Post-bloom mechanical thinning for can peaches using a hand-held electrical device

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Abstract:

Hand thinning is a necessary but costly practice in peach (*Prunus persica* L. Batsch) production. A hand-held mechanical device has been tested to thin peach trees, trained in “free Italian vase”, 50 to 62 days after full bloom. Hand thinning (HT); mechanical thinning (MT); mechanical and hand thinning (MHT); and un-thinned (UT) were tested from 2008 to 2011 in Murcia, south-eastern Spain. After thinning, the distance between the remaining fruits was measured: the shortest distance was 5.2 cm for MT, with no significant differences between MHT and HT at 8.6 and 8.8 cm, respectively. The differences in distances did not affect the yield and size of the fruit at harvesting in any of the cases. There were no significant differences between HT, MT and MHT treatments in fruit per tree, mean fruit weight and yield efficiency in the four years the test lasted. Farmers considered the hand-held mechanical device positively because it increased field efficiency. Moreover, with HT the work rate was 2 trees h^{-1}, with MHT it was 8 trees h^{-1} and with MT, 23 trees h^{-1}. The most expensive system was HT (4.07 €

tree^{-1}) as opposed to 1.37 € tree^{-1} for MHT. The lowest cost was for MT with 0.49 € tree^{-1}. Moreover, with HT the operating time was 324 h ha^{-1}, with MHT it was 90 h ha^{-1} and with MT, 30 h ha^{-1}. The most expensive system was HT (2713 € ha^{-1}) as opposed to 915 € ha^{-1} for MHT. The lowest cost was for MT with 328 € ha^{-1}. The net value of fruit (€ tree^{-1}) showed no significant differences between HT, MT, and MHT. Based on our study, MT appears to be a promising technique for thinning peach trees for the canning industry, because although the reduction of production costs is not high in comparison with the total cost of the crop, the increase in work speed is of great interest to thin the trees on the most appropriate dates.

Keywords: Mechanical thinning; Peach; Fruit; Harvest; *Prunus Persica;* Hand-held thinners.

1. Introduction

Fruit thinning is one of the most expensive cultural practices in peach production. Removing excess fruit between full bloom to 50 days after bloom is a standard commercial practice to produce large fruit for market. Hand thinning is costly and spend much time, depending on tree size, shape, flower production, thinning intensity and season; in Spain it takes between 25-30 min at flower stage (Martin et al., 2010), in Virginia (USA) 15 min by tree at post-bloom are reported (Marini, 2002) and in California (USA) 60 minutes are used to full bloom thinning (Berlage and Langmo, 1982).

Chemical thinning as an option for stone fruit is both limited and unpredictable (Stover and Greene, 2005). It is difficult to find a winning strategy for chemical thinning in peach because the chemical compounds are strongly limited by environmental conditions (Costa and Vizzotto, 2000). Furthermore, nowadays there is increasing pressure from consumers for the use of less, or ideally no, agrochemicals in fruit production (Webster and Spencer, 2000).

Attempts to thin peaches by physical or chemical methods have resulted in the unsatisfactory uneven distribution of fruit along shoots or preferential removal of larger fruit (Southwick et al., 1995). However, several authors have demonstrated that it is possible to obtain peaches of marketable sizes without a uniform separation between fruits. Corelli-Grappadelli and Coston (1991) have reported that the effect of fruit position is greater than that of distance between the fruits. Marini and Sowers (1994) have shown that if peaches are thinned non-uniformly throughout the canopy, the lack of thinning individual shoots will be partially compensated by the adequate thinning of most of the tree. Miranda and Royo (2002) have evaluated the effect of the intensity of hand thinning and fruit distribution along the shoot and the yield of different peach cultivars and have concluded that fruit distribution on the shoot had little or no influence over final diameter or yield.

