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# External Fruit Quality and Harvest Time of Low-Chill Peach and Nectarine Varieties at Santa Fe, Argentina

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**ABSTRACT**

**Background:** We studied low chilling peach varieties recently introduced at the central area of Santa Fe, Argentina, to increase the range of options available to growers of warm-temperate areas**. Objective:** The aim of this study was to evaluate the external fruit quality and the harvest time of different low-chill peach and nectarine varieties in central Argentina. **Results:** The harvest period began on the last week of October and extended continuously until the end of December. Although the different varieties ripened in an adequate sequence throughout the season, the second week of November was a critical period in which six varieties reached maturity simultaneously. On the other hand, only a limited number of varieties ripened during the second and fourth weeks of December. Fruit size of peach but not of nectarine showed a positive and significant relationship with the length of the fruit development period. Three peach varieties ('Flordastar', 'Rojo dos' and 'San Pedro 1633') and four nectarines ('Sunwright', 'Nectarine 24', 'Carolina', and 'Brasil') produced small fruits (<100 g), which can affect their marketing. Red over-color on the skin was deficient, since only seven varieties developed 50% of red cover**. Conclusion:** The new varieties tested are suitable for extending the harvest period at the central area of Santa Fe, and will increase the range of options available to growers. However, before recommending its use, internal quality and fruit yield of these varieties should be evaluated for more years.



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## INTRODUCTION

Peach is grown on nearly 30.000 hectares in Argentina, mainly in the provinces of Mendoza and Buenos Aires (INDEC, 2002). Peach varieties are characterized by their medium and high chilling requirement (Valentini *et al*., 2001). Recently, the introduction of low-chill varieties has allowed the crop to spread into warmer areas such as the provinces of Salta and Jujuy (Toncovich, 2009), and to a lesser extent to Misiones (Piekún *et al*., 2001), Corrientes (Ayalón Luaces *et al*., 2004), and Santa Fe (Gariglio *et al*., 2009) provinces.

Fruit tree crops have been introduced into the central-east area of the Santa Fe over the last 10 years and today there are small operations (0.5-4 ha) that have been able to obtain high economic returns in the regional market. The mean chilling accumulation in this area was reported to be around 300 chilling hours (CH) in a ten-year period (Gariglio *et al*., 2006), with great variability between years. As a consequence, only peach varieties with low-chilling requirements (<450 CH) showed adequate vegetative and reproductive traits (Gariglio *et al*., 2009).

Low-chill varieties are bred for production in areas without optimal agroecological conditions for the species; consequently, they normally bear fruits with lower quality attributes than the traditional varieties developed for colder areas (Topp *et al*., 2008).

About 10 low-chill peach varieties have been recommended for commercial production in the central area of Santa Fe (Gariglio *et al*., 2009). However, continued research is needed to evaluate the new improved varieties that are constantly released into the market, to study genotype-environment interactions, and to increase knowledge about low-chill peach varieties, which are not widely known in Argentina (Alayón Luaces *et al*., 2004). In adition, since each variety has its own specific harvest time and these fruits have a short shelf life (Gorny *et al*., 1999), availability of a large number of varieties that ripen in succession is critical to lengthen the harvest period, thus allowing growers to extend the presence of their produce in the regional market.

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The aim of this study was to evaluate the external fruit quality and the harvest time of new low-chill peach and nectarine varieties to increase the range of options growers can choose from to fit their production needs in the central area of Santa Fe and other low chilling regions.

## MATERIALS AND METHODS

This work was carried out in the experimental field of the Facultad de Ciencias Agrarias of the Universidad Nacional del Litoral, located in Esperanza (31°26' S; 60°56' W; 40 m above sea level), in the province of Santa Fe, Argentina.

