Effect of fruit thinning on fruit quality and alternate bearing of ‘Setubalense’ mandarin (*Citrus deliciosa*)

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Abstract

Citriculture plays a major role in agriculture worldwide, especially in the Mediterranean region. However, there are limitations in citrus production. Alternate bearing can be a big problem when it is very intense. Trees produce a heavy yield one year (“on” year) and light ones the next (“off” year). During the “on” year, trees produce many small-sized fruits, while in the “off” year, they produce very few, larger fruits. The small size of the fruits is a limitation, as they are less well accepted in the market. The ‘Setubalense’ cultivar, a traditional Portuguese Mediterranean mandarin (*Citrus deliciosa*), is recognized for its excellent organoleptic characteristics. Despite this, the issues of alternate bearing and small fruit size are leading to the loss of this cultivar. Fruit thinning is a cultural practice involving the removal of some fruits, while leaving others. This practice can be used to manage alternate bearing and to improve fruit size. However, its impact on the plant is not well understood, whether it affects the plant as a whole or at a more localized level, such as within individual branches. To address this, two experiments were installed in August 2019. In the first experiment thinning involved removing 50% of the fruits from the entire tree. In this experiment, the fruit size and fruit quality were higher in the trees where fruit thinning was performed. In the second experiment, thinning was applied to selected branches, also removing 50% of the fruits. In this case, no significant differences were observed, neither in fruit size nor in fruit quality. Furthermore, fruit thinning did not reduce alternate bearing in either experiment.

Keywords: *Citrus reticulata*, fruit size, Mediterranean mandarin, ‘Setubalense’, productivity

INTRODUCTION

‘Setubalense’ is a Portuguese cultivar of the Mediterranean mandarin (*Citrus reticulata* Blanco) that produces fruits with a characteristic aroma and flavor, much appreciated by some consumers. This mandarin is well adapted to Mediterranean soil and climate conditions and is associated with the Mediterranean diet (Duarte et al., 2016). However, the fruits have many seeds and can sometimes be light in colour. In addition, the alternate bearing and the small fruit size are leading to the decline of this cultivar (Pacheco and Duarte, 2016).

The alternate bearing is a cyclical yield in which trees produce heavy yields one year (the “on” year) and light ones the next (the “off” year). In the “on” year, each tree produces heavy yields with many small-sized fruits. In the “off” year, each tree produces very few, large fruits (Shalom et al., 2012). Heavy yields are also damaging to trees’ health (Ouma, 2012).

The small size of the fruits of this mandarin in the “on” years can be a limitation, since they are less accepted by the market (Hamza et al., 2012) and in mandarin cultivars fruit size is crucial in determining the profit (Ouma, 2012).

Fruit thinning consists of removing fruits after fruit set and natural June drop had happened (Ouma, 2012). This practice can be made to reduce fruit load (reduce branches’ breakage), increase fruit size, improve fruit quality, and stimulate floral initiation for next

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year's yield (Rivadeneira et al., 2015; Brar et al., 1992; Khurshid and Sanderson, 2023; Mostafa and Abdel-Aal, 2009). For good results, fruit thinning must be done in the correct timing, which depends on the fruit development stages (Matias et al., 2023). Fruit thinning can be manual, mechanical, or chemical (Rivadeneira et al., 2015; Ortiz et al., 2020). Chemical fruit thinning should be done at stage I of fruit growth (Figure 1). Manual fruit thinning should be done at stage II (Figure 1). After the natural fruit drop finishes in June, the number of fruits left on the tree gives a good indication of the crop load (Ouma, 2012).

