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Long-Term Evaluation of the Influence of Mechanical Pruning on Olive Growing

A. B. Dias,* J. O. Peça, and A. Pinheiro

ABSTRACT

In Portugal, olive (*Olea europaea* L.) traditional groves of around 100 trees ha^{-1} necessitate increasing pruning costs every year. As a result farmers tend to lengthen pruning intervals. With the purpose of studying an alternative to the expensive, labor-intensive manual pruning practice, field trials were established with three treatments: (i) manual pruning with a chain saw; (ii) mechanical pruning, performed by a tractor mounted circular disc-saws cutting bar; and (iii) mechanical pruning, as in the mechanical pruning treatment, followed by a manual pruning complement. Olive production and harvesting efficiency were evaluated every year for 8 yr. Olives were harvested with a trunk shaker, and the remaining nondetached fruits were collected manually. The pruning rate of mechanical pruning (487 trees h^{-1}man^{-1}) was substantially higher than the values of manual pruning and mechanical+manual pruning, which were the same (20 trees h^{-1}man^{-1}). Over the 8-yr period, mechanical pruning had an average yield of 36.4 kg tree^{-1} yr^{-1} which was significantly higher than the 30.1 kg tree^{-1} yr^{-1} of manual pruning and no significantly different from the 34.1 kg tree^{-1} yr^{-1} of mechanical+manual pruning. The shaker efficiency was significantly influenced by the year, ranging from 72 to 96%; no significant differences were found between treatments in terms of harvesting efficiency. Results indicate that after mechanical pruning trees can be kept for at least 8 yr without any significant loss in olive yield and no effect in harvesting efficiency, therefore reducing costs. Mechanical+manual pruning, performed in the same year, did not yield further improvement.

It is a fact that farmers face increasing costs on labor-intensive manual pruning of olive trees. Pruning intervals tend to be lengthened and trees are left severely pruned when finally the operation is performed. It is expected that such substantial reduction in the volume of the canopy may lead to a decrease in production, at least in following years until the tree has recovered. Although no precise data was found available to quantify the overall problem, it is believed that a cheaper, more mechanized, less labor-intensive technique is needed. These facts justify this study.

A mechanized alternative involves pruning cuts made in the tree canopy by a tractor-mounted cutting device progressing at a constant speed between the tree rows (Pastor and Humanes, 1998). The potential of mechanized vs. manual pruning was previously shown in long-term research by these authors. They conducted rain-fed field trials in a 12 by 12 m olive grove array using the Picual cultivar. Observations from 1981 to 1997 revealed similar olive yield per tree in mechanized and manual pruned trees. These authors also stated the importance of occasional manual selective pruning to clear excessive wood from trees that were subjected to mechanized pruning.

Pastor and Humanes (1998) also conducted rain-fed field trials in a much denser olive grove of 8 by 4 m using the same cultivar. The objective was to compare different intervals for mechanized pruning with traditional manual pruning. Observations from 1981 to 1989 revealed that in all the mechanized pruning tests, irrespective of pruning interval, olive yield per tree was similar to the yield of manual pruned trees. These tests indicate that mechanized pruning does not need to occur at frequent intervals, thus it can be part of a management program that reduces costs.

Pastor and Humanes (1998) also conducted field trials of different pruning methods executed every 2 yr, methods included selective manual pruning, mechanical pruning, and mechanical pruning complemented by a manual clearing of excessive wood. Observations from 1989 to 1997 revealed that all the mechanized pruning treatments with or without manual complement, resulted in similar olive yield per tree which, in turn, was significantly higher than the yield of manual pruned trees. This research emphasized the potential of mechanized pruning as well as suggesting that a selective manual complement to the mechanized pruning does not provide any further advantages. Fontanazza and Baldoni (1991) and Fontanazza (1996) put forward sequences of pruning action combining mechanized pruning and manual pruning to be performed in different years.

The potential of the sequence suggested by Fontanazza (1996) was evaluated by Camerini et al. (1999). Field trials were conducted in a rectangular array of 6 by 3 m, 8 yr-old olive grove of the Frantoio and Leccino cultivars, trained as "monocone". The sequence started by hedging both sides of the tree in the first year, no cut in the second year, followed by manual pruning in the third year to clear excessive wood. Observations over a period of 9 yr revealed that trees subjected to the purposed pruning sequence showed an average 59% increase in olive yield relative to trees strictly manual pruned. Fontanazza (1996) and Giametta and Zimbalatti (1994) reported an important increase on rate of pruning using mechanized techniques even if a manual pruning complement is required. Other researchers (Pastor,1982;

Departamento de Engenharia Rural da Universidade de Évora/Instituto de Ciências Agrárias e Ambientais Mediterrânicas, Núcleo da Mitra, Apartado 94, 7002-554 Évora, Portugal. Received 6 May 2011. *Corresponding author (adias@uevora.pt).

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Giametta and Zimbalatti, 1997; Ferguson et al., 2002; Lodolini et al.,2006), also made contributions to the evaluation of mechanical pruning. Their results are short term, however, being based on 2, 3, 4, and 3 yr of data, respectively.

As a general overview of the published work one may conclude that mechanized pruning brings no loss in olive yield and it is performed much faster. Specifically, there are different responses according to different olive production systems (tree density, tree training, varieties, irrigation, etc.) meaning any new pruning method must be assessed according to the realities of each production system.

