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# Changes in the Reproductive Traits of Low-chill Peach Tree in Response to Reproductive Shoot Pruning after Harvesting

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**Summary**

This work studied the effect of the renovation of the fruiting shoots after harvest on the reproductive behaviour of low-chilling peach trees cultivated in the central-east area of the province of Santa Fe (Argentina). After the harvest period, one group of plants was left unpruned (NP, control), while a second group of plants was pruned (P) by heading back or thinning out their bearing shoots. P did not affect flower density, fruit set and fruit load per plant at the next spring, but it significantly changed the distribution of fruits in the canopy, increasing the proportion of those located in the intermediate stratum of the tree (+ 10 to 40 %). P significantly reduced fruit size at the beginning of the fruit growth period, but the differences became insignificant at harvest, which was delayed three days by the pruning treatment. Fruit yield per tree was not significantly affected by summer pruning. Therefore, this cultural practice can be recommended in order to extend the pruning period of low chilling peach trees.

**Key words.** bearing shoots – early varieties – green pruning – *Prunus persica* – summer pruning

## Introduction

In the last decade, fruit tree crops were introduced and evaluated as an alternative to the diversification of the production system in the central-east area of the province of Santa Fe (Argentina), characterized by the cultivation of annual horticultural crops (Gariglio et al. 2009). At present, micro-enterprises of low-chilling peach and apple, fig, citrus, and raspberry, began to be complementary economic activities for farms. The climate of the region was classified as temperate humid with no dry season, very hot summers (Köpen 1931), and with a winter chilling accumulation which only reaches 300 chilling hours in average (Gariglio et al. 2006).

Low-chilling peach trees growing under these ecological conditions are vigorous and large, and they have a short period of winter rest which limits the time for winter pruning to only 30–40 days (Weber et al. 2011). Furthermore, the traditional winter pruning of peach trees is highly labour-demand (McEachern et al. 2000; Marini 2003a). As the availability of skilled labour to carry out the specific agronomical practices of fruit tree crops (pruning, fruit thinning, harvesting) is insufficient due to the recent expansion of the activity, winter pruning have difficulties of implementation and usually fails to be completed.

However, precocious peach varieties have a long growing season after the harvest period that reaches 135 to 180 days in our region (Gariglio et al. 2009). Thus, pruning the fruit-bearing shoots after harvesting is an alternative cultural practice that may be used to extend the time for pruning. Summer pruned trees only need a light winter pruning to adjust the number of bearing shoots and to remove the branches that were not previously removed to avoid sunburn damage over the tree scaffold (Weber et al. 2011).

The renovation of bearing shoots after harvesting caused an improvement of the rejuvenation of wood by enhancing the growth of basal shoots that arose on older wood or directly from the scaffold, thus allowing the restoration of the leaf area removed by pruning. However, pruned tree prioritizes branch regrowth over radial trunk expansion, causing a reduction in the annual trunk growth, and a decrease of the size and vigor of the tree (Weber et al. 2011).

Even though the vegetative and phenological behavior of peach trees in response to the renovation of bearing shoots after harvest has been evaluated in the central area of Santa Fe (Weber et al. 2011), changes in the yield components of the tree have not been sufficiently tested yet. It was observed that summer pruning promotes new axes emission (Phillips and Weaver 1975; Shimamura et al. 1987; Furukawa et al. 1988), and reduces tree vigor (Furukawa et al. 1992; Grossman and DeJong 1998), promoting floral induction and increasing flower density both in stone fruits (Webster and Shepherd 1984; Guimond et

al. 1998; Marini 2003b) and pome fruit trees (Miller 1982; Herrera 2001) in which flowering spur development was observed at pruning cut sites. However, negative effects on flowering are reported in apple (Saure 1987), especially in cases of severe pruning (Forshey and Elfving 1989). Summer pruning after harvest was utilized in peach under protected cultivation in China and South Italy but in this case a complete renovation of the canopy is performed, cutting back all bearing shoots (Topp et al. 2008). This continuous removal and formation of a new canopy rapidly depletes the tree of its bearing potential and crops decline in a few years (Caruso et al. 1989). Moreover, while much is known about summer pruning, there is little information regarding the response of peach tree to the replacement of bearing shoots during the growing season. The aim of this work was to evaluate the effect of the renovation of the reproductive shoots after harvest on the reproductive behavior of peach tree, cv. 'Flordaking', cultivated in the central-east area of Santa Fe (Argentina).