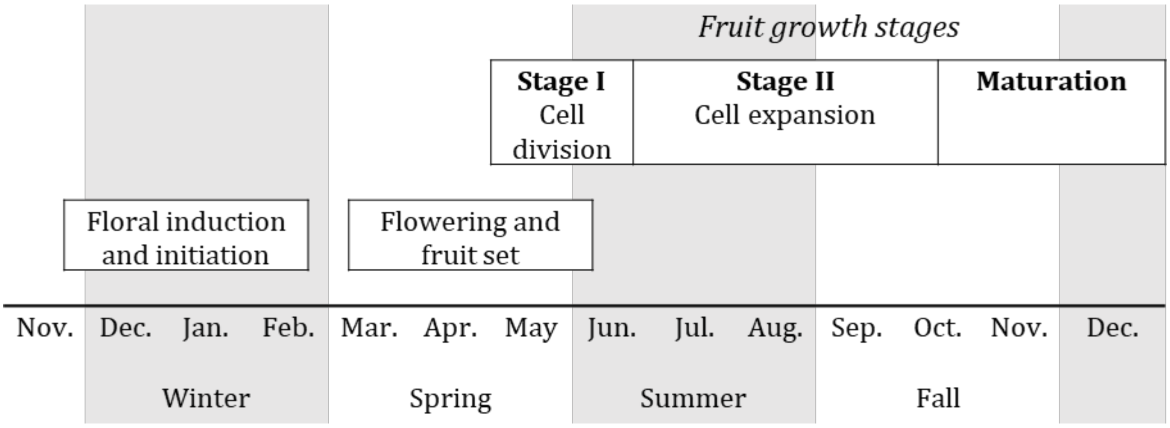

Figure 1. 'Setubalense' mandarin phenological cycle in Mediterranean conditions.

Despite being known the positive effects of fruit thinning in several citrus cultivars, it is not well-known how it works within the plant. It is not clear if fruit thinning has a general effect on the whole plant or if it works at a more restricted level, within a branch.

Trying to overcome the lack of knowledge about how the fruit thinning works within the plant and evaluating if this practice can be used to improve fruit size and quality and to manage alternate bearing in 'Setubalense' mandarin, two experiments were performed. In one experiment fruit thinning was made on entire trees, removing fruits from all canopy, while in the other experiment, fruit thinning was performed only on selected branches.

MATERIALS AND METHODS

Plant material and experimental design

The trial was carried out in a 15-year-old orchard of 'Setubalense' mandarin (*Citrus reticulata* Blanco) grafted onto sour orange (*C.* × *aurantium* L.) rootstock.

Fruit thinning was made in August 2019 and was tested in 2 experiments. Both experiments had the same 2 treatments: T1 – where no thinning was done (control) and T2 – manual fruit thinning by removing 50% of the fruits (fruit thinning).

In the first experiment (E1), 4 pairs of trees were selected, with similar size, vigor, and yield. In each pair, one tree was left unthinned (T1), while, in the other one, fruit thinning was made on the entire tree, in all the canopy (T2).

In the second experiment (E2), 10 branch pairs were selected in 10 different trees. In each pair, one branch remained unthinned (T1), and in the other, the fruits were thinned, removing 50% of the fruits (T2).

Fruit size determination

During the experiments, the fruit growth was monitored by periodic measurements of their diameter with a digital caliper.

In the first experiment (E1), 20 fruits tree^{-1} were measured at each date. The measured fruits were chosen randomly at each measurement. Measurements were always made on the west side of the canopy and, whenever possible, on fruits that were at shoulder height.

In the second experiment (E2), all fruits from each selected branch were measured.

Fruit yield and biennial bearing index (BBI)

In the first experiment (E1), fruit yield (kg $tree^{-1}$) was accounted for both 2020 and 2021 years. The biennial bearing index (BBI) was calculated using Equation 1.

$$BBI = \frac{[2020\ \text{yield}\ (\text{kg.tree}^{-1})]-[2021\ \text{yield}\ (\text{kg.tree}^{-1})]}{[2020\ \text{yield}\ (\text{kg.tree}^{-1})]+[2021\ \text{yield}\ (\text{kg.tree}^{-1})]} \times 100 \quad (1)$$

In the second experiment (E2), all fruits from the identified branches were harvested and weighted, in both the 2020 and 2021 harvests.

Fruit quality

Fruit quality was measured after the 2020 harvest, using 20 fruits $tree^{-1}$ in the first experiment (E1) and all fruits that grew on the selected branches in the second experiment (E2).

