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Fig production under an intensive pruning system in the moist central area of Argentina

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ABSTRACT

The aim of this work was to evaluate fruit yield and harvest distribution, and to identify the main factors that affect the fruit yield of two parthenocarpic fig varieties trained under an intensive pruning system in the temperate-humid central area of Santa Fe, Argentina. Fig trees of the cultivars 'Guarinta' and 'Brown Turkey' were planted 4 × 2 m apart and trained in small open vases. Fruit yield per plant, number of nodes and fruits per shoots, shoot length, and number of unripened fruits per shoot were registered during 10 years after planting (2006–2016). Relationships between meteorological data and plant parameters were determined. Fruit yield varied between 4.43 and 12.1 t ha^{-1} according to the year and variety. Commercial fruit yield tended to diminish four years after planting. Annual duration of the harvesting period ranged from 8 to 21 weeks and showed a positive relationship with the annual fruit yield. The harvesting period was negatively affected by both tree age and weather variables, such as the number of rainy days and the accumulated precipitation from January to May. The last three years of experimentation were the rainiest, so it was not possible to clearly establish if the declination of fruit yield and the duration of the harvesting period with tree age were a consequence of climatic conditions, tree age, or both factors. The end of the harvest period was not due to the absence of fruits but to the lack of ripeness in all years.

1. Introduction

The fig (*Ficus carica* L.) is a small-sized tree native of Western Asia distributed and cultivated throughout the Mediterranean region. Turkey, Egypt, Iran, Greece, Algeria, Morocco, Syria and Spain are the main producing countries (El Rayes, 1995; Flaishman et al., 2008). In the Americas its cultivation is widespread, mainly in the United States, Brazil, Peru, Bolivia, and Argentina (Dalastra, 2008; Morton, 2013).

The fig tree requires a warm climate with hot summers and mild winters (El Rayes, 1995; Gaaliche et al., 2011), although it can grow adequately under less favorable conditions (Nienow et al., 2002; Leonel and Tecchio, 2010; Limeira Da Silva et al., 2016). The tree has low chilling requirements and tolerates light frost. Even the most tolerant varieties can support temperatures as low as −15 to −20 °C (Andersen and Crocker, 2010). In general, it adapts well to different soils except for those with poor drainage, being one of the few fruit trees with greater salinity tolerance (Flaishman et al., 2008).

In Argentina, fig cultivation was increased by 391%, from 155 ha in 1988 to 606 ha in 2002 (INDEC, 2002), although FAOSTAT (2018) does not register significant changes in the cultivated area and fruit production during the same period. Crop technology has been modified over the last years by increasing the tree density and incorporating an intensive pruning system and localized drip irrigation. These technological changes have resulted in higher fruit yields and quality (Prataviera and Godoy Aliverti, 1991), which was reflected in the export of small volumes of fresh fruits to European markets (Miranda and Battistella, 2002). Despite increases of fig cultivation in Argentina, the production is not enough to supply the domestic market, and consequently 500 tons of dried figs must be annually imported from Turkey and Chile (Prataviera, 2003).

The traditional training system used for fig trees is an open vase with three main branches, which allows for a medium-size tree (Gaaliche et al., 2011). Instead, new plantations in Argentina have high tree density (> 1000 plants per hectare) and are intensely pruned so the canopy is annually renewed (Prataviera, 2003). This pruning system keeps the trees small, and consequently horticultural practices can be completed without ladders. Fruit yields obtained using this intensive pruning system were over 15,000 kg ha^{-1}. The best-performing

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cultivars were 'Brown Turkey', 'Guarinta', 'Brogiotto Bianco', 'Servantine' and 'Kadota' (Prataviera, 2003).

'Brown Turkey' produces large pear-shaped fruit that can reach 80–90 g, with white or light pink pulp and external copper-coloration at maturity. 'Guarinta' originated from a mutation of 'Málaga', and is also characterized by large, pear-shaped fruit, yellowish-green external coloration and reddish pulp (Prataviera and Godoy Aliverti, 1991).

During the last 10 years, small fig plots for experimental and demonstrative purposes were planted at different sites at the central area of Santa Fe province (Gariglio et al., 2014), allowing the adoption and spread of fig as a complementary commercial activity for traditional horticultural crops (Travadelo et al., 2017). The central area of Santa Fe has a temperate humid climate with no dry season (Köppen, 1931). However, fig trees grow wild in dry and sunny areas (Morton, 2013). The recent introduction of fig in the central humid area of Santa Fe merits further investigation in order to improve the knowledge of the crop production under an intensive pruning system optimizing fruit yield and harvest distribution. The aim of this work was to evaluate fruit yield, harvest distribution, and to identify the main factors that affect fruit yield of two parthenocarpic fig varieties trained under an intensive pruning system in the temperate-humid central area of Santa Fe, Argentina.

2. Materials and methods

The trial was carried out in a commercial orchard at the horticultural area known as 'Cinturón Hortícola Santafesino' located around Santa Fe city, in the central-east area of the province of Santa Fe, Argentina (31°26′ S; 60°56′ W; 40 m above sea level). The climate was classified as Cfa: temperate humid mesothermal, according to Köppen (1948). The main meteorological parameters of the area were recorded by an automatic meteorological station (LI-1400, LI-COR® Biosciences, USA) during the trial and are summarized in Table 1.