## Materials and Methods

This work was conducted in an experimental orchard located in the area of Esperanza, Santa Fe, Argentina (60° 50' W, 31° 25' S, altitude 40 m) over three consecutive years (2005–2007). Nine-year old peach trees [*Prunus persica* (L.) Batsch], cv. 'Flordaking', grafted onto 'Cuaresmillo' seedling rootstocks were used. The trees were planted at 5 × 3 m in a deep loamy soil, drip irrigated and fertilized according to their individual needs, and trained to open-vase form.

Representative trees selected for their uniformity in size and trunk girths received different treatments after harvesting, during the first week of November. One group of plants remained unpruned (NP) as control trees, whereas a second group of plants was pruned each year (P). Summer pruning consisted of heading back the recently harvested bearing shoots to basal current season shoots which were at least 10 cm long; bearing shoots were thinned out when a new current season shoot (10 cm long) protruded directly from the branch framework. In order to avoid sunburn, care was taken not to prune branches that protected the scaffold from direct sunlight. In both treatments, vigorous watersprouts were removed after harvesting. NP trees received traditional dormant pruning 15–25 days before the beginning of their bloom; in P trees, a light pruning was also performed during the dormant period to remove branches that were previously left to avoid sunburn of the tree scaffold.

During the winter, ten homogeneous current season shoots per plant were randomly selected 1.8 m above the ground level and their lengths were also measured. The number of flowers and fruits was weekly measured at the selected twigs from the release of dormancy to the stage of pit hardening. Additionally, fruit diameter evolution was weekly measured with a digital calipter. Flower density was subsequently expressed as the maximum number of flowers reached per metre of shoots (flowers $m^{-1}$), and the percentage of fruit set as the relation between number of fruits at pit hardening and flower density in each selected twig (% of number of fruits/number of flowers). Finally, the relation between flower density and percentage of fruit set was verified.

The number and distribution of fruits per plant were evaluated at harvest taking into account their distribution in three levels of plant height; L1: lower, up to 1.5 m height; L2: intermediate, from 1.5 to 2.5 m height; and L3: upper, from 2.5 m and higher. The distribution of fruits according to their size (diameter, mm) and weight (g) was also analyzed.

### *Statistics*

A randomized complete block design with a single tree plot of five replications was used. The data were tested for normal distribution and variance homogeneity and means were compared via an LSD test using the software Statgraphics plus for Windows 3.1 (Statistical Graphics Corp). A 5 % probability level was used to indicate significant differences between treatments.

## Results

Summer pruning did not affect flower density and fruit set of low chilling peach (Table 1). Furthermore, the number of fruits set per metre of bearing shoot showed a linear increase with flower density in both treatments, but the slope was significantly reduced (−13.8 %; P = 0.0342) by summer pruning (Fig. 1).

Pruning treatments did not cause a significant effect on fruit load per plant during three years of study despite the high variability observed between years. Non-significant interaction between the variable year and treatment was observed (Table 2).

Table 1. Flower density (FD) and fruit set (FS) of peach trees, cv. 'Flordaking', pruned (P) or not pruned (NP) after harvest. Data are the means of two years of measurements ± the standard error.

| Treatment | FD (flowers $m^{-1}$) | FS (%) |
|---|---|---|
| NP | 18.78 ± 0.01 | 81.64 ± 0.05 |
| P | 16.63 ± 0.02 | 83.44 ± 0.03 |
| Significance | ns | ns |

ns, *: non significant or significant at $P \leq 0.05$.

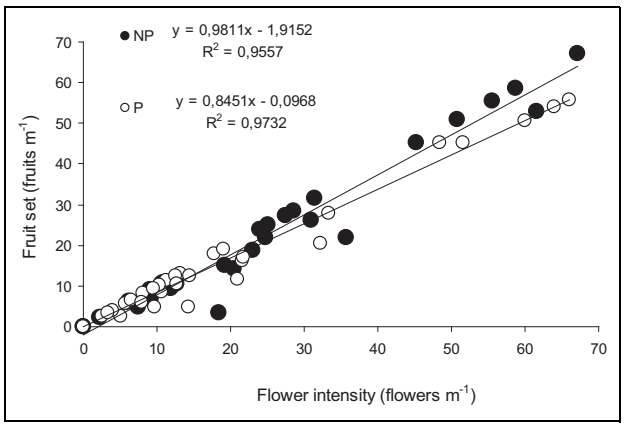



Fig. 1. Relationship between flower density and number of fruit sets per unit of length of mixed shoot in peach trees, cv. 'Flordaking', pruned (P, open circles) or not pruned (NP, close circles) after harvest.