Firstly, non-destructive analyses were performed, which included weight, diameter, and colour. The colour was measured with a colourimeter (Konica Minolta, chroma meter CR-400), which recorded the colour values in HunterLab colour space. Then, the citrus colour index (CCI) was calculated using Equation 2, where L, a, b are the coordinates of the Hunter Lab colour space.

$$CCI = \frac{1000 \times a}{L \times b} \quad (2)$$

After these determinations, destructive analyses were performed. Rind thickness was determined by calculating the mean between 2 measurements positioned at 90° between each other in the equatorial zone of the fruit. The total soluble solids (°Brix) was measured with a refractometer (ATAGO, PAL-BX|ACID1), at room temperature. The acidity in the fruit juice was determined by titration with a 0.1 M sodium hydroxide (NaOH) solution. Maturation index (MI) was calculated using Equation 3.

$$MI = \frac{\text{Total soluble solids (°Brix)}}{\text{Acidity (\% of } C_8H_8O_7)} \quad (3)$$

RESULTS AND DISCUSSION

Experiment 1 – fruit thinning on entire trees

1. Fruit size.

In the 2020 yield, from, at least, the middle of October 2019, the fruits from T2 trees were significantly bigger than the fruits from T1 trees (Figure 2). This pattern got increasingly pronounced until the harvest, in January 2020. In the last measurement, fruits from T2 trees were more than 5 mm bigger in comparison to fruits from T1 trees. These results prove that manual fruit thinning of 'Setubalense' mandarin increased fruit size, as intended. The positive effect of fruit thinning on fruit size has been reported in different citrus cultivars (Duarte et al., 2006, 1996; Guardiola and García-Luis, 2000; Liu et al., 2022; Ortolá et al., 1991).

In the 2021 yield, a similar pattern was observed (Figure 3). In September the fruits had a similar size in both treatments. However, from the middle of October 2020, the fruits from T2 trees kept getting bigger. It was not possible to measure 20 fruits $tree^{-1}$ as in the previous year since some of the trees did not even have 20 fruits in the entire canopy.

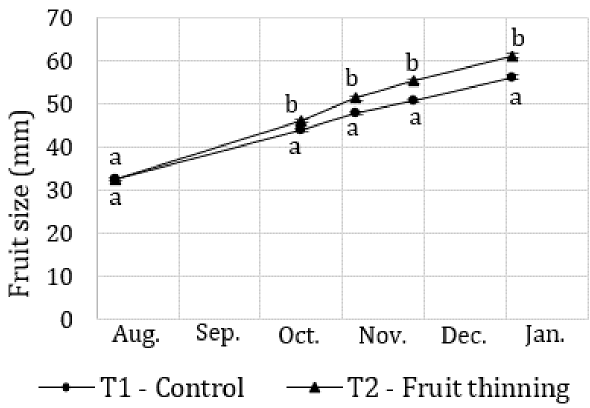

Figure 2. Fruit diameter (mm) on experiment 1, from 2019/2020 yield. Mean ± standard error; *n*=80. At each date, means with the same letter don't differ significantly from each other according to the t-Student test (p=0.05).

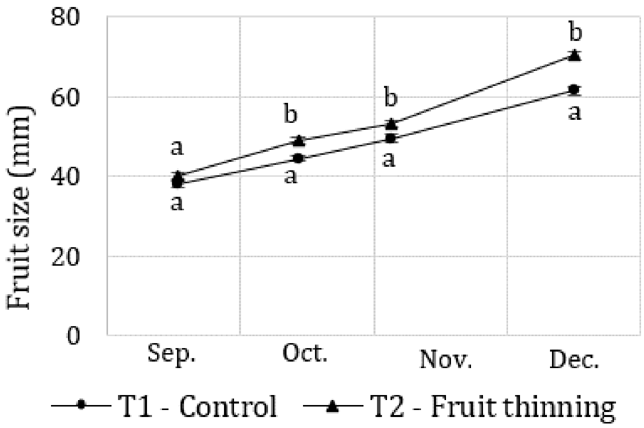

Figure 3. Fruit diameter (mm) on experiment 1, from 2020/2021 yield. Mean ± standard error; *n*(T1)=68; *n*(T2)=65. At each date, means with the same letter do not differ significantly from each other according to the t-Student test (p=0.05).

