

# Analysis of Different Mechanical Pruning Strategies on the Production of 'Clemenules' Mandarin and its Costs

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## Abstract

Spain is the sixth citrus producer in the world and the first exporter for fresh consumption. However, the profitability of citriculture is going down due to the increasing production costs and the low prices perceived by farmers. Between farming operations, pruning is done manually, which represent around 12.5% of the total production costs. The objective of this study was to analyse the effect of different mechanical pruning strategies on the production of mandarins variety 'Clemenules' comparing them with manual pruning, and to determine their costs. A trial with a random blocks experimental design with 5 repetitions was carried out in a commercial Clemenules orchard located in Chiva (Valencia). During season 2017, eight pruning strategies were assessed: C (control, no pruning); M (manual pruning, with hand saw and pruning shears); and six mechanical pruning with disc pruner: TEW (Topping, Hedging both sides, East and West), TR (Topping, Manual follow-up), TER (Topping, Hedging Est side, Manual follow-up), TE (Topping, Hedging Est side), EW (Hedging both sides) and E (Hedging Est side). The results of trials showed differences in production and costs between the pruning strategies. C was significantly the most productive with 157 kg/tree; the following more productive were M, EW and E ranging between 128 and 132 kg/tree with no differences between them; and in a third level were all treatments where Topping was carried out (TEW, TE, TER and TR) that oscillate between 72 and 85 kg/tree without significant differences between them. Costs were higher for treatments with manual pruning. Cost for M was 441 €/ha and for the treatments with manual follow-up pruning they oscillated between 459 and 293 €/ha. However, the cost for mechanical pruning ranged between 25 to 110 €/ha depending on the number of machine passes. To get more consistent conclusions, more seasons comparing pruning strategies must be performed.

**Keywords:** disc pruner, mechanization, work capacity, citrus

## 1. Introduction

Spain is the sixth producer of citrus fruits worldwide and the first exporter for fresh consumption, to which it allocates around 50% of its production (MAGRAMA, 2015). Therefore, citrus fruits are a key product in the Spanish agrarian economy. Despite the social and economic importance of the cultivation of citrus fruits in the Valencian Community, serious problems of profitability are manifest; for example, the abandonment of farm exploitations. In fact, the useful agricultural area (UAA) has decreased from 2003 to 2013 by 9%. The lack of profitability is mainly due to excessive production costs. In Spain, production costs are very high and much higher than those of competing countries in foreign markets, such as the USA (Florida or California), or even countries that compete directly in the European market such as Morocco, Egypt or Israel (Juste et al., 2000). The main cause is the excess parcelling of agricultural land present in the Valencian Community, where approximately 28.5% of farms have sizes of 0.1-1 ha and 50% of 1-5 ha. In this context, reduction of production costs is the only tool available to the farmer to increase their profitability. That reduction could be achieved via the mechanization of the crop.

Pruning is a fundamental task for proper physiological development of citrus fruits. It consists of eliminating less productive or damaged branches, which leads to a better distribution of nutrients in the plant that reduces the amount of fruit produced, but increases its size and, therefore, its quality. In addition, the amount of light and aeration in the tree's crown is increased.

In Spain, this task has traditionally been done manually, gathering together a significant number of workers, which means an increase in production costs. The cost of pruning can amount to 21.6% of total production costs, not considering the harvest (Mateu, et al 2018).

In the USA, investigation into mechanical pruning began in the 1950s. According to Moore (1958) mechanical pruning supplemented with manual pruning could reduce costs by 30-50% without affecting the production or quality of lemons. In Spain, Zaragoza et al (1980, 1981) conducted the first experiments with mechanical pruning. They observed that, in general, yields from trees pruned both manually and mechanically decreased compared to the controls (without pruning), but the following year, when trees were not pruned, on average the yields were equal for all the treatments for the two biennia the trials lasted. Production in all the pruning treatments on 'Washington Navel' orange trees was lower than the unpruned treatments by 14%. No differences were observed