Table 2. Crop load in peach trees, cv. 'Flordaking', pruned (P) or not pruned (NP) after harvest. Data are the means of each year ± the standard error.

| Year | Treatment | Crop load (Fruit per plant) |
|---|---|---|
| 2005 | NP | 50.7 ± 6.7 |
| | P | 68.9 ± 11.4 |
| 2006 | NP | 149.5 ± 20.8 |
| | P | 172.9 ± 32.5 |
| 2007 | NP | 368.2 ± 36.6 |
| | P | 289.3 ± 32.6 |
| Significance | year | * |
| | treatment | ns |
| | year × treatment | ns |

ns, *: non significant or significant at $P \leq 0.05$.

After three years of experimentation, summer pruning significantly affected the distribution of fruits in plant height, increasing the proportion of those located in the intermediate stratum (A2; +10 to + 40 %) and decreasing those of the upper one (A3; −45 to −50 %). No significant interaction between the variable treatment and year was observed (Table 3).

Summer pruning delayed flowering eight days on average and these phenological differences were reduced to three days at harvest; consequently, pruning after harvest significantly reduced fruit size at the beginning of the fruit growth period (−23.7 %) (Fig. 2a), but these differences diminished from the last 15 days of fruit growth, becoming insignificant at harvest (Fig. 2a, Table 4). In the other hand, if the evolution of fruit diameter was expressed as a function of the time from full bloom, it was very similar in both treatments, but the period of fruit growth was four days shorter in fruits from summer-pruned trees (Fig. 2b).

Despite medium fruit size at harvest was not affected, fruit size and weight distribution showed that summer pruning increased the proportion of fruits with a diameter of 70–75 mm (100–120 g fruit$^{-1}$) (+30 %) and more than 80 mm (> 140 g) (+40 %), and decreased the proportion of those in the range of 60–65 (−50 %) and 75–

Table 3. Fruit distribution, at different levels of plant height, in peach trees cv. 'Flordaking', pruned (P) or not pruned (NP) after harvest. L1: lower, up to 1.5 m; L2: intermediate, from 1.5 to 2.5; and L3: upper, from 2.5 m. Data are the means of each year, expressed in percentage (%) ± the standard error.

| Year | Treatment | Fruit distribution on plant height (%) | | |
|---|---|---|---|---|
| | | L1 | L2 | L3 |
| 2005 | NP | 11.80 ± 3.3 | 53.78 ± 3.5 | 34.42 ± 5.3 |
| | P | 8.37 ± 1.8 | 74.80 ± 2.5 | 16.83 ± 2.5 |
| 2006 | NP | 24.20 ± 2.0 | 68.17 ± 4.8 | 7.70 ± 5.7 |
| | P | 20.40 ± 2.0 | 75.30 ± 0.9 | 4.30 ± 1.5 |
| 2007 | NP | 8.05 ± 0.6 | 48.18 ± 4.5 | 43.77 ± 4.2 |
| | P | 17.65 ± 2.4 | 58.50 ± 7.1 | 23.86 ± 5.5 |
| Significance | year | * | * | * |
| | treatment | ns | * | * |
| | year × treatment | ns | ns | ns |

ns, * non significant or significant at $P \leq 0.05$.