2. Yield.

The 2020 harvest was made in the first week of January. The yield (kg tree^{-1}) was significantly inferior on T2 trees (Figure 4) which was expected since 50% of the fruits were removed five months before the harvest. Usually, when the leaf/fruit ratio is increased by fruit thinning, the remaining fruits become larger but not in direct proportion to the increase of leaves per fruit ratio, causing yield reduction (Ouma, 2012). The 2021 harvest was also made in January. In both treatments, the yield (kg tree^{-1}) was equal and significantly lower than the 2020 yield (Figure 4).

The biennial bearing index (BBI), between 2020 and 2021 yields, was statistically similar in both treatments (Figure 5), suggesting that fruit thinning did not have any effect controlling alternate bearing. Besides, BBI was very high, almost 95% in T1 trees and 87% in T2 trees since 2021 yield was much lower than 2020 yield, regardless the treatment.

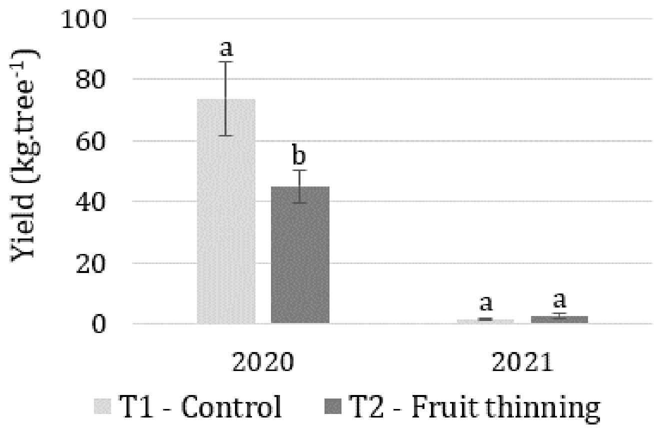

Figure 4. 2020 and 2021 yield (kg tree^{-1}) on experiment 1. Mean ± standard error; *n*=4. At each yield, means with the same letter don't differ significantly from each other according to the t-Student test (p=0.05).

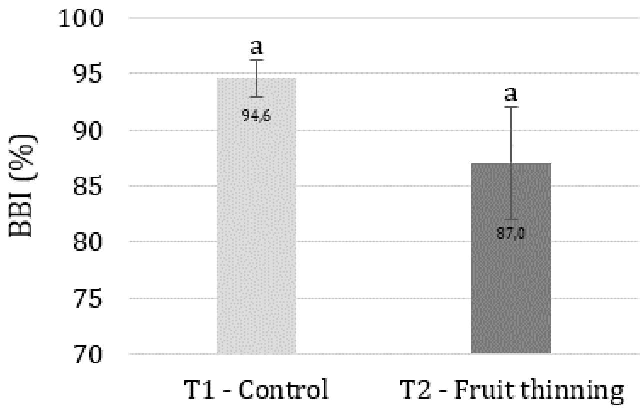

Figure 5. Biennial bearing index (BBI) on experiment 1. Means with the same letter do not differ significantly from each other according to the t-Student test (p=0.05).

Relation between the 2020 and 2021 yields (Figure 6) suggests that 2021 yield in T1 trees did not relate with the 2022 yield since the linear regression's slope was almost zero. The 2021 yield was low (1.3 to 2.1 kg tree^{-1}) regardless of what the previous year's yield was. Although, it seems that T2 trees had a slightly different scenario, where there appears to have been a negative relationship between the two yields, which makes sense. This means that trees with lowest yields in 2020 had the highest yields in 2021 and vice-versa. Yet, 2021 yield was very low, even in T2 trees (0.7-4.4 kg tree^{-1}).

In the 2020 yield, a relation occurred between the number of fruits tree^{-1} and fruit weight, in both treatments (Figure 7). This type of relationship between these two variables is normal and was observed by other researchers (Guardiola et al., 1982; Yildirim et al., 2012; Matias et al., 2020). The negative linear regression shows that the heavier the fruits, the fewer fruits tree^{-1}. However, although T2 presented fewer fruits tree^{-1}, the fruit weight was higher than T1 (Figure 7).

