to Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and to Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG), for financial support; and to Universidade Federal de Lavras (UFLA), for the materials used to conduct the study.

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