between the trees pruned by hand and those that were pruned mechanically. However, there was no difference between unpruned trees and trees pruned by hand for 'Salustiana' oranges, but there was a 17% reduction in the yield of those that were mechanically pruned compared to those that were not pruned. It is demonstrated that in the year in which mechanical pruning is practiced, production is reduced, but if the effect of mechanical pruning is analysed over several years, this effect is diluted because the tree compensates, in the years that it is not pruned, for the production lost in the years when it was mechanically pruned (Zaragoza and Alonso, 1980, Fallahi and Kilby, 1997, Kallsen, 2005, Rouse et al., 2006, Sauls, 2008, Mendonça et al., 2008, Yildirim et al., 2010; Martín-Górriz et al., 2014). However, few studies have been conducted on the influence of mechanized pruning in Spain and its effect on the different citrus varieties cultivated in the Valencian Community is unknown.

The objective of this study is to study the effect of different strategies of mechanical pruning versus manual pruning on the production and quality of 'Clemenules' variety mandarin oranges, the most important mandarin, and to determine their costs.

## 2. Materials and methods

The trial was carried out in a commercial plot of 'Clemenules' variety mandarin oranges of 3.4 ha located in Chiva (Valencia) 39°26'30"N, 0°32'60"W. The trees were planted with 6 m by 3 m row and tree spacing and over raised beds. Prior to the trial, all the treatments had received a pruning of the tree skirts.

The experimental design consisted of a random block design with five repetitions. Eight different treatments or pruning strategies were carried out: C (Control, no pruning), M (manual pruning, with hand saw and pruning shears), TR (Topping, Manual follow-up), TER (Topping, Hedging Est side, Manual follow-up), TE (Topping, Hedging Est side), TEW (Topping, Hedging both sides, East and West), EW (Hedging both sides) and E (Hedging Est side). A minimum of 20 trees was used per treatment and repetition, except the control, which was 5 trees. Two trees were selected at random in each treatment and repetition as an experimental unit for evaluation of production. A pruner with five cutting discs (Model Jumar FH666, Jumar agrícola S.L, La Rioja, Spain) and a tractor Landini 90 REX 90 CV (Landini, Fabbri, Italy) were used to perform mechanical pruning. Topping was done with two horizontal cuts, one for each side of the crown, to cover the entire crown, and hedging consisted of one cut on the side corresponding to the treatment.

In the case of mechanized pruning, the times used to make the different types of cuts were quantified during the pruning treatments and were used to determine the costs of the pruning operation for each strategy. The times for treatment were attained by totalling the times used in making the various cuts. In the case of manual pruning, the time it took for an operator to perform pruning per tree was quantified.

After pruning the trees, the characterization of the biomass pruned was carried out by measuring the following variables:

- Length of the branches cut according to the type of cut (cm). One hundred branches per type of cut were measured.
- Diameter of the cut branches according to the type of cut (mm). One hundred branches were measured per type of cut.
- Biomass attained depending on the treatment (kg/tree). The cut branches were weighed according to the type of cut made with a digital dynamometer (Advanced Force Gauge 500 N, Mecmesin, England, U.K.) and the weights obtained in the different types of cuts were totalled to obtain the total biomass per strategy.

To study the effect of pruning strategies on production, absolute production (kg/tree) was estimated in the two trees of the sample unit by treatment and repetition. To do so, the fruit harvested was weighed with the same digital dynamometer used for the biomass. In addition, the outer diameter calibre of a total of 50 fruits per treatment and repetition (mm) was measured with a digital calliper.

A simple variance analysis (ANOVA) was performed to study the effect of different pruning strategies on the response variables of absolute production and calibre. In all the analyses, it was verified that the data complied with the hypothesis of homoscedasticity by means of the Levene Test. The normality of the data was checked by analysing residuals on normal probability paper. The Least Square Differences (LSD) test was used to compare the means of the treatments. In all analyses, the confidence level was considered as 95%. A descriptive statistical analysis was carried out to study the biomass variable.

To obtain the theoretical work capacities, the time (min) used to prune a tree or to carry out the manual follow-up of half a tree or a complete tree was used in cases of manual pruning, and in the case of mechanized pruning, the time used in pruning at height or laterally at a known distance and knowing the number of trees in that distance was measured. The time used to make a pruning cut on a tree was calculated. Once the time spent per tree was attained, the number of trees pruned per hour (tree/hour) was calculated. To calculate costs, the cost of the pruner was considered at 7.88€/h, the cost of the tractor with the pruner and tractor operator at €39/h and a total of 556 trees/ha.