Fruit thinning (August 2019) was done before flower induction for the 2021 yield (Figure 1), which should have had some effect in reducing alternate bearing. However, the low production in the 2021 yield following fruit thinning was likely due to a lack of shoot formation before the 2020 blooming. During the year, in the northern hemisphere, citrus trees have essentially 3 shoot-forming seasons: spring, summer, and fall. Blooming, in single-annual-bearing cultivars, as in mandarins, occurs only in spring, and grows on branches that were formed during the summer and fall shoots of the previous year (Matias et al., 2023). The lack of new shoots in the summer and fall of 2019 could perhaps explain the lack of blooming in spring 2020, which formed the 2021 yield (Mesejo et al., 2020).

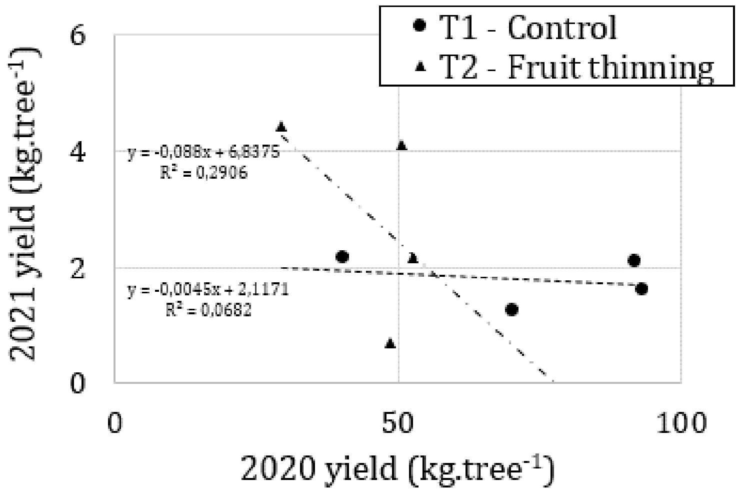

Figure 6. Relation between 2020 and 2021 yields (kg tree-1).

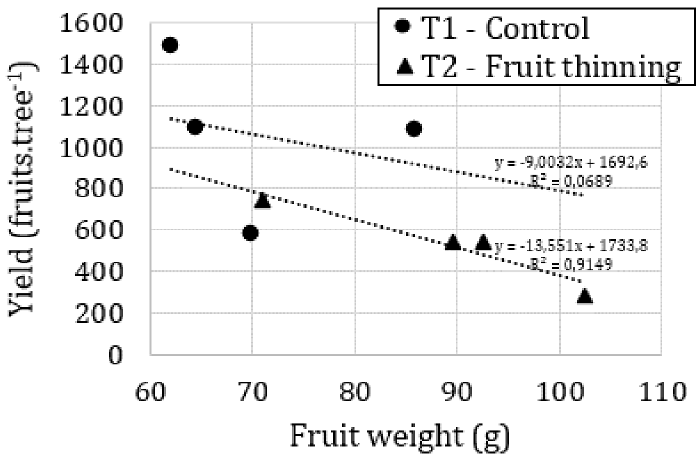

Figure 7. Relation and linear regression between fruit weight (g) and yield (fruits tree-1), from 2020 yield on experiment 1.

3. Fruit quality

Several fruit quality parameters were higher in fruits from T2 trees (Table 1), including fruit size, total soluble solids, and maturation index. Acidity was lower in fruits from T2 trees, indicating better fruit maturation (Julhia et al., 2019). The positive effect of fruit thinning on fruit quality has also been reported by other researchers in other mandarin cultivars (Liu et al., 2022; Brar et al., 1992) and orange cultivars (Khurshid and Sanderson, 2023). On the other hand, chemical thinning does not always result in improvements in fruit size or quality (Stander et al., 2018).

Table 1. Several fruit quality parameters from the 2020 yield.