Twenty six low-chill peach and nectarine (*Prunus persica* (L.) Batsch) varieties from Brazil and the United States were tested. All cultivars were grafted onto 'Cuaresmillo' seedling rootstocks. Trees of 11 varieties were 10 years old at the beginning of the trial, while the remaining 15 were 3 years old (Table 1). The trees were planted 5 × 3 m apart on an Abruptic Argiudoll soil, provided with supplementary drip irrigation, and trained to the standard open vase system. Fertilization, pest management and pruning were made following normal commercial practices.

Trees were chosen by their uniformity in size and vigour. The phenological phases of full flowering, and period of fruit growth from full flowering to harvest were measured for each variety.

Harvesting time was determined by the change in the skin background color from green to yellow or white. The samples consisted of ten fruits picked at random from each plant of each variety. Individual measurements were made on every fruit of the samples to determine average weight using an Ohaus balance, model Scout II, and average equatorial fruit diameter using a digital caliper (0-150 mm). Percentage of red over-color of the skin was estimated visually. In addition, on four-fruit subsamples we measured the epicarp color parameters L *, a *, b *, C * h * (CIELAB scale) on both the sun-exposed and shaded sides of the fruit, using a Minolta CR-400 colorimeter.

The experiment was conducted over two consecutive years (2010-2011), using a randomized complete block design with single-tree plots and eight replications per cultivar. Analysis of regression and variance were performed on the data, and means were compared by Duncan's test ($p \leq 0.01$).

## RESULTS AND DISCUSSION

Low-chill peach varieties grown in the central east area of Santa Fe began flowering at the end of June, and reached full bloom between mid-July and the first week of August. 'Flordaking' and 'Marfin' were the later flowering varieties, showing full bloom at the middle and at the last week of August, respectively.

The length of fruit development period (FDP), from full bloom to harvest, ranged from 15 to 18 weeks for most varieties, with extreme values of 14 weeks for 'Nectarina 24', and 24 weeks for 'Maciel'.

The harvest period started on the last week of October and extended continuously until the end of December (Table 2). In a previous study, the average date of beginning of harvesting was reported to be October 20$^{th}$ (Gariglio *et al*., 2009), that is, one week earlier than in this experiment. Although harvesting showed succession in time, the second week of November was a critical period in which six varieties reached maturity at the same time. Also, the harvest period started simultaneously during the first week of November for four varieties, and during the last week of November for other four varieties. On the other hand, a limited number of varieties reached maturity during December, especially during the second and fourth weeks, in which only one variety was harvested on each week (Table 2).

A direct and significant relationship ($p = 0.0174$) was observed between FDP length and fruit weight (Fig. 1A) and diameter (Fig. 1B) at harvest for peach varieties, although the correlation coefficients were not high ($r^2 = 0.32$ and 0.28 for weight and diameter, respectively). In some varieties such as 'Flordastar', 'Marfin', 'Rojo dos', 'Aurora 1' and 'San Pedro 1633', fruit size was lower than that expected according to their FDP length. In contrast, fruit of other varieties such as 'Opodepe', 'Earlygrande', 'Hermosillo', 'Fla 91-8C' and 'Jubileo', were bigger than expected for their FDP.

The relationships between FDP length and fruit size at harvest reported for apple and peach (George, 1999) can account for the difficulty to obtain an adequate fruit size at harvest in early low-chill peaches and nectarines (Ferguson *et al*., 2008). However, the increased availability of new low-chill varieties with different harvesting times and better fruit size developed by breeding programs in different countries might explain the lack of relationship between the chilling requirement of a variety and its FDP in this experiment ($P = 0.687$: $r^2 = 0.0028$), or in previous ones (Ferguson *et al*., 2008). FDP length in this experiment ranged from 90 to 130 days, except for 'Maciel', in which the FDP reached 158 days. These values are longer in comparison with those observed in Florida, where varieties with a FDP of only 60 days were evaluated (Ferguson *et al*., 2008).

In contrast with peaches, no relationship was observed in nectarines between FDP length and fruit size at harvest. This fact, and the medium correlation coefficient between both variables in peach (Fig. 1) can be explained by the existence of other factors involved in the definition of fruit size, especially the genetic characteristics of each variety (Wang *et al*., 2006), the influence of environmental and endogenous stimuli (Grossman and DeJong, 1995), and the effects of different cultural practices.