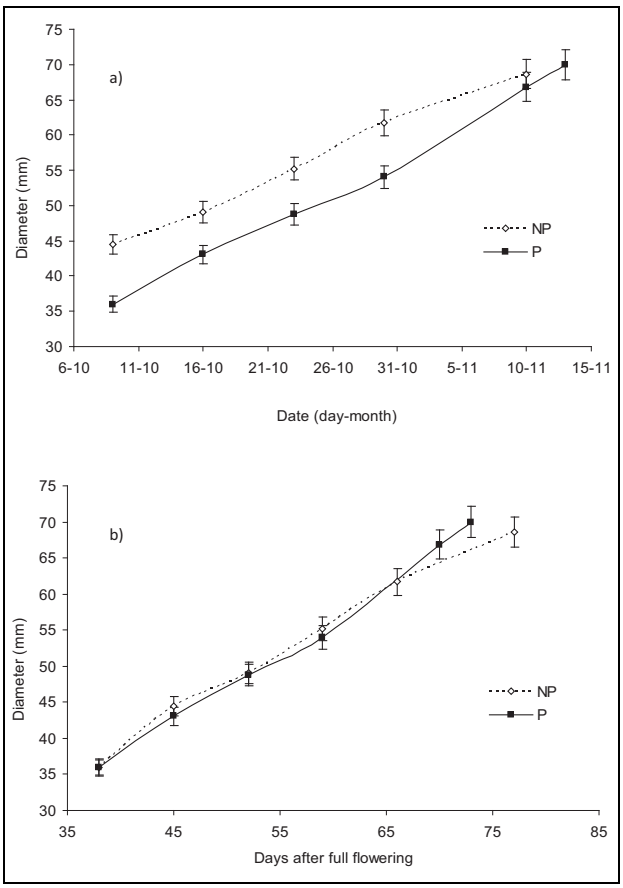



Fig. 2. Fruit diameter evolution in peach trees, cv. 'Flordaking', pruned (P) or not pruned (NP) after harvest. Chronological time (a), and time from full bloom (b). Data are the means of 40 replications per year and three years of measurements ± the standard error.

80 mm (−20 %) (80–100 and 120–140 g fruit$^{-1}$, respectively).

As occurred with crop load, fruit yield per tree was not significantly affected by summer pruning. However, fruit yield showed high variability between years, reaching the lowest value (4.0 kg tree$^{-1}$) in the first year and the highest value (20.2 kg tree$^{-1}$) in the third year of experimentation (average data of both treatments). Non-significant interaction between variables year and treatment was observed.

## Discussion

Plant response to summer pruning is very complex and depends on variety, climatic conditions, and timing and severity of pruning (Crasweller 1999; Marini 2003b). As a general rule, the amount of regrowth that occurs is greater when pruning is performed earlier and with the increases of pruning severity (Ferree et al. 1984). Summer pruning after harvest (November) promotes intense vegetative regrowth allowing the total restoration of the leaf area removed by pruning after 80 days (Weber et al. 2011), but scarce regrowth was observed when summer pruning was performed three months later, during February (Gariglio et al. 2012) under the agro-ecological conditions of the central-east area of Santa Fe.

Table 4. Diameter (mm) and weight (g) of fruits at harvest, in peach trees, cv. 'Flordaking', pruned (P) or not pruned (NP) after harvest. Data are the means of 40 replications each year ± the standard error.

| Year | Treatment | Diameter (mm) | Weight (g) |
|---|---|---|---|
| 2006 | NP | 70.0 ± 0.6 | 105.2 ± 2.5 |
| | P | 73.0 ± 0.4 | 115.4 ± 3.4 |
| 2007 | NP | 69.0 ± 0.7 | 98.5 ± 3.2 |
| | P | 70.0 ± 1.7 | 110.4 ± 6.7 |
| Significance | year | ns | ns |
| | treatment | ns | ns |
| | year × treatment | ns | ns |

ns, * non significant or significant at $P \leq 0.05$.

The high rate of vegetative growth normally reduces floral induction (Wilkie et al. 2008), by the improvement of the partition of carbohydrates and the translocation of gibberellins to the new axes, the latter being a potent inhibitor of flower induction in fruit tree species (Goldschmidt and Samach 2004; Reig et al. 2006). As intensity and timing of summer pruning affect the amount of vegetative regrowth, both factors could also affect floral induction of stone and pome fruit trees (Furukawa et al. 1992; Crasweller 1999). An exception to this rule is the case of sweet cherry; in this crop, summer pruning significantly increases the number of flowers bud per shoots in 1-year-old wood regardless of pruning intensity because the removal of the apical meristem plays a larger role on flower bud induction in comparison with the shoot length or the number of nodes that remain after pruning (Guimond et al. 1998).

The effect of time of summer pruning on flower bud induction also depends on when floral induction occurs (Asín et al. 2007), normally being less affected by later treatments because the physiological process has been finished, as observed in pear (Asín et al. 2007) and peach (Crasweller 1999).

Floral bud induction of low and medium chilling peach varieties occurs immediately after harvest (González-Rossia et al. 2007). Consequently, it was expected that the increase of the shoot growth rate improved by pruning at this time causes a significant reduction on the flower density of pruned trees. However, in our experiment flower density was not affected by pruning after harvest, possibly because it caused opposite effects on

floral induction and diferentiation. Pruning stimulates vegetative growth (Médiène et al. 2002), but also improves light penetration into the canopy (Marini and Barden 1982; Saure 1987; Herrera 2001; Marini 2003b; Weber et al. 2011), which is required for floral induction and floral bud differentiation (Marini 2003b). Thus, it is possible that both effects may be neutralized and flower density was not affected.