The following formula was used to obtain costs:

$$\text{Costs} \left( \frac{\text{€}}{\text{ha}} \right) = \frac{1}{\text{TWC}} \times C \times N \quad (1)$$

Where: TWC is the theoretical working capacity (tree/h); C is the cost in €/h of the machinery, plus the tractor operator or the pruners and N the number of trees/ha. The total costs were calculated by totalling the costs of manual and mechanical pruning.

### 3. Results and discussion

#### Characterization of biomass pruned

In the manual pruning treatments, the diameter of cut of the branches for 75% of the values are between 10-20 cm; maximum values were between 30 and 40 cm, whereas for the cuts with a disc pruner, the thickness of 75% of the cut branches oscillated between 6-10 cm and the maximum was between 16-18 cm. The values of diameter of cut braches for lateral and topping pruning were similar (Figure 1).

Similar to the cut diameter, the lengths of the cut branches are much greater for manual pruning, where 75% of the values are between 80 and 140 cm whereas 75% of the lengths of the branches cut with the pruner varies between 40-60 cm with similar values for hedging and topping (Figure 2). This is because the pruner accesses the interior parts of the tree and makes the cuts from the inside on main branches of greater thickness and length, while the disc pruner has no access to the interior and only cuts the twigs that are on the outside.

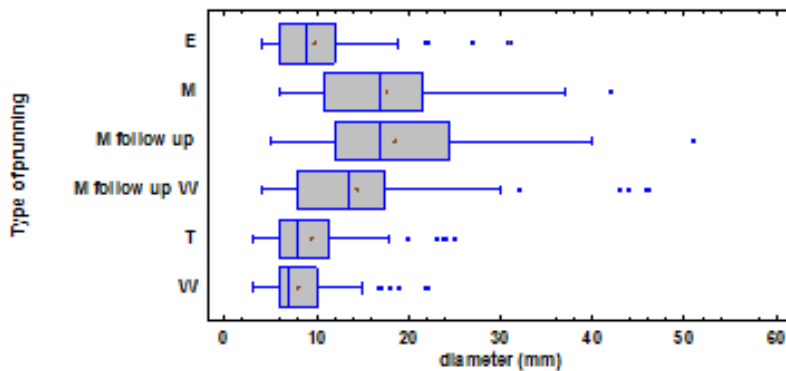


Figure 45. Diagram of boxes and whiskers of the cut diameter of the branches for each type of cut. C: Control; M: Manual pruning; TR: Topping, Manual Follow-up; TER: Topping, Hedging Est Side, Manual follow-up; TEW: Topping, Hedging both sides, East and West; TE: Topping, Hedging Est side; EW: Hedging both sides; E: Hedging Est side.

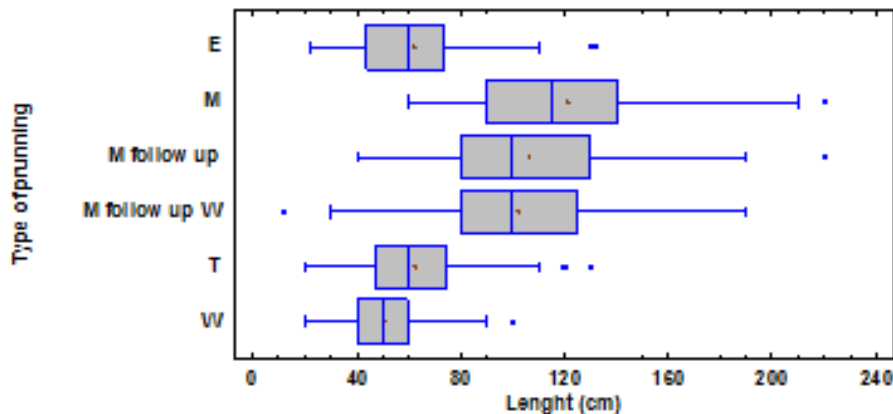


Figure 46. Diagram of boxes and whiskers of the cut length of the branches for each type of cut. C: Control; M: Manual pruning; TR: Topping, Manual Follow-up; TER: Topping, Hedging Est Side, Manual follow-up; TEW: Topping, Hedging both sides, East and West; TE: Topping, Hedging Est side; EW: Hedging both sides; E: Hedging Est side.