Regarding the genetic characteristics of a variety, the number of cells per fruit has been reported to be the variable that best explains differences in fruit size between different varieties (Scorza *et al*., 1991). Another genetic characteristic is the chilling requirement for breaking dormancy for each variety, but no relationship was found between this variable and fruit size under the agroecological conditions of this study (P = 0.845; $r^2$ = 0.0082). Temperature is the most important environmental stimulus, since it regulates the respiration process as well as the metabolic and enzymatic activities (DeJong and Moing, 2008). A linear increase in fruit growth rate between 5 and 35 °C has been reported for peaches (Grossman and DeJong, 1994). However, as air temperature increases, availability of carbohydrates decreases (DeJong *et al*., 1996) and FDP becomes shorter (Topp and Sherman, 1989), both factors negatively affecting fruit size (Topp and Sherman, 1989; Topp *et al*., 2008).

Fruit size is also affected by plant age and size, and by the intensity of fruit thinning performed after fruit set (Ferguson *et al*., 2008; Njoroge and Reighard, 2008; Martin-Gorriz *et al*., 2011). The different ages of the peach trees used in this trial should be considered in the interpretation of the results.

Early peaches have a low fruit weight, normally between 50 and 110 g. For approppriate marketing in the European Community, peach fruit weight should be greater than 150 g; however, this threshold value is lowered to near 100 g for precocious low-chill peach varieties (Badenes *et al*., 1998). In our trials only three peach varieties (‘Flordastar’, ‘Rojo dos’ and ‘San Pedro 1633’) and four varieties of nectarines (‘Sunwright’, ‘Nectarine 24’, ‘Carolina’, and ‘Brasil’) did not reach this threshold value (Fig. 2A). 'Flordastar' peach has consistently produced small fruit in the central area of Santa Fe (Gariglio *et al*., 2009), contrasting with results reported in Valencia, Spain (Badenes *et al*., 1998). In addition, we consider that the small size of ‘Rojo dos’ and ‘San Pedro 1633’ peach fruits can be attributed to other factors such as plant age (Ferguson *et al*., 2008), and that their size can be increased significantly by proper cultural practices such as early and intense fruit thinning, and adequate irrigation management during the final stage of fruit growth (Ferguson *et al*., 2008). Most of the nectarine varieties evaluated produced small fruit, close to the lower limit for their marketing (Fig. 2A).

The minimum fruit diameter required for European markets is 56 mm (European Regulation 1861/2004), while in Argentina it is lower –45 mm for the domestic market and 50 mm for export (SAG Regulation Nº 554/83). All varieties reached the minimum marketing size required by Argentinean regulations, but nectarine ‘Carolina’ did not achieve the minimum diameter set by the European regulation. The varieties ‘Aurora’, ‘Rojo dos’, ‘Sunwright’, ‘Flordastar’ and ‘San Pedro 1633’ reached the minimum fruit size, although very close to the lower European threshold (Fig. 2B). The best commercial sizes were obtained with the ‘Hermosillo’, ‘Maciel’, ‘Earlygrande’ and ‘Opodepe’ varieties, which reached calliper-4 diameter (65-70 mm), whereas most varieties (8) attained calliper-3 diameter (60-65 mm) according to the Argentinean regulations.

Although there are no regulations concerning red over-color of the skin, fruits with more than 40-50% of reddish coloration are the most valued by consumers (Ferrer *et al*., 2005; Sartori *et al*., 2009). Five of the nectarines tested (70%) but only three peach varieties (‘Earlygrande’, ‘Hermosillo’, and ‘Rojo dos’) presented red over-color on more than 50% of the fruit surface (Table 3), whereas other eight varieties reached values between 30 and 50%. Unlike other maturity parameters of climacteric fruits such as flesh firmness, soluble solids content, acidity, and volatile compounds contents (Ferrer *et al*., 2005; Ramina *et al*., 2008), red color does not change after harvest. Thus, it is of great importance to implement cultural practices, such as summer pruning or reflective mulch (Layne *et al*., 2001; Andreotti *et al*., 2009), which increase pre-harvest fruit exposure to sunlight and enhance skin red color (Kataoka and Beppur, 2004).

