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Pomology/ Original Article

Performance of fig tree cultivars in the production of unripe figs for processing in Brazil

Abstract – The objective this work was to evaluate the productive performance of fig tree cultivars in the production of green figs for industrialization in Brazil. The Brunswick, Mini Figo, Troyano, Roxo de Valinhos, Bêbara Branca, Lemon, Três Num Prato, and Pingo de Mel fig tree cultivars were evaluated. The experimental design was randomized complete blocks, with four blocks and eight treatments (fig tree cultivars) at a spacing of 3.0x1.5 m (2,222 plants per hectare). The experiment was conducted over two growing seasons (2022/2023 and 2023/2024). Plants were pruned during dormancy. After bud break, two secondary lateral shoots were maintained (12 productive shoots). Green figs 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 (kg) and estimated yield (Mg ha^{-1}) were calculated for each growing season, as well as fruit dimensions, shoot length and final mass, and harvest duration. The cultivars showed differences in their productive performance. Cultivar Troyano yielded the greatest quantity of fruits and provided a greater production and estimated yield.

Index terms: *Ficus carica*, cultivar diversity, harvest period.

Desempenho de cultivares de figueira na produção de figos verdes para processamento no Brasil

Resumo – O objetivo deste trabalho foi avaliar o desempenho produtivo de cultivares de figueira na produção de figos verdes para a industrialização no Brasil. As cultivares de figo Brunswick, Mini Figo, Troyano, Roxo de Valinhos, Bêbara Branca, Lemon, Três num Prato e Pingo de Mel foram avaliadas. O delineamento experimental foi em blocos ao acaso, com quatro blocos e oito tratamentos (cultivares de figueira), no espaçamento de 3,0x1,5 m (2.222 plantas por hectare). O experimento foi conduzido durante duas estações de crescimento (2022/2023 e 2023/2024). As plantas foram podadas no período de dormência. Após o início da brotação, foram conservadas duas brotações secundárias por haste lateral (12 hastes produtivas). Os figos 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. Foram calculadas a produção média por planta (kg) e a produtividade estimada (Mg ha^{-1}) para cada estação de crescimento, bem como as dimensões dos frutos, o comprimento e a massa final das hastes, e a duração da colheita. As cultivares apresentaram diferenças no seu desempenho produtivo. A cultivar Troyano foi a que produziu maior quantidade de frutos e propiciou maior produção e produtividade estimada.

Termos para indexação: *Ficus carica*, diversidade de cultivares, período de colheita.

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Introduction

The fig tree (*Ficus carica* L.) is commercialized in several countries, being produced mainly in the Mediterranean region. Turkey produces most figs worldwide, followed by Egypt, Algeria, Morocco, Iran, Syria, and the United States (Usai et al., 2020; Oliveira et al., 2024).

In the southern hemisphere, Brazil is one of the largest fig producers. In the country, fig cultivation covers an area of approximately 2,130 hectares, with a total production of 18,227 tons of figs and an average productivity of 8.55 tons per hectare of fresh fruit (IBGE, 2024). Overall, the fig tree is used to produce mature figs for the fresh fruit market or immature fruits (green figs) for the production of sweets such as crystallized figs and jams (Silva et al., 2019; Almeida et al., 2022).

In Brazil, the only commercially exploited cultivar is Roxo de Valinhos. Brought by Italian immigrants to the country through the region of Campinas in the state of São Paulo, this cultivar is known worldwide as Brown-Turkey, Corbo, Nero, Black-Wide, Portugal-Black, and Nigra, among other names (Ferraz et al., 2020). This cultivar is characterized by its high vigor and production of fresh figs, which are well accepted in the fresh fruit market, in addition to being suitable for the drastic pruning management adopted in Brazil (Almeida et al., 2022). However, 'Roxo de Valinhos' does not provide a high production of immature fruits destined for industrialization (Oliveira et al., 2024), hindering the expansion of the cultivation of green figs in the country.

The main Brazilian state where fresh figs are produced is São Paulo, where fig trees are irrigated and subjected to two annual prunings, producing over the entire year. Green figs are mainly produced in the states of Minas Gerais and Rio Grande do Sul, where the climate does not allow of the management of two prunings (Souza et al., 2021). Regarding the productivity of green figs, 3.8 tons per hectare were reported in the north of the state of Minas Gerais (Gonçalves et al., 2006) and 3.68 tons per hectare in Paraná (Dalastra et al., 2011). With the modification of the adopted management system, productivity increased to 4.80 and 5.07 tons of green figs per hectare in the south of Minas Gerais (Oliveira et al., 2024) and in Paraná (Campagnolo et al., 2010), respectively. Despite these increases, concerns about the sustainability of Brazilian fig production are growing, mainly because cultivation is based on the use of a single cultivar.