Existing commercial mechanical tractor-driven thinning equipment requires hedge-trained trees (Baugher et al., 2010; Schupp et al., 2011; Miller et al., 2011; Hehnen et al., 2012), but in south-eastern Spain, the most common training system is the “free Italian vase”, where that equipment cannot operate appropriately. Thus, hand-held devices were employed because they can be used in any training system (Martin et al., 2008).

The objective of this study was to evaluate a hand-held mechanical thinning device as an alternative to hand thinning in “free Italian vase” peach trees. Hand thinning, mechanical thinning, mechanical follow-up hand thinning, and no-thinning (control) were compared from 2008 to 2011 in Murcia, south-eastern Spain. The parameters for analysis were thinning time; crop load; fruit size; and economic value of marketable fruit for the canning industry.

2. Materials and Methods

2.1 Treatments

The experiment was conducted between 2008 and 2011 in a peach (*Prunus persica* L. Batsch, cv Carson) orchard located in Caravaca (Murcia, Spain). Carson is a mid-season clingstone cultivar grown in Spain for the canning industry. The trees were nine years old at the beginning of the trials and planted in a frame of 5 m between rows and 3 m in the row. The trees measured 3 m in diameter and were 3.5 m tall. The average trunk height was 0.60 m, and the average trunk diameter was 0.14 m. The main branches were 1.7–2.1 m long and formed 140–160º angles with the trunk. The secondary branches were 0.8–1.3 m long and formed 80–120º angles with the trunk. The trees were trained to a “free Italian vase” shape and were hand-pruned.

Four treatments were used:

1. Un-thinned (UT): Control treatment. This treatment was used as a reference to determine the number and size of fruits produced by un-thinned trees and also to measure the thinning intensity; but this treatment has no commercial interest since peach trees are always thinned.

2. Hand thinning (HT): The thinning was done by workers who eliminated green fruits from all the branches on the tree (with or without ladders), leaving one fruit approximately every 10 cm, which is adequate for the canning industry and the fresh market.

3. Mechanical thinning (MT): an electric hand-held fruit remover was used (Volpi, Davide e Luigi Volpi S.p.A. Casalromano, Italy). This device was 2.5 m long and weighed 2 kg. It had a head with six rotating fingers and was powered by a 12 V electric motor that operated at two fixed speeds, 714 and 833 rev min^{1}. After preliminary tests, 714 rev min^{-1} was determined to be the most suitable speed for thinning. Electricity was supplied by a 12 V, 75 Ah car battery, which remained on the ground, and a 15-m long electric extension cord. This equipment was chosen because it gave the best results in the preliminary tests of six electrical devices (Martin et al., 2008).

4. Mechanical and hand thinning (MHT): Mechanical thinning with the device used in MT treatment was then followed by hand thinning. In 2008, follow-up thinning was done in the same conditions as HT, the workers used ladders, but in the following years, the follow-up was done without the use of ladders and acting only on the remaining clusters. This treatment was carried out by a team of three workers; one removed the fruits with the mechanical device and the other two thinned the clusters by hand after the mechanical thinning.

The experiment was designed as a randomised block, divided into plots; each plot had six trees (replicates).

2.2. Thinning and harvesting dates

Thinning dates were April 17th, 2008 (50 DAFB); May 7th, 2009 (62 DAFB); May 11^{th,} 2010 (53 DAFB); April 28th, 2011 (50 DAFB). Harvesting was done when the fruit was visually mature. In 2008 it was done in two passes (130 and 138 DAFB) and in 2009-2011 it was done in three passes (in 2009: 130, 136 and 140 DAFB; in 2010: 125, 130 and 134 DAFB; in 2011: 133, 138 and 142 DAFB).

On the first thinning day of 2008-2011, the trunk diameter of each tree was measured at 30 cm above the ground to calculate the trunk cross-sectional area (TCSA). Time consumed for thinning was measured tree by tree.

Thinning intensity was evaluated in 2008 following the methodology proposed by Berlage and Langmo (1982). A complete sample of green fruit removed at thinning was kept for each tree. This methodology allows to evaluate the thinning intensity, but not the uniformity of fruit distribution on the branches.