L is the Hunter parameter that indicates the lightness of the color, with a range of variation from 0 for black and 100 for white. Red color is a highly valued quality attribute; however, the visual characteristic of fruits most appreciated by consumers is red color with high brightness (high L value) (Jia *et al*., 2005).

The average L parameter in our experiment showed a medium value which was significantly higher (p=0.0001) in the shaded side of the fruit (63.21) than in the sun-exposed side (50.30), although the opposite was found in some varieties (Table 3). Decreasing light intensity by bagging the fruit reduces chlorophyl and anthocyanins content and increases the L value of the fruit skin (Jia *et al*., 2005); thus, the complex effect of light on clorophyll degradation and anthocyanins synthesis can explain the variations in L value for both sides of the fruit found among the varieties. ‘Earlygrande’ showed the highest L value (80.27) while ‘Sunwright’ showed the lowest one (30.25). Seven varieties reached L values over 60%, five of them characterized by a reddish skin coloration (‘Flordaking’, ‘Tropic Snow’, ‘Don Agustín’, ‘Flordaprince’, ‘Flordastar’, and ‘Fla 91-8c’), and two of them by yellowish skin coloration (‘Jubileo’ and ‘Maciel’).

The low L value of ‘Sunwright’ can be explained by its low hue angle (h*), which represents in an angular value (h= arctg b/a), the preponderance of red (a) over yellow (b) color and vice versa. As a general rule, a lower value of h* is preferable because it indicates a preponderance of red (Ferrer *et al*., 2005; Sartori *et al*., 2009). The sun-exposed side of fruits showed lower h* values than the shaded side (57.42 and 83.91, respectively) because greater exposure to sunlight increases anthocyanins content (Kataoka and Beppur, 2004; Jia *et al*., 2005).

**Table 1:** Low-chill peach and nectarine (n) varieties tested in the central-east area of Santa Fe, Argentina

| Variety | | CH[a] | Flesh type[b] | Flesh color[c] |
|---|---|---|---|---|
| 1 | Carolina (n) | 325 | M | G |
| 2 | Don Agustin (Fla. 81-12) | 300 | M | G |
| 3 | Earlygrande | 260 | M | G |
| 4 | Fla. 91-8c | 100 | M | G |
| 5 | Floradaking | 450 | M | G |
| 6 | Folordaprince | 150 | M | G |
| 7 | Flordastar | 250 | M | G |
| 8 | Hermosillo | 350 | M | G |
| 9 | Lara (n) | 350 | M | G |
| 12 | Nect 24 (n) | - | M | G |
| 10 | SunWright (n) | 150 | M | G |
| 11 | Tropic Snow | 250 | M | W |
| 13 | Aurora 1 | 50 | NM | G |
| 14 | Brasil (n) | - | M | W |
| 15 | Chimarrita | 350 | M | W |
| 16 | Fla. 1-8bis | - | M | G |
| 17 | Flordagem | 250 | M | G |
| 18 | Jubileo | 300 | NM | G |
| 19 | Maciel | 300 | NM | G |
| 20 | Marfim | 350 | M | W |
| 21 | Nect 22 (n) | - | M | G |
| 23 | Nect 29 (n) | - | M | G |
| 24 | Opedepe | 150 | M | G |
| 25 | Rojo dos | 400 | M | G |
| 26 | San Pedro 1633 | 297 | M | G |

[a]CH = Chilling requirement of the variety; [b]Flesh type: M = melting; NM = non melting; [c]Flesh color: G = golden; B = white.