Although 'Roxo de Valinhos' is vigorous and resilient, some problems have been identified, such as its susceptibility to nematodes and low productivity, as previously reported (Ferraz et al., 2020). Other fig tree cultivars have different agronomic and pomological features, mostly due to genetic mutations in stem cuttings (Mirheidari et al., 2020), showing the importance of further research for their use. Studies on plant propagation (Bisi et al., 2016) and on the quality of the produced sweets (Curi et al., 2019a) have been carried out with different fig cultivars, obtained from the active germplasm bank of Instituto Nacional de Investigação Agrária e Veterinária (INIAC) from Portugal and Instituto Agronômico de Campinas (IAC) from Brazil. However, to estimate the genetic diversity of fig trees, it is essential to characterize and evaluate the materials in the germplasm, mainly as to the production and productivity of green figs, which will allow of observing the potential and variability of cultivars (Curi et al., 2019b; Almeida et al., 2022).

The objective of this work was to evaluate the productive performance of fig tree cultivars in the production of green figs for industrialization in Brazil.

Materials and Methods

The experiment was conducted in the municipality of Lavras, in the south of the state of Minas Gerais, Brazil (21°14'S, 45°00'W, at 918 m altitude). According to the Köppen-Geiger climate classification, the local climate is Cwb, tropical high altitude (mesothermic), with dry winters and rainy seasons between October and March, with more intense rain events occurring between December and February (Pio et al., 2023). Climatic data for the experimental period was collected at the climatological station of Universidade Federal de Lavras, located in the municipality of Lavras, in the state of Minas Gerais (Figure 1).

The fig tree cultivars evaluated in the present study were: Brunswick, Mini Figo, Troyano, Roxo de Valinhos, Bêbara Branca, Lemon, Três num Prato, and Pingo de Mel, obtained from the active germplasm banks of INIAV and IAC. The used seedlings were produced from segments of branches fragmented at the time of pruning and placed in plastic bags (Bisi et al., 2016).

The experimental area was established in November 2017, when the seedlings were five months old.

The soil at the study site was classified as a Cambissolo Háplico, according to the Brazilian soil classification system (Santos et al., 2018; Guimarães et al., 2021), corresponding to an Inceptisol (Soil Survey Staff, 2014). The soil analysis, in the 0–20 cm layer, revealed the following results: pH 5.6 (water), 46.3 g dm^{-3} soil organic matter content, 133.6 mg dm^{-3} phosphorus (Mehlich-1 extractor), 10.4 $mmol_c$ dm^{-3} calcium, 2.2 $mmol_c$ dm^{-3} magnesium, sum of bases of 13.0 $mmol_c$ dm^{-3}, and cation exchange capacity of 16.5 $mmol_c$ dm^{-3}. For the preparation of the experimental area, 2.6 Mg ha^{-1} dolomitic limestone were applied, whereas, for base fertilization, 10 L organic matter from compost and sources of phosphorus (300 g super simple phosphate per planting site) and potassium (150 g potassium chloride per planting site) were applied.

The fig trees were distributed in four blocks, spaced 3.0 m between rows and 1.5 m between plants, representing a population density of 2,222 plants per hectare. After planting, the seedlings were topped and reduced to a height of 40 cm above the ground. After 30 days, shoot thinning was performed, and only three shoots were maintained per plant, which were then allowed to grow freely. In June 2018, these three shoots were reduced to 15 cm, forming the three primary lateral branches. After 45 days, shoot thinning was performed again, and two shoots per primary lateral branch were maintained. These shoots grew freely until June 2019, when pruning was performed by shortening them to 15 cm, forming the secondary lateral branches. At this point, the plants in the experimental area had their canopy structure formed, i.e., with six secondary lateral branches each. The plants were kept in the experimental area for three years before the beginning of the experiment so that the secondary lateral branches could grow in diameter.

The experimental design was randomized complete blocks, with four blocks and eight treatments (fig tree cultivars). Five plants were used per experimental unit, totaling 160 plants, of which only the three central ones (useful plants) were evaluated, i.e., 96 plants. In the first growing season (2022/2023), in June 2022, two shoots per secondary lateral branch were maintained (12 productive shoots) 45 days after pruning. In the second growing season (2023/2024), in June 2023, the productive shoots were pruned, and, after 45 days, two shoots per secondary lateral branch were maintained.