Baugher et al. (1991) measured the fruit density on terminal, middle, and basal fruiting shoot positions before and after trees were thinned. In order to measure fruit spatial distribution, in 2010 and 2011 the thinning intensity was determined by measuring the length of four stems and the distance between green fruits before and after each thinning treatment on each tree. Two short shoots (less than 50 cm in length) and two long shoots (longer than 50 cm) were measured per tree. The distinction between short and long shoots was made because it was noticed that long shoots were easy to thin with the device ; moreover, short shoots were in the inner part of the tree were the device access was more difficult. In 2010, thinning intensity was measured the same day that the trees were thinned (May 11th, 2010; 53 days after full bloom: DAFB). In 2011, thinning intensity was measured twice on the same shoots: the first time on the thinning day (April 28th, 2011; 50 DAFB) and the second, one month after thinning (80 DAFB).

On each harvest date, several parameters were analysed: (i) the fruit harvested from each tree was weighed using an electronic balance with a resolution of 50 g to determine the yield (kg tree^{-1}) and yield efficiency (g cm^{-2} TCSA); (ii) the number of fruits per tree (no. fruit tree^{-1}) was counted, and the crop density (no. fruit cm^{-2} TCSA) was calculated; (iii) the fruit weight (g fruit^{-1}) was obtained indirectly by dividing the yield per tree by the number of fruits; and (iv) the fruit size category (% no. fruit tree^{-1} and kg tree^{-1}) was obtained from a sample of 150 fruits per tree. This was measured using an electronic calliper with 0.1 mm resolution. The fruits collected were divided into two categories based on their calibre: fruits over 55 mm, which is the minimum size accepted by the canning industry, and fruits under 55 mm. Thinning operations were recorded with a camcorder, and the time required to thin each tree was measured to calculate the thinning costs.

To evaluate quality parameters, on each harvest date, a sample of 100 fruits was taken. Several parameters were analysed: (i) the flesh firmness was measured by means of a Magness–Taylor style penetrometer probe (Fruit Pressure Tester, FT-327, Facchini SRL, Alfonsine, Italy) equipped with an 8 mm diameter probe (section 50mm^2); (ii) the soluble solids concentration in the fruits was determined from juice samples using a hand refractometer (Atago Pocket Pal-1, Atago Co. Ltd., Tokyo, Japan); and (iii) the level of acidity was obtained by neutralising 1.5 mL of the squeezed, spin-dried and filtered juice with 0.1N NaOH, using a digital pH meter (Crison pH Burette 24, Crison

Instruments S.A., Barcelona, Spain). The results were expressed in terms of the dominant acid as grams of malic acid per litre (g malic acid L^{-1}).

Statistical analyses were performed using a commercially-available statistics package (Statgraphics Plus, version 5.1., STSC Inc., Rockville, MD, USA).

The cost of thinning by treatment was calculated as follows:

- Hand thinning costs were based on a labour rate of 8.30 € h^{-1}, including taxes.
- Mechanical thinning costs were calculated following ASAE D497.7 (2011) and ASAE EP496.3 (2011). The economic costs for the mechanical device were based on a machine life of five years or 1200 h of use (commercially available price of €1530), an annual usage of 240 h, an interest rate of 7%, a salvage value of 12% of the purchase price, storage at 0.75% of the purchase price and cumulative repair and maintenance costs at 82% of the purchase price. The cost of the mechanical device was 2.44 € h^{-1} and the cost of hand-labour was 8.30 € h^{-1}. The total cost of the mechanical thinning treatment was 10.74 € h^{-1}.
- Mechanical and hand thinning treatment was carried out by a team of three workers; one removed the fruits with mechanical device (10.74 € h^{-1}) and the other two thinned by hand after mechanical thinning (8.30 € h^{-1}).