**Table 2:** Time of beginning of harvest (week) for different low-chill peach and nectarine (n) varieties tested in the central-east area of Santa Fe, Argentina.

| **Variety** | IV Oct | I Nov | II Nov | III Nov | IV Nov | I Dec | II Dec | III Dec |
|---|---|---|---|---|---|---|---|---|
| Fla 91-8C | ■ | | | | | | | |
| Flordastar | ■ | | | | | | | |
| Nect 24 (n) | ■ | | | | | | | |
| Earlygrande | | ■ | | | | | | |
| Flordaprince | | ■ | | | | | | |
| Flordaking | | ■ | | | | | | |
| Opodepe | | ■ | | | | | | |
| Sunwright (n) | | | ■ | | | | | |
| Don Augustin | | | ■ | | | | | |
| Nect. 22 (n) | | | ■ | | | | | |
| Rojo dos | | | ■ | | | | | |
| Nect. 29 (n) | | | ■ | | | | | |
| SanPedro1633 | | | ■ | | | | | |
| Flordagem | | | | ■ | | | | |
| Tropic Snow | | | | ■ | | | | |
| Lara (n) | | | | ■ | | | | |
| Aurora | | | | | ■ | | | |
| Carolina (n) | | | | | ■ | | | |
| Jubileo | | | | | ■ | | | |
| Hermosillo | | | | | ■ | | | |
| Brasil (n) | | | | | | ■ | | |
| Fla 1-8 bis | | | | | | ■ | | |
| Chimarrita | | | | | | | ■ | |
| Maciel | | | | | | | | ■ |
| Marfin | | | | | | | | ■ |

The parameter C* (Chroma) indicates in a single value the ratio of red to yellow color. The C* value for the sun-exposed side of fruits was 43.99, whereas that of the shaded side was 38.42. This difference (15%) was scarcely perceptible but significant. Extreme values reached by the different peach and nectarine varieties were 15.82 for 'Chimarrita' and 52.63 for 'Aurora' (Table 3).

The color parameters can also be used to determine the best time for harvesting because they are strongly related to the physico-chemical modifications that occur during the fruit maturation process, although the relationships must be established specifically for each variety (Ferrer *et al*., 2005).

In conclusion, the low-chill peach and nectarine varieties tested are promising options for cultivation in the central area of Santa Fe, and may allow growers to extend the harvesting period uninterruptedly from the last week of October to the end of December, with a concentration of maturity dates (68% of the varieties studied) during November. Fruit size of peach but not of nectarines varieties showed a positive and significant relationship with the length of the fruit development period. The peach varieties 'Flordastar', 'Rojo dos' and 'San Pedro 1633', and the nectarines 'Sunwright', 'Nectarina 24', 'Carolina' and 'Brasil' produced small fruit

(<100 g), which can affect their commercialization. Red over-color of the skin was deficient because only seven varieties reached 50% of red cover.

**Table 3:** Percentage of skin red over-color and Hunter parameters at the sun-exposed (SES) and shaded side (SS) of fruits of different low-chill peach and nectarine varieties.