During the experiment, spray containing 2% copper sulfate fungicide was applied every 15 days, and insecticides, when necessary, in addition to the

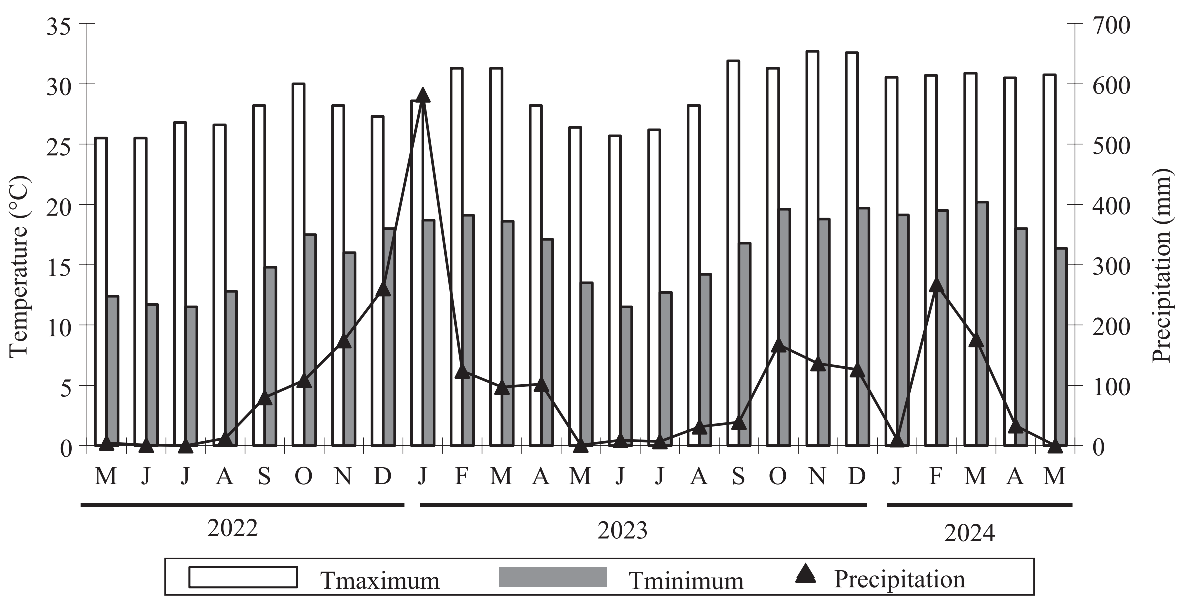

Figure 1. Average maximum and minimum temperatures and monthly accumulated precipitation between May 2022 and May 2024, collected at the climatological station of Universidade Federal de Lavras, located in the municipality of Lavras, in the state of Minas Gerais, Brazil.

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periodic removal of weeds. At the time of pruning, 10 L organic matter were distributed per plant. For plant maintenance, 300 g ammonium sulfate were applied in October and January, and 200 g simple superphosphate and 200 g potassium chloride were applied in September (Pio et al., 2023).

In both growing seasons, the start and end of harvest, as well as harvest time (in days), were registered. Between November and April of each growing season, biweekly harvests were conducted. For industrial fig production, green fruits were harvested at the harvesting point, when fruits had a red and swollen ostiole (Pio et al., 2023). The total number of fruits and total harvest mass per plant were quantified. The fruits were weighed using a digital scale, with a capacity of 20 kg. At the end of the cumulative harvests, the total number of fruits per plant, average fruit mass (g), average production per plant (kg per plant), and estimated yield (Mg ha^{-1}) were calculated for each growing season. For this, average production per plant was multiplied by the population density of the fig trees (2,222 plants per hectare) and divided by 1,000.

A sample of 20 fruits per plant was separated at harvest, in December of each growing season, in order to quantify fruit length and average diameter (cm) using a digital caliper.

At the beginning of June, at the time of pruning in each growing season, the average length of the productive shoots (cm) was measured. For this, with the aid of a graduated tape, the length from the apex to the insertion point of all productive shoots per plant was measured, and, subsequently, the average length of the productive shoots of each plot was calculated. The fresh mass of the productive shoots (g) was quantified using a digital scale, with a capacity of 20 kg.

The data were subjected the analysis of variance and the Scott-Knott comparison of means, at 5% probability of error. The analyses were performed using the SISVAR analysis of variance software, version 5.6 (Ferreira, 2019).

Results and Discussion

The beginning of the harvests was similar in both growing seasons, starting at the end of November (end of spring) in the first growing season and at the beginning of December in the second one (Table 1). However, there were significant differences in the harvest periods between cultivars. In the first growing season, the harvesting of all cultivars, except of Troyano, was completed in February. In the second growing season, the harvesting of the Brunswick and Pingo da Mel cultivars was completed in February, resulting in a harvest period shorter than that of Lemon and Troyano, whose harvests continued until April.