Table 77 shows the biomass obtained from the different treatments carried out. As expected, in the treatments that received manual pruning, whether manual pruning or a revision of manual pruning, the biomass is greater than in the treatments carried out with the disc pruner. In general, the biomass value for each pass of the mechanical pruner is around 4 kg/tree, whereas the biomass in the manual pruning of the total tree is 5 times higher.

Table 77. Mean biomass per tree depending on treatment. C: Control; M: Manual pruning; TR: Topping, Manual Follow-up; TER: Topping, Hedging Est Side, Manual follow-up; TEW: Topping, Hedging both sides, East and West; TE: Topping, Hedging Est side; EW: Hedging both sides; E: Hedging Est side.

Treatment	Mean biomass (kg/tree)
C	0
M	25.17
TR	22.09
TER	18.34
TEW	12.44
TE	8.014
EW	5.51
E	4.30

#### Pruning time, theoretical work capacity and costs

The working speed of the tractor was 2.1 km/h regardless of whether it was topping or hedging; hence, each pruning cut, for the given tree spacing, was 0.07 min/tree and it will take a total 0.31 minutes/tree to prune a tree mechanically on both sides plus topping (TWE). The time used to perform the manual pruning was 6.06 min/tree whereas the time used to perform the manual follow-up of the entire tree was 5.59 min/tree and the manual follow-up of half a tree was 2.93 min/tree. Table 78 shows the times used for each of the treatments, as well as the theoretical work capacities and costs. It can be observed how the TR treatment presents a higher cost than the M treatment, making evident that manual follow-up after mechanized pruning is not a viable option, since the time used by the pruner is practically the same as in the M treatment. When manual follow-up is done to only half a tree (TER) the cost is reduced by 34% compared to the 75% reduction in the TEW treatment. On the other hand, the reduction of the cost between mechanical pruning (€25 to 110/ha depending on the number of the pruner's cuts) and manual pruning (€441/ha) is very high being on the order of 75% in the case of making three cuts, and 80% if only one side and topping are pruned, and 94% if a single cut is made.

Table 78. Pruning time, theoretical work capacity and costs based on treatment type. C: Control; M: Manual pruning; TR: Topping, Manual Follow-up; TER: Topping, Hedging Est Side, Manual follow-up; TEW: Topping, Hedging both sides, East and West; TE: Topping, Hedging Est side; EW: Hedging both sides; E: Hedging Est side.

Treatment	Mean time	T.W.C	T.W.C mecanizada	Costs (€/ha)
C	0	0	0	0
M	6.06	9.9	0	441
TR	5.75	10.9	361.4	459
TER	3.16	21.1	254.3	293
TEW	0.31	0	196.1	110
TE	0.24	0	254.3	85
EW	0.14	0	428.6	50
E	0.07	0	857.1	25

#### Fruit calibre and production

Figure 3 shows the mean calibres of the fruit in the different treatments; although there were significant differences between the different treatments, they are all included in the same commercial category. Therefore, there would be no depreciation in the price.

Regarding the production of all the treatments that received pruning, they reduced production compared to the control treatment. On the other hand, in treatments where pruning at topping was carried out, a decrease in production was observed in comparison to treatments that did not receive this type of pruning, whether it is manual, mechanized pruning or treatment C (Figure 48). No significant differences were observed between the treatments without topping.