| Variety | Skin red over-color (%) | L[1] | | C*[2] | | h*[3] | |
|---|---|---|---|---|---|---|---|
| | | SES | SS | SES | SS | SES | SS |
| Carolina (n) | > 70 | 38.75lm | 46.66lm | 37.49hi | 44.09de | 33.10bc | 45.28ab |
| Sunwright (n) | 56-70 | 30.25n | 46.70lm | 32.33il | 42.76ef | 23.40a | 48.96bc |
| Nect 24 (n) | | 37.56lm | 51.57i | 34.69il | 40.31gh | 30.07ab | 54.74c |
| Hermosillo | | 56.51fg | 43.07n | 39.72gh | 33.86l | 72.07gh | 45.53ab |
| Earlygrande | | 80.27a | 69.08ab | 41.8efg | 37.09hi | 78.47il | 53.79bc |
| Rojo dos | | 40.38il | 54.49hi | 36.88il | 42.58fg | 35.85cd | 65.34d |
| Nect 22 (n) | | 38.27lm | 58.28fg | 37.61hi | 42.47fg | 31.90bc | 72.59de |
| Lara (n) | 40-55 | 35.49m | 56.45gh | 28.57l | 39.47gh | 32.71bc | 87.66g |
| Flordastar | | 64.53de | 47.93l | 42.66de | 36.73i | 77.11hi | 44.29a |
| Fla 91-8c | | 63.25e | 51.52i | 42.19de | 36.73i | 82.72lm | 56.23c |
| Fla 1-8bis | 31-39 | 53.20fg | 62.71de | 40.69gh | 47.13bc | 67.62f | 88.83gh |
| Brasil (n) | | 50.32gh | 63.86de | 34.81hil | 38.68hi | 68.08fg | 99.18i |
| Nect 29 (n) | | 43.51i | 66.92bc | 40.48gh | 48.10bc | 40.89cd | 84.64fg |
| Opodepe | | 56.33fg | 64.42cd | 37.91hg | 43.45de | 71.44gh | 86.55g |
| Flordaking | 25-30 | 69.23b | 53.05hi | 44.44cd | 38.47hi | 95.25no | 54.84c |
| Don Agustin | | 68.59bc | 67.35bc | 46.43bc | 45.70cd | 95.88no | 87.98g |
| Flordagem | | 48.24h | 61.91ef | 38.21gh | 46.68bc | 55.86e | 90.18gh |
| Marfin | | 57.86f | 69.68ab | 33.38il | 40.34gh | 75.901hi | 105.42il |
| Chimarrita | | 53.54fg | 71.97a | 15.82a | 40.26gh | 44.63d | 108.72l |
| Tropic Snow | | 68.90bc | 53.70hi | 37.63hi | 33.08l | 100.73o | 65.20d |
| Aurora | | 66.27de | 60.54ef | 52.63a | 48.07bc | 89.74mn | 76.48ef |
| Flordaprince | | 66.88cd | 60.39fg | 49.51ab | 43.88de | 94.24no | 70.30de |
| San Pedro 1633 | | 58.69f | 67.71bc | 43.44de | 48.93b | 72.15gh | 87.77g |
| Jubileo | < 25 | 63.80de | 68.30ab | 48.26b | 52.55a | 87.50mn | 87.98g |
| Maciel | | 65.25de | 68.78ab | 49.59ab | 52.23a | 96.40no | 97.27hi |

Different letters in the column indicate significant difference for $p \leq 0.05$.
[1]L= Lightness; [2]C= Chroma; and [3]h= hue angle of the color, according to the Hunter parameters.