The economic profit of the thinning treatments was calculated considering the yield (kg $tree^{-1}$) of fruits with a size over 55 mm. The price for canning peaches was 0.44 € kg^{-1} in 2008; 0.33 € kg^{-1} in 2009; 0.43 € kg^{-1} in 2010; and 0.22 € kg^{-1} in 2011. These peach prices were obtained from the wholesale weekly prices received by producers in the field (CARM, 2011). The thinning cost (€ tree^{-1}) was subtracted from the production value (€ tree^{-1}) to obtain the net margin.

3. Results

3.1. Effect of thinning on distance between green fruits

Although the objective for the three treatments was for the same number of fruits to remain per tree, hand thinning (HT) was the treatment that removed most fruits; mechanical thinning (MT) detached 64% compared with HT, and mechanical followed by hand thinning (MHT) removed 78% of HT.

The effect on the distance between fruits due to the factors: treatment, shoot length, date of measure, distance, and year was analysed with a multi-factorial analysis of variance for the years 2010 and 2011, with the effect of all the factors being significant, with the exception of that of year.

In the UT trees, the distance between green fruits was 3.6 cm, MT left the green fruits at a significantly greater distance (5.2 cm) than UT, but at a significantly lower distance than those of MHT and HT, of 8.6 and 8.8 cm, respectively, with no significant differences between the latter two.

Before thinning, there were no significant differences in the distance between green fruits in short (3.4 cm) and long (3.6 cm) shoots. After thinning, there were significant differences in the distance of the green fruits located on short shoots, 4.7 cm, compared with the long shoots, 5.8 cm. This means that the long shoots were thinned more intensively than the short ones.

In 2011 the distance between green fruits was measured on two dates, 50 DAFB, which was the thinning day, and also 80 DAFB (Table 1). In all the treatments the distance increased from the first to the second date, due to the falling of fruits damaged in the thinning operation but not totally removed and due to natural causes. In all the cases in which thinning was carried out, the differences in the distances were low and not significant, but in the case of UT the distance increased significantly, passing from 3.2 to 4.3 cm. This physiological drop has been noticed in some peach varieties when the load is high, due to the competition for nutrients between fruits (Blanco, 1987; Blanco and Socias, 1988; Byers, 1989; Costa et al., 1982; Miranda and Royo, 2002). Thus, to have a precise vision of fruit distance between fruits in thinning treatments, the distance must be measured some days after the operation has been done, in this case roughly one month later.

3.2. Thinning time and thinning cost

Thinning time was significantly different for HT, MT and MHT treatments in the four years of trials (Table 2). In this experiment, HT was carried out following the farmer's normal practices and took 25-32.7 min tree^{-1} depending on the year, and was therefore the most time-consuming treatment. These results agree with those obtained by Berlage and Langmo (1982); Marini (2002) and Martin et al. (2010).

Mechanical thinning required 2-3.3 min tree^{-1} which meant that it was the least time-consuming treatment. It saved 87-93% of time with respect to HT, which supposes a substantial increase in the work rate, which was 18.9-30.3 trees h^{-1} versus 1.9-2.4 trees h^{-1} for HT.

In 2008, MHT (using ladders to do the follow-up hand thinning) lasted 13.4 min $tree^{-1}$. In 2009-2011, ladders were not employed and the operators who carried out the follow-up thinning were forced to follow the rhythm of the thinner. This reduced the thinning time to 5.3-10.8 min $tree^{-1}$, allowing a saving time of 67-82% with respect to HT. In the MHT treatment, the use of ladders in the follow-up thinning did not improve the size of the fruit harvested (Martin et al., 2010).

Mechanical thinning and MHT reduced thinning time and increased the work rate, which as an average for the four years was 2 trees h^{-1} for HT, 8 trees h^{-1} for MHT and 23 trees h^{-1} for MT. This increase in the work rate is considered positive by producers because they can work faster, thinning on the best dates and using only well-trained operators.

Thinning costs were significantly different between HT, MT and MHT treatments. Thinning cost was on average 4.07 € $tree^{-1}$ in HT; 1.37 € $tree^{-1}$ in MHT and 0.49 € $tree^{-1}$ in MT. In comparison with HT, MT and MHT produced savings of 88% and 66%, respectively.