Fig trees of the cultivars 'Guarinta' and 'Brown Turkey' were planted at 4 × 2 m spacing (1250 trees ha^{-1}) during August 2005 in a well-drained sand-loamy soil, using complementary drip irrigation. Trees were trained to a small open vase with an intensive pruning system, consisting in the winter thinning of the current-year shoots or its heading back to one node. After pruning, the tree scarcely reached 0.8 m in height. Only three shoots per plant were left during the year of planting, which were duplicated each year until its stabilization at 24–30 shoots per plant from the fourth year. An educational video briefly explains the process of pruning (Gariglio, 2017). Fruit yield per plant was registered weekly during 10 years after planting. Relationships between meteorological data and plant parameters were determined, and the best regression model was selected using the following criteria: minimizing the conditional model estimator (CME), the Akaike information criterion (AIC), and the Bayesian information criterion (BIC).

During two growing seasons (2010/2011 and 2011/2012), four representative current shoots around each tree were labeled. In addition, 200 current shoots of different vigor for each variety were also randomly identified between the plants of the trials. Shoot lengths and the number of nodes per shoots were measured at the end of each of the two growing seasons, whereas the nodes with fruit and the number of fruits per shoots were counted weekly from the time they became visible. The percentage of nodes with fruits was determined as the ratio of the fruit number to the total number of nodes of each current shoot. Furthermore, the existence of a correlation within shoot length and fruit per shoot was observed.

The proportion of unripe fruits per current shoot was measured on 10 current shoots per plant at the end of the growing season in 6-year-old and 10-year-old plants during the last year of experimentation.

A completely randomized experimental design with one-tree plots and 10 replications per cultivar was used. Analysis of variance was performed on the data, and means were compared using the least significant difference (LSD Fisher) test with 5% significance. Statistical analysis was performed using InfoStat software (Di Rienzo et al., 2012) developed at the Universidad Nacional de Córdoba, Argentina.

3. Results and discussion

Commercial fruit yields of fig trees were affected by variety ($p = 0.0164$) and tree age ($p < 0.0001$), with an interaction between both variables ($p = 0.0087$). The average fruit yield (kg $plant^{-1}$) of the 10-year study was higher for the cv. 'Brown Turkey' (+15%) compared with 'Guarinta'. Fig behaved as a precocious tree that produced marketable fruit during the first growing season after planting (Fig. 1), as was previously mentioned (Ateyyeh and Sadder, 2006; Crane and Brown, 1950; El Rayes, 1995; Flaishman et al., 2008; Gaaliche et al., 2011; Limeira Da Silva et al., 2016). Tree yield increased annually during the first four years of plantation, during which time both varieties achieved their highest fruit production (12.1 and 10.5 kg pl^{-1} for 'Brown Turkey' and 'Guarinta' respectively) (Fig. 1). After four years, fruit yield declined 26% on average for three consecutive years, and subsequently it stabilized around 5 kg $plant^{-1}$ in the seventh year after planting (Fig. 1). The declination of fruit production after the fourth year of growth showed a polynomial relationship ($y = 0.3345x^2 - 5.6957x + 28.869$; $r^2 = 0.884$).

The interaction between the variables tree age and variety on fruit yield was explained because during the growing seasons 2013/2014 and 2014/2015, fruit yield of 'Guarinta' was higher than 'Brown Turkey,' in contrast with the others years (Fig. 1).

The annual fruit yield reached in our trial was in accordance with that observed in different areas of Brazil under an intensive pruning system using the cv. 'Roxo de Valinhos' (Leonel and Tecchio, 2010; Nienow et al., 2002). However, there are many factors that can modify the fruit yield and quality of fig trees, such as the agro-ecological

Table 1
Monthly medium values (M) and coefficient of variation (CV) of the main meteorological parameters recorded at the central area of Santa Fe province during 2007–2016.

ParameterMonths		J	F	M	A	M	J	J	A	S	O	N	D
Radiation (Mj m^{-2})	M	776	589	593	370	265	210	257	350	432	578	691	737
	CV (%)	7	6	28	20	13	14	22	11	7	9	12	7
T MAX (°C)	M	32.9	30.6	28.6	26.1	21.8	18.1	18.2	19.7	23.1	26.1	30.1	31.7
	CV (%)	4	3	4	6	7	7	10	15	7	6	4	6
T MED (°C)	M	26.7	24.5	22.5	19.6	15.9	11.7	11.5	12.9	16.4	19.8	23.9	25.6
	CV (%)	4	5	4	5	10	9	19	18	8	4	6	5
T MIN (°C)	M	20.2	18.9	16.6	13.7	10.9	6.1	5.6	6.8	10.2	13.9	17.2	19.2
	CV (%)	6	7	5	9	13	24	47	31	12	10	9	6
Precipitation (mm)	M	130	182	174	89	42	15	16	38	100	142	173	173
	CV (%)	72	41	54	64	43	103	169	111	115	84	89	95

T MAX: Maximum temperature; T MED: Medium temperature; T MIN: Minimum temperature.