The difference observed in the number of harvest days may be related to the environmental conditions of each growing season. In the second growing season, for example, temperature was higher at the beginning of summer, especially between December and January 2024, and accumulated precipitation was lower during this period, but greater between the end of summer and the beginning of autumn (Figure 1). Ferraz et al. (2020) concluded that the duration of the growing season varies according to genotype and

Table 1. Start of harvest, end of harvest, and number of harvest days for different fig (*Ficus carica*) tree cultivars cultivated in two growing seasons (2022/2023 and 2023/2024) for the production of green figs for industrialization(1).

Cultivar	First growing season – 2022/2023			Second growing season – 2023/2024		
	Start of harvest	End of harvest	Number of harvest days	Start of harvest	End of harvest	Number of harvest days
Brunswick	21/11/2022	23/02/2023	94b	06/12/2023	05/02/2024	61c
Lemon	21/11/2022	23/02/2023	94b	06/12/2023	14/04/2024	130a
Bêbara Branca	12/12/2022	23/02/2023	73d	06/12/2023	14/03/2024	99b
Roxo de Valinhos	12/12/2022	23/02/2023	103a	06/12/2023	14/03/2024	99b
Troyano	01/12/2022	20/03/2023	109a	06/12/2023	14/04/2024	130a
Pingo de Mel	21/12/2022	23/02/2023	64e	20/12/2023	05/02/2024	47d
Três Num Prato	12/12/2022	03/02/2023	83c	06/12/2023	14/03/2024	99b
Mini Figo	01/12/2022	23/02/2023	84c	06/12/2023	14/04/2024	99b
CV (%)			3.58			3.06

(1)Means followed by equal letters, in the columns, do not differ by the Scott-Knott test, at 5% probability. CV, coefficient of variation.

environmental conditions, such as solar radiation, accumulated degree days, and air temperature.

Another reason for the difference in harvest duration could be related to the performance of the evaluated cultivars. Compared with Roxo de Valinhos, cultivar Troyano had a longer harvest period, allowing for harvest optimization (Monteiro et al., 2022). The beginning of harvest of the Troyano cultivar also allows of scheduling the time of harvest (Ferraz et al., 2020).

Ferraz et al. (2020) attributed the longer harvest period observed for the Troyano cultivar to its more intense vegetative development. In the present study, this is supported by the quantification of productive shoots at the end of the growing seasons. The final length and fresh mass of the shoots, in 2023/2024, obtained for Brunswick and Troyano were simultaneously greater than those of the other cultivars in both growing seasons (Table 2). The Pingo de Mel and Roxo de Valinho cultivars presented relatively short shoots, whereas Mini Figo and Lemon had shoots with shorter lengths and, consequently, a lower fresh mass compared with that of Roxo de Valinhos. In the literature, Ferraz et al. (2020) also found that cultivar Troyano had relatively long shoots. Monteiro et al. (2022) added that this cultivar had the highest starch content in the shoots compared with other cultivars, explaining its greater vegetative vigor and larger shoot diameter (Ferraz et al., 2020). Therefore, the Troyano cultivar has great potential to be introduced to green fig production in Brazil, as it is a viable alternative for incorporating diversity into fig orchards (Ferraz et al., 2020).

According to Souza et al. (2021), the length of the productive shoot is of great importance in the case of the fig tree because it is directly related to the number of leaves and, consequently, to the number of fruits per plant, as fruits are emitted in the axil of each peduncle. Therefore, the longer the shoot is, the higher the number of fruits. However, this was not observed in the present study, since the Troyano cultivar produced the greatest quantity of fruits in both growing seasons, but Brunswick did not, despite both cultivars having the longest shoots (Table 2).

The Troyano cultivar showed the highest number of fruits per plant, even in comparison with that of Roxo de Valinhos, which is in alignment with the results reported by Ferraz et al. (2020). In 2023/2024, cultivar Troyano produced four times more figs than Roxo de Valinhos, a cultivar that produced fruits with a higher mass in both growing seasons, together with Troyano and Três Num Prato (Table 2); the Mini Figo cultivar produced fruits with a lower mass.

Despite its shorter shoot lengths and, consequently, lower fresh shoot mass, the Mini Figo cultivar produced the second highest quantity of fruits, only below that of Troyano in the two growing seasons. In addition, the Bêbara Branca cultivar had a good shoot length and fresh mass in both growing seasons, even though it produced the lowest number of fruits. Therefore, the final shoot length may not be related with the quantity of fruits produced. Pio et al. (2019) found that the productive capacity of fig trees is dependent on their ability to adapt to subtropical regions.