3.3. Fruit harvested

The control treatment (UT) was significantly different from all of the others (HT, MT, and MHT) for the factors: fruit per tree; crop density; mean fruit size; mean fruit weight; yield; and yield efficiency in the four years (Table 3).

In the thinning treatments (HT, MT, and MHT) there were no significant differences in number of fruits per tree; crop density (no. cm^{-2} TCSA); and yield efficiency (g cm^{-2} TCSA).

Thinning treatments reduced, on average for the four years, the number of fruits per tree by between 50-60% as compared to UT. Similar values are reported by other researchers such as Schupp et al. (2008) who reduced crop load by an average of 58% using drum shaker devices, and Myers et al. (2002) consider that 50% is a standard degree of thinning in peaches. However, a major difficulty of thinning is to find the optimal thinning intensity. This is so because the optimum thinning level to maximise grower profit will depend on many factors, including yield; fruit size; fruit size distribution; minimum size standards; etc.

There were also significant differences in fruit size and fruit weight (Table 3) of UT in comparison with the three thinning treatments (HT, MT, and MHT). Peach fruit size is negatively related to the number of fruit per tree (Johnson and Handley, 1989). Hand thinning, MT and MHT treatments increased fruit size (mm) by 10%, and fruit weight (g $fruit^{-1}$) by 47% on average for the four years as compared to UT. On the other hand, yield (kg $tree^{-1}$) was reduced by 31% in HT, MT and MHT with respect to UT.

Figure 1 shows the distribution (%) of fruit diameters for all the treatments. In UT, 18% of fruit had a calibre of less than 55 mm, which is the minimum calibre accepted by the industry. This percentage was considerably lower in the thinning treatments: 8% in MT, 4% in MHT, and 3% in HT.

The average fruit weight was linearly correlated with the fruit number per tree. Johnson and Handley (1989) and Marini and Sowers (1994) have proposed a relationship between average fruit weight and fruit number as a linear equation y = m x +b. Using our data, a mathematical relationship was established between average fruit weight (y, g $fruit^{-1}$) and crop density (x, number fruit cm^{-2} TCSA). The following formula was obtained: y = 200.3 - 13.7 x (R^2 = 69%; P<0.05) (Fig. 2). Johnson and Handley (1989) obtained a R^2 value between 67% and 92% comparing peach cultivars in early, mid- and late-season. The linear relationship was significant but the slope depended on the cultivar. "Carson" is a mid-season ripening cultivar. With our data, crop density explained 69% of the variability in fruit weight, and thus other factors must also influence fruit weight. Miranda and Royo (2002) established a mathematical relationship between fruit diameter and precocity, pruning load, and crop density which explained 55% of the variability in fruit diameter.

Since yield efficiency is a product of fruit weight and crop density, Johnson and Handley (1989) proposed a relationship between average fruit weight and crop density using a curvilinear equation of the form $y= mx^2 + bx$. Using our data, a mathematical relationship was established between average yield efficiency (y, g cm^{-2} TSCA) and crop density (x, number fruit cm^{-2} TCSA). The following formula was obtained: $y = -0.0127 x^2 + 0.195 x$ (R^2 = 82%; P<0.05) (Fig. 2).

These two relationships obtained for "Carson" cultivar (Fig. 2) may be a useful tool to determine firstly, the thinning intensity needed to obtain the desired fruit weight; and secondly, to estimate yield efficiency for the thinning intensity selected.

3.4. Physical–chemical properties of fruits

Flesh firmness decreases with maturation and ripeness of stone fruits. Typical firmness levels at normal commercial maturity of mid-season peaches are 45-55 N (Kader and Mitchell, 1989). As shown in Table 4, average flesh firmness decreased from the first to the last harvest date; although in 2010 and 2011 the flesh firmness values obtained on the first day of harvest were lower than those in 2008 and 2009.