Treatment	Weight (g)	Diameter (mm)	CCI	RT (mm)	TSS (°Brix)	Acidity (g 100 mL^{-1})	MI
T1 – Control	70.55 a	56.04 a	5.01 a	2.89 a	5.47 a	0.72 a	7.70 a
T2 – Fruit thinning	88.89 b	61.11 b	5.03 a	3.02 a	6.34 b	0.66 b	9.46 b

In each column, means with the same letter do not differ significantly from each other according to the t-Student test (p=0.05).
CCI – citrus colour index; RT – rind thickness; TSS – total soluble solids; MI – maturation index.

Experiment 2 – Fruit thinning on selected branches

1. Fruit size.

In the 2020 yield, the fruits from T1 and T2 branches were similar in size (Figure 8). In the 2021 yield, the selected branches did not have any fruits since the trees were in the "off" year in the alternate bearing. This shows that fruit thinning only on branches did not have any effect in the fruit size.

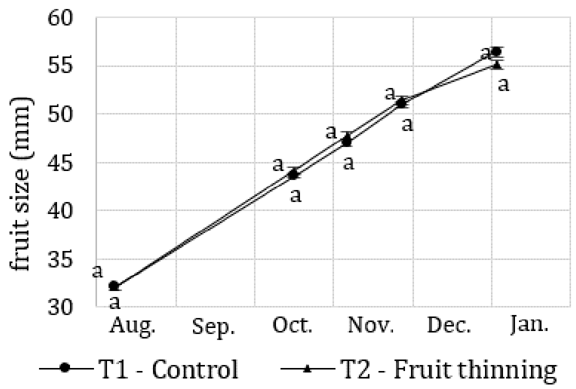

Figure 8. Fruit size (mm) on experiment 2, from 2020 yield. Mean ± standard error; n(control)=196; n(thinning)=115. At each date, means with the same letter do not differ significantly from each other according to the t-Student test (p=0.05).

At the last measurement, the relationship between fruit diameter and fruit weight (Figure 9) were similar in both treatments.

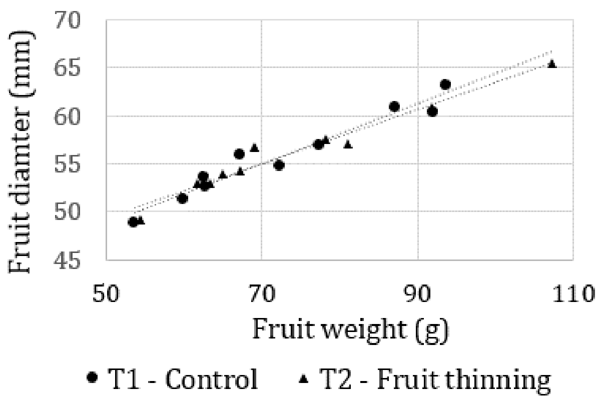

Figure 9. Relation between fruit weight (g) and fruit diameter (mm) at the last measurement (harvest).

2. Fruit quality.

Almost all fruit quality parameters tested were similar in both treatments (Table 2). Acidity seems to have been higher in fruits from T2 branches (0.02 g 100 mL^{-1} higher), but can be unrelated to the fruit thinning since were not observed differences in any other parameter.

Table 2. Several fruit quality parameters from the 2020 yield.

Treatment	Weight (g)	Diameter (mm)	CCI	RT (mm)	TSS (°Brix)	Acidity (g 100 mL^{-1})	MI
T1 – Control	73.54 a	56.39 a	4.90 a	2.67 a	5.25 a	0.65 a	8.12 a
T2 – Fruit thinning	70.53 a	55.14 a	4.90 a	3.62 a	4.87 a	0.67 b	7.30 a

In each column, means with the same letter do not differ significantly from each other according to the t-Student test (p=0.05).
CCI – citrus colour index; RT – rind thickness; TSS – total soluble solids; MI – maturation index.

CONCLUSIONS

The following conclusions can be drawn from the study:

- Fruit thinning in entire trees improved fruit size and quality in 'Setubalense' mandarin;
- Fruit thinning was not effective to control or manage alternate bearing in 'Setubalense' mandarin;
- Fruit thinning only on selected branches did not have any effect on fruit size or quality neither in controlling alternate bearing.

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The PodaCitrus website can be consulted at podacitrus.webnote.pt.

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