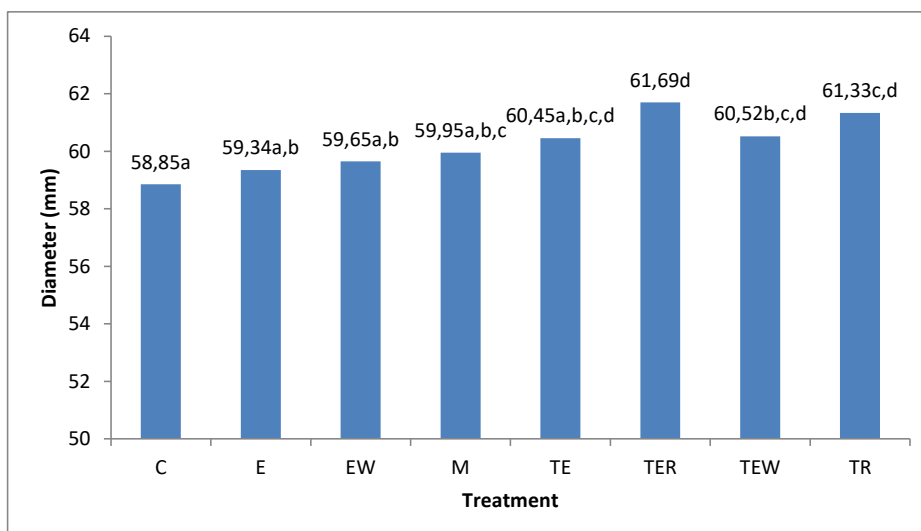


Figure 179. Mean calibres of the fruit (mm) depending on the pruning treatment. Different letters show significant differences between treatments (LSD,  $p < 0.05$ ). C: Control; M: Manual pruning; TR: Topping, Manual Follow-up; TER: Topping, Hedging Est Side, Manual follow-up; TEW: Topping, Hedging both sides, East and West; TE: Topping, Hedging Est side; EW: Hedging both sides; E: Hedging Est side.

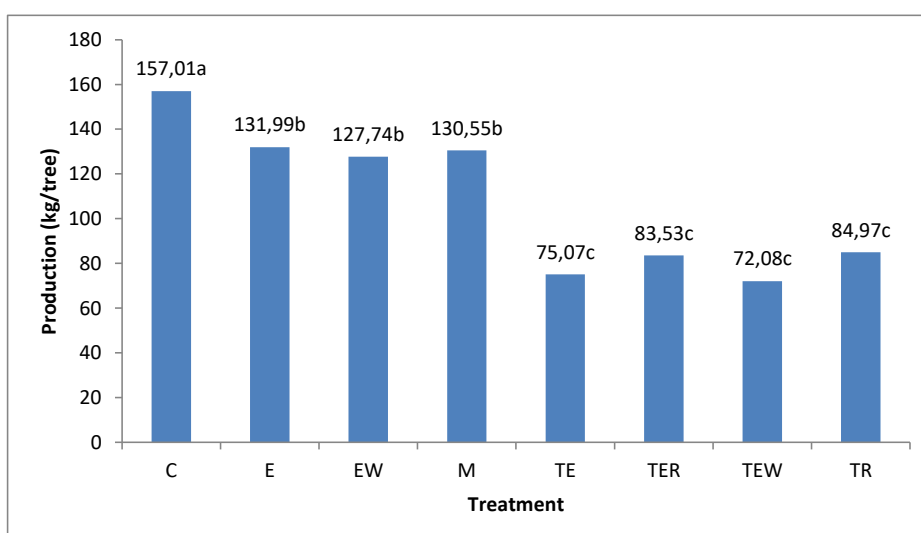


Figure 48. Mean absolute production per tree (kg/tree) based on treatment. Different letters show significant differences between treatment (LSD,  $p < 0.05$ ). C: Control; M: Manual pruning; TR: Topping, Manual Follow-up; TER: Topping, Hedging Est Side, Manual follow-up; TEW: Topping, Hedging both sides, East and West; TE: Topping, Hedging Est side; EW: Hedging both sides; E: Hedging Est side.

#### 4. Conclusions

The highest yields were obtained in treatment C followed by those obtained in treatments E and M. If we observe the calibres, the highest is in the TER treatment. Although there is variation in the size of the fruit, the calibres obtained are all in the same commercial category, which means there is no depreciation of the commercial value of the fruit. The totally mechanized pruning implies a 75% reduction in cost compared to manual pruning.

As has been observed for the 'Clemenules' variety, all treatments in which mechanical pruning was performed at topping had lower production. For that reason, the possibility of combining manual pruning and mechanized lateral pruning in different campaigns could be considered.

These data were attained in a single year; to be able to draw conclusions, it is necessary to repeat this test over several years to observe the performance of this variety with mechanized pruning and its influence on fruit production and quality.

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