Soluble solids concentration was always greater on the first picking date, due to the selective manual harvesting (Table 4). On the first dates, workers take only the biggest and most coloured fruits, meanwhile on the last, they take all the remaining fruits of the tree, whatever their state of maturity.

Acidity increased with the time, which can be explained by the fact that the last fruits were immature.

3.5. Economical aspects

The highest total yield was obtained with UT (100 kg tree $^{-1}$ on average for four years). Despite 10% not having reached the commercial minimum size of 55 mm (Table 5) yet, a higher yield was observed in this treatment than in the others. In all the years, UT fruit had a higher gross value and net value than those of all thinning treatments.

There were no significant differences in total yield between HT, MT and MHT during the four years. Hand thinning was the treatment that produced the least non-commercial peaches (1%), versus 5% in MT and 2% in MHT, although these differences were not significant. Despite that, there were no significant differences in yield of commercial sizes, gross and net value of fruit among HT, MT and MHT.

The treatment with higher net value was UT with 32 € $tree^{-1}$, meanwhile HT, MT and MHT reached 20 € $tree^{-1}$, 22 € $tree^{-1}$ and 23 € $tree^{-1}$, respectively.

4. Discussion

By definition, successful thinning results in a reduction in crop load and in an increase of the fruit size. Unfortunately, reducing crop load is also likely to reduce yield. Historically, it has been assumed or implied that a significant increase in fruit size will compensate for the loss of yield that typically results from thinning. For example, in 1903 Walker urged peach growers in Arkansas to remove ½ to ¾ of the small fruit, promising that the value of the fruit would be increased sufficiently to pay 1000% of the cost of thinning, with no reference to the value of the lost fruit. However, it is clear that a reduction in total yield is only beneficial if sufficiently more fruit can be marketed or marketed at a higher price. Silsby et al. (1991) report that it is possible that improvement in fruit size and quality did not compensate for loss of yield.

In this test, thinning treatments (HT, MT and HMT) reduced the number of fruits per tree with respect to UT by an average of 45%, being the average yield of UT trees 100 kg $tree^{-1}$ versus 69 kg $tree^{-1}$ of HT, MH, and MHT (Table 3). Obviously, the size in these last treatments was higher, 66 mm versus 60 mm in UT. Generally when the fruit is for the fresh market, the increase in size can compensate the yield losses due to the strong differences in prices by calibre, but for processing peaches, fruit size is not the most important determinant of price, because all fruit greater than 55 mm in diameter receive the same price. Thus, in our trials, UT reached an average net value of 31.92 € tree^{-1}, meanwhile HT, MT, and MHT obtained 20.09, 21.97, 22.92 € tree^{-1} respectively (Table 5).

The practice of fruit thinning has been used for hundreds, perhaps thousands, of years to manipulate cropping and blooming in peach (Dennis, 2000). Although in this test UT was the best economical solution, farmers will never leave the trees un-thinned because the non-commercial fraction (10% in this case) also supposes costs in harvesting and managing fruit. Moreover, thinning can influence fruit quality parameters. Link (2000) showed that thinning improves fruit size, colour and is accompanied by higher contents of soluble solids. Thinning therefore improves the taste and also the appearance of the fruit. Unfortunately, in our test the quality of the fruit was not analysed for the different treatments.

There were no significant differences between HT, MT, and MHT treatments in fruit per tree, mean fruit weight, and yield efficiency (Table 3). Consequently, for this cultivar, independently of the thinning method used, the size and yield of fruit can be estimated depending on crop density (Fig. 2) and assuming a spectrum of probable prices for the fruit size, to estimate the yield net value. Scott and Rasmussem (1990) developed a mathematical model to optimise the thinning intensity in peaches using easily measurable parameters. Mathematical models are useful tools for optimising thinning, but the parameters must be obtained for any particular agricultural situation.