The green fig production and estimated productivity of the Troyano cultivar reached values of 6.85 and 13.31 Mg ha^{-1} (Table 3), respectively, which were much higher than those of 3.01 and 3.20 Mg ha^{-1} of the

Table 2. Stem length, fresh stem mass, and fruit number and fresh mass of different fig (*Ficus carica*) tree cultivars cultivated in two growing seasons (2022/2023 and 2023/2024) for the production of green figs for industrialization[(1)].

Cultivar	Stem length (cm)		Fresh stem mass (g)		Number of fruits		Fresh fruit mass (g)	
	2022	2023	2022	2023	2022	2023	2022	2023
Bêbara Branca	161.48c	152.04c	634.0c	462.0b	92.42d	98.95f	8.11c	8.08b
Três Num Prato	161.12c	161.31b	451.0f	367.0c	107.05d	144.88d	9.63b	10.65a
Pingo de Mel	193.70b	183.96a	582.0d	447.0b	112.23d	168.94c	4.98e	4.94b
Roxo de Valinhos	178.50b	163.25b	515.0e	421.0b	133.83c	126.35e	10.16a	11.41a
Lemon	134.62d	128.45d	258.0h	222.0d	135.75c	272.75b	5.48d	5.50b
Brunswick	216.84a	195.90a	855.0a	562.0a	136.67c	119.92e	5.06e	5.50b
Mini Figo	117.32e	122.45d	321.0g	250.0d	221.78b	251.77b	3.73f	3.68c
Troyano	183.62b	180.43a	806.0b	568.0a	326.55a	589.75a	9.45b	10.15a
CV (%)	9.74	9.83	7.70	8.53	9.57	8.98	5.64	5.61

[(1)]Means followed by equal letters, in the columns, do not differ by the Scott-Knott test, at 5% probability. CV, coefficient of variation.

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Table 3. Production per plant, estimated productivity, and average fruit length and diameter of different fig (*Ficus carica*) tree cultivars cultivated in two growing seasons (2022/2023 and 2023/2024) for the production of green figs for industrialization(1).

Cultivar	Production per plant (kg)		Estimated productivity (Mg ha^{-1})		Fruit length (cm)		Fruit diameter (cm)	
	2022	2023	2022	2023	2022	2023	2022	2023
Bêbara Branca	0.74d	0.79c	1.66d	1.77c	4.5b	4.0a	2.7b	2.3b
Três Num Prato	1.03c	1.54b	2.29c	3.43b	4.8a	4.0a	3.2a	2.9a
Pingo de Mel	0.55d	0.83c	1.24d	1.85c	3.1f	2.7c	2.4d	2.1c
Roxo de Valinhos	1.35b	1.44b	3.01b	3.20b	4.6b	3.6b	3.2a	2.7a
Lemon	0.74d	1.50b	1.65d	3.33b	3.9d	2.6c	2.8b	2.3b
Brunswick	0.69d	0.66c	1.53d	1.46c	3.7e	2.7c	2.6c	2.1c
Mini Figo	0.83d	0.92c	1.84d	2.06c	2.7g	2.5c	2.4d	2.0c
Troyano	3.08a	5.99a	6.85a	13.31a	4.2c	3.4b	3.3a	2.8a
CV (%)	10.19	14.39	10.19	14.39	5.89	6.86	4.84	5.34

(1)Means followed by equal letters, in the columns, do not differ by the Scott-Knott test, at 5% probability. CV, coefficient of variation.

Roxo de Valinhos cultivar. Similarly, for the Roxo de Valinhos cultivar, Gonçalves et al. (2006) and Dalastra et al. (2011) obtained values of 3.80 and 3.68 Mg ha^{-1} green figs in the northern region of the state of Minas Gerais and in the western region of the state of Paraná, respectively.

Regarding fruit dimensions, the largest length and diameter were found for the Três Num Prato cultivar, although the diameters of the figs of Roxo de Valinhos and Troyano were also large in both growing seasons. These results agree with those of Ferraz et al. (2020), who found that 'Roxo de Valinhos' trees produce fruits with greater dimensions than those of 'Troyano' trees.

Based on the obtained results, the Troyano cultivar may be an excellent option for diversifying the economic exploitation of figs in Brazil.

Conclusion

The Troyano fig (*Ficus carica*) cultivar produces a greater quantity of fruits and shows a higher production and estimated productivity than the other evaluated cultivars, indicating that it could be an option for the production of green figs in Brazil.

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