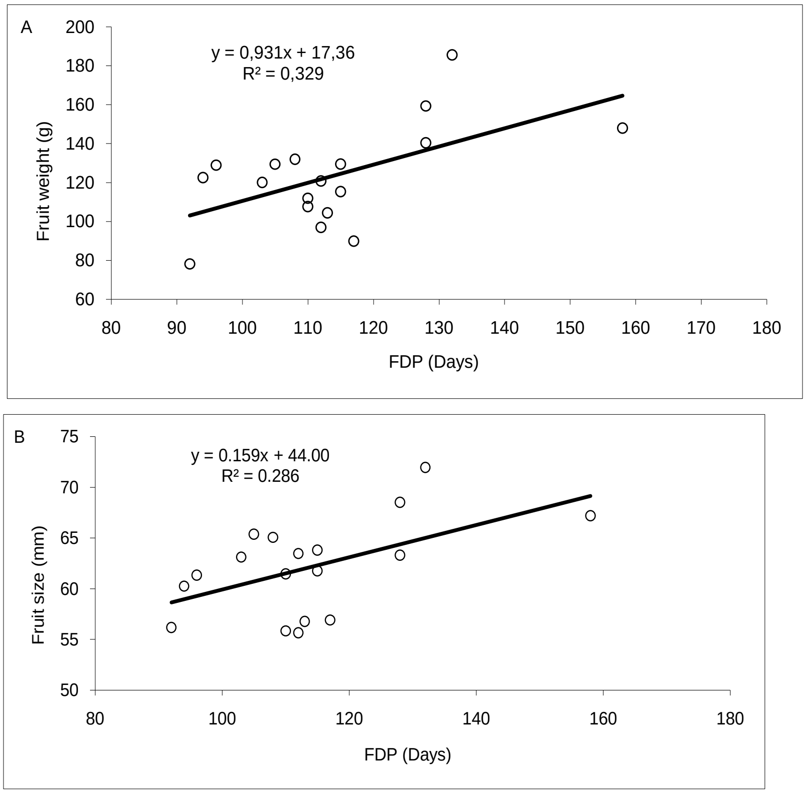


**Fig. 1:** Relationships between length of fruit development period (FDP) and fruit weight (A) and diameter (B) at harvest for different low-chill peach varieties.

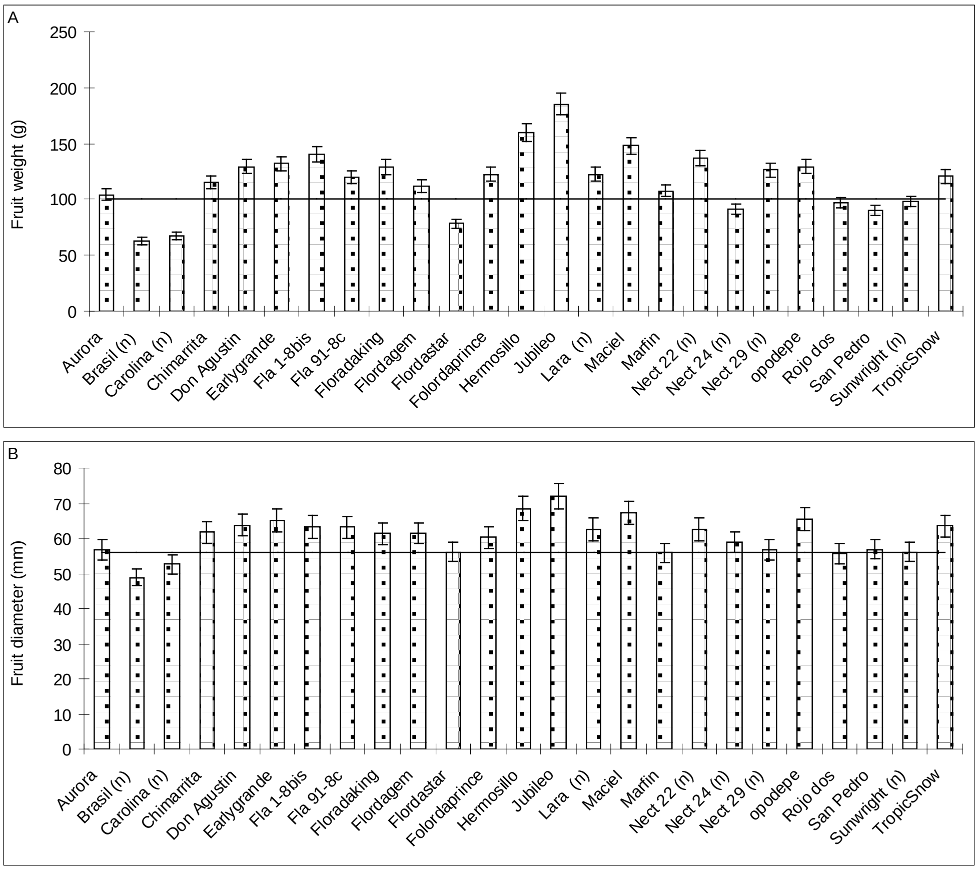


**Fig. 2:** Fruit weight (A) and diameter (B) of different low-chill peach and nectarine varieties. Lower threshold values of 100 g and 56 mm per fruit were considered for an appropriate marketing (solid line).

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