Some cultivars of stone fruits tend to develop a pattern of biennial bearing that may vary greatly in intensity (Seehuber et al., 2011). Thinning reduced the fluctuation in yield, but the fruit size result in a single year is not representative. Mechanical thinning is the most "environmentally friendly" and cheaper system to thin peaches.

5. Conclusions

Both treatments which employ a hand-held mechanical device (MT and MHT) have allowed a considerable reduction in the thinning time, 90% with MT and 75% with MHT, with respect to hand-thinning (HT). The operating time with HT was 324 h ha^{-1}, with MHT it was 90 h ha^{-1} and with MT, 30 h ha^{-1}.

The highest thinning cost was for HT with 2713 € ha^{-1}. Due to the reduced value of the thinning in comparison with the increase in the work rate, mechanical thinning treatments supposed a considerable saving in thinning costs, 88% and 66% savings for MT and MHT respectively, with respect to HT.

There were no significant differences between HT, MT, and MHT treatments in fruit per tree, mean fruit weight, yield efficiency and net value of fruit in any of the four years of the test. Thus, MT is the best option, because it was the least expensive and the yield and fruit size obtained were not different from the other thinning treatments.

The used of hand-held mechanical devices will permit growers to optimise the net return that can be obtained for a specific orchard.

Acknowledgements

This research was funded by the *Consejería de Agricultura de la Región de Murcia, Spain*. The authors thank Eng. Regino Aragón (IMIDA) and *Marín Giménez Hermanos S.A.* (Caravaca, Spain) for their support.

References

ASAE D497.7, 2011. Agricultural machinery management data. ASABE Standards, 8 pp.

ASAE EP496.3, 2011. Agricultural machinery management. ASABE Standards, 6 pp.

Baugher, T.A., Elliot, K.C., Leach, D.W., Horton, B.D., Miller, S.S., 1991. Improved methods of mechanically thinning peaches at full bloom. J. Am. Soc. Hort. Sci. 116 (5), 766-769.

Baugher, T.A., Ellis, K., Remcheck, J., Lesser, K., Schupp, J., Winzeler, E., Reichard K., 2010. Mechanical string thinner reduces crop load at variable stages of bloom development of peach and nectarine trees. Hortscience 45(9), 1327–1331.

Berlage, A.G., Langmo, R.D., 1982. Machine vs. hand-thinning of peaches. Trans. of the ASAE 25 (3), 538-548.

Blanco, A., 1987. Fruit thinning of peaches trees (*Prunus persica* (L.) Batsch): The effect of paclobutrazol on fruit drop and shoot growth. J. Hort. Sci. 62 (2), 147-155.

Blanco, A., Socias, R., 1988. Caída de frutos en el melocotonero de carne amarilla dura ‘Sudanell-1’. Investigaciones Agraria, Prod. Veg. 3, 45–57.

Byers, R.E., 1989. Response of peach trees to Bloom thinning. Acta Hortic. 254, 125-132.

CARM, 2011. Estadistica Agraria Regional. Available at: http://www.carm.es/. Accessed 14 October 2011.

Corelli-Grappadelli, L., Coston, D. C., 1991. Thinning pattern and light environment in peach tree canopies influence fruit quality. Hortscience 26, 1464-1466.

Costa, G., Grandi, M., Giulivo C., Ramina, A., 1982. Fruit load and tree vigor as related to the natural and CEPA-induced abscission in immature “Andros” cling peaches. Riv. Ortoflorofrutt. It. 66, 297-303.

Costa, G., Vizzotto, G., 2000. Fruit thinning of peach trees. Plant Growth Regul. 31, 113–119.

Dennis, F.G.Jr., 2000. The history of fruit thinning. Plant Growth Regul. 31, 1–16.

Hehnen, D., Hanrahan, I., Lewis, K., McFerson, J., Blanke, M., 2012. Mechanical flower thinning improves fruit quality of apples and promotes consistent bearing. Sci. Hortic.134, 241–244. DOI: 10.1016/j.scienta.2011.11.011.