Even though flower density was unaffected in our experiment, it showed a lower value (13 to 15 flowers $m^{-1}$) in comparison with that reported by Pérez (2004) for a large number of low-chilling peach varieties studied in the subtropical area of Mexico (24–97 flowers $m^{-1}$ of bearing shoots). Although flower density is not normally a limiting factor to obtain an adequate fruit yield, it is of importance in regions subject to spring frost damage, such as the central area of Argentina, because the possibility to set fruit after frost occurs (Topp et al. 2008).

Fruit set of stone fruits is not affected by flower density (González-Rossia et al. 2006) as it happens with citrus (Agustí 2003). In our experiments, the relationships between flower density and fruit set for non-pruned trees showed a linear relationship with a slope value very close to the unity (0.9811, Fig. 1); however, summer pruning significantly reduced the slope of the line (−13 %). Therefore, although in our experience fruit set was not affected by summer pruning (Table 1), it could be affected in situations of higher flower density (> 30–40 flowers $m^{-1}$), as was observed in selected fruiting shoots with different intensity of flowering (Fig. 1). As summer pruning delays the time of flowering, weather conditions could differently affect pollination, pollen tube growth, egg fertility (Williams 1965), and the initial fruit growth period – when fruit drop occurs – for both treatments (Lauri et al. 1996; Rodrigo et al. 2000). Consequently, with our evidence, we cannot know whether the decrease in the slope of fruit set with flowering density is a direct effect of summer pruning on fruit set or an indirect effect caused by changes on the tree phenology with pruning. Anyway, it was demonstrated that summer pruning after harvest did not affect fruit set of peach tree, at least at medium flower density, being fruit set the critical factor to reach high fruit trees productivity in the central area of Santa Fe as can be observed in the high variability of crop load between years (see Table 2). This is because blooming and fruit set take place during the period of frequent late frost occurrence (Gariglio et al. 2009).

In previous experiments we observed that fruit set, and consequently the number of fruit per plant at harvest, was drastically reduced by winter pruning during the years characterized by light late frost occurrence in comparison with trees that were only pruned during the growth period (Gariglio et al. 2012). This negative effect of winter pruning on fruit set was previously observed when long pruning and short pruning techniques were evaluated in peach trees growing in China (Singh and Daulta 1985; Li et al. 1994b). These authors observed that long pruning increased resistance of flowers to late frost in spring because the high quality buds that have a higher resistance to frost were generally situated at the middle region of the shoot, and these buds were eliminated when short pruning was practiced (Li et al. 1994b). However, in our previous experiments long pruning was performed during winter, and consequently, this hypothesis cannot explain our results (Gariglio et al. 2012).

There is good evidence that winter pruning stimulates vegetative growth (Li et al. 1994a; Marini 2003b) of deciduous trees, and that competition for carbohydrates from shoot growth accentuates early fruit abscission, even at a relatively low crop load (Racskó et al. 2007), as it occurs with the competition between growing organs in citrus (Agustí et al. 2002; Syvertsen and Lloyd 1994) and other subtropical crops such as mango (Ramírez and Davenport 2010). Thus, it is possible that winter pruning diminishes fruit set of low-chilling peach under suboptimal low temperature conditions by increasing competition between vegetative and reproductive growth and because fruits acts as weak sink under this suboptimal temperature conditions. This could be an important reason for the implementation of summer pruning of low-chilling peach after harvest to reduce winter pruning intensity.

Although summer pruning did not modify medium fruit size and tree yield, there was a significant effect of pruning on the distribution of the fruits into the canopy, increasing the relative proportion of those situated in the intermediate stratum of plant height, which is in relation with the greater proportion of reproductive shoots observed in this intermediate stratum (in comparison with the upper one) for summer pruned trees (Weber et al. 2011). This effect of pruning is explained by an improvement of the internal distribution of light (Stebbins 1997; Weber et al. 2011) and a change in the dominant position of vegetative growth which is transferred from the apical to the basal zone of the canopy after pruning (Li et al. 1994a).

In conclusion, the renovation of bearing shoots of low-chilling peach trees after harvest did not affect flowering density, the percentage of fruit set, and fruit tree yield, but improved a better distribution of the fruits within the canopy. Therefore, this cultural practice can be recommended in order to extend the pruning period of low-chilling peach trees in the central-east-area of Santa Fe, Argentina.

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