Johnson, R.S., Handley, D.F., 1989. Thinning response of early mid and late-season peaches. J. Amer. Soc. Hort. Sci. 114, 852–855.

Kader, A.A., Mitchell, F.G., 1989. Maturity and quality. In: La Rue, J.H., Johnson, R.S., (Eds.). Peaches, plums and nectarines: growing and handling for fresh market. University of California, Publication No. 3331, pp. 191-196.

Link, H., 2000. Significance of flower and fruit thinning on fruit quality. Plant Growth Regul. 31, 17–26.

Marini, R.P., 2002. Heading fruiting shoots before bloom is equally effective as blossom removal in peach crop load management. Hortscience 37(4), 642–646.

Marini, R.P., Sowers, D.L., 1994. Peach fruit weight is influenced by crop density and fruiting shoot length but not position on the shoot. J. Am. Soc. Hortic. Sci. 119 (2), 180–184.

Martin, B., Torregrosa, A., García Brunton, J., Bernad Godina, J.J., Aragón, R., 2008. Preliminary tests of mechanical thinning of peaches for processing industry. International Conference on Agricultural Engineering. AgEng 2008. 23-25 Jun 2008. Hersonissos, Crete – Greece.

Martin, B., Torregrosa, A., Garcia Brunton, J., 2010. Post-bloom thinning of peaches for canning with hand-held mechanical devices. Sci. Hortic. 125(4), 658-665. DOI: 10.1016/j.scienta.2010.05.025.

Miller, S., Schupp, J., Baugher, T., Wolford, S., 2011. Performance of mechanical thinners for bloom or green fruit thinning in peaches. Hortscience 46, 43–51.

Miranda, C., Royo, J.B., 2002. Fruit distribution and early thinning intensity influence fruit quality and productivity of peach and nectarine trees. J. Am. Soc. Hortic. Sci. 127 (6), 892–900.

Miranda, C., Royo, J.B., 2003. A statistical model to estimate potential yields in peach before bloom. J. Am. Soc. Hortic. Sci. 128 (3), 297–301.

Myers, S.C., Savelle, A.T., Tustin, D.S., Byers, R.E., 2002. Partial flower thinning increases shoot growth, fruit size, and subsequent flower formation of peach. Hortscience 37, 647–650.

Schupp, J.J., Baugher, T. Auxt, Miller, S.S., Harsh, R.M., Lesser, K.M., 2008. Mechanical thinning of peach and apple trees reduces labor input and increases fruit size. Horttechnolgy 18 (4), 660-670.

Schupp, J.R., Baugher, T. Auxt., 2011. Peach blossom string thinner performance improved with selective pruning. Hortscience 46(11), 1486-1492.

Scott, R., Rasmussem, J.M., 1990. Peach thinning optimization model. Acta Hortic. 276, 247-255.

Seehuber, C., Damerow, L., Blanke, M., 2011. Regulation of source: sink relationship, fruit set, fruit growth and fruit quality in European plum (*Prunus domestica L.*)-using thinning for crop load management. Plant Growth Regul. 65, 335–341. DOI 10.1007/s10725-011-9606-x.

Silsby, K.J., Robinson, T., Dellamano, F., 1991. Empire hand thinning study. Proc. New York State Hort. Soc. 136, 175–185.

Southwick, S.M., Weis, K.G., Yeager, J.T., Zhou, H., 1995. Controlling cropping in ‘Loadel’ cling peach using gibberellin: Effects of flower density, fruit distribution, fruit firmness, fruit thinning, and yield. J. Amer. Soc. Hort. Sci. 120, 1087-1095.

Stover, E.W., Greene, D.W., 2005. Environmental effects on the performance of foliar applied plant growth regulators. Horttechnology 15, 214–221.

Walker, E., 1903. Peach growing in Arkansas. Ark. Expt. Sta., Fayetteville, Bul 79, pp 42–68.

Webster, A.D., Spencer, J.E., 2000. Fruit thinning plums and apricots. Plant Growth Regul. 31, 101–112.