The present work extends the present knowledge of mechanical pruning of olive trees, complemented or not by a manual selective cuts, regarding the effect on yield over a large period of time, and makes the original contribution of the effect of these techniques on shaker performance.

MATERIALS AND METHODS

The olive grove is located in the Alentejo region of southern Portugal, within Herdade de Torre de Figueiras (39°3'34" N; 7°28'22" W). This olive grove is rain fed, 35 yr of age, planted to the local olive oil cultivar Blanqueta of Elvas, and having a 10-m distance between trees planted in a triangular array. The orchard is privately owned and characterized by high standards of husbandry.

Mechanical pruning was used, and a R&O (Reynolds & Oliveira Ltd., Monte da Granja- Estremoz, Portugal) pruning machine was mounted on a front loader of a 50*kW* (DIN) 4WD agricultural tractor. The pruning machine (Fig. 1) has a 3-m cutting bar with six hydraulically driven circular disc-saws. The cutting bar could be positioned at a height of 0.5 to 5.2 m, with cuts possible at angles ranging from horizontal to vertical. Manual pruning and the manual pruning complement to mechanical pruning were executed by means of hand-held chain-saws. Harvesting was done using an 88 *kW* (DIN) self-propelled multidirectional OMC (Orchard Machinery Corp., Yuba City, CA) trunk shaker.

In the winter of 1997, three treatments were established. Treatments included (i) manual pruning performed by one man per tree, making selective cuttings with a chain-saw to open the canopy to the sun and to clear the tree from all the woody nonproductive branches, (ii) mechanical pruning consisting of a horizontal cut at the uppermost part of the canopy (topping), approximately 1-m deep, performed using the pruning machine, and (iii) mechanical pruning followed by a manual pruning complement. This manual pruning complement is done to further clear the tree from undesirable nonproductive wood. Trees were not pruned again during the experiment. From here forward, Treatments i, ii, and iii will be referred to as manual, mechanical, and mechanical + manual, respectively.

The experimental design was a randomized complete block with three replications, leading to nine plots with 40 trees per plot. A sample of 10 trees, randomly selected from each plot, was kept without any further pruning for the 8 yr of the experiment, leading to a total of 90 trees included in the study. At harvest these 90 trees were individually managed. Total yield per tree was obtained based on the mass of olives detached by the shaker plus those that the shaker was unable to detach and that were manually removed from the tree. Fruit drop before harvest was small and therefore not considered.

Fig. 1. R&O pruning machine at work.

Harvesting efficiency was calculated as follows:

$$\text{Harvesting efficiency } (\%) = \frac{\text{Mass collected by the shaker}}{\text{Total yield}}$$

Alternatively to a fixed amount of time imposed for vibrating, the length of time for vibration was left for the olive-harvester operator to decide. This decision was justified by the fact that there were variation in yield among trees, even within a particular pruning method and, consequently, a fixed amount of vibrating time could be insufficient for trees with a larger yield and above the required for trees with lower yield, leading to artificial values of harvesting efficient by defect or excess, respectively.

Furthermore vibration has a minor influence since harvesting rates are, above all, dependent on the time spent moving the shaker from one tree to the next (Almeida et al., 2001).

Data were submitted to ANOVA using MSAT-C software. One factor randomized complete block design combined over years were the model used. Pruning treatment was considered as fixed effect and year was considered as random effect. For significant ($P < 0.05$) effects further multiple comparison was completed by the Multiple Range Duncan tests for the corresponding treatments combinations.

RESULTS AND DISCUSSION

Olive yield and the vibrating time of the trunk shaker are affected by the influence of year, pruning treatment and interaction year × pruning treatment (Table 1), although shaker harvesting efficiency was only influenced by the conditions of the year.

The oscillation on yield common on this specie (Lavee, 1996) is apparent in the results, particularly in the 3 yr following pruning, however the influence of all the factors that may influence olive

Table 1. *P* values from the analysis of variance for the effect of years after pruning olives trees, pruning treatment and years × pruning treatment on yield and shaker performance (vibrating time and harvesting efficiency).

Source	Yield	Vibrating time	Harvesting efficiency
Year	0.0000†	0.0000	0.0000
Pruning treatment	0.0045	0.0002	0.1076
Year × pruning treatment	0.0037	0.0010	0.4005

† *P* values that suggest significance of the effects requiring multiple comparison are in italics.

Table 2. Influence of the interaction of years after pruning olives trees × pruning treatment on olive yield per tree (kg tree^{-1}).

Treatment	1997	1998	1999	2000	2001	2002	2003	2004
Manual	26.4hi†	10.9j	43.8cf	21.2ij	16.9ij	43.6cf	19.7ij	58.7ab
Mechanical	26.8hi	20.6ij	51.4bd	18.2ij	35.8eh	33.2fh	41.0df	63.9a
Mechanical + manual	28.2gi	17.4ij	45.1ce	20.0ij	35.0eh	35.9eh	38.5eg	53.0bc

† Means followed by the same letter are not significantly different by Duncan multiple range test at the 5% level.

yield at a particular year was not addressed in this study, since the main objective was to evaluate different pruning techniques.

With the exception of two campaigns (2001 and 2003) olive yield (Table 2) of mechanical pruning and of manual pruning did not vary significantly ($P < 0.05$). However, in those 2 yr the yield of manual pruning was significantly lower ($P < 0.05$). Taking into account the historic yield of manual pruning, these 2 yr were particularly disastrous for this treatment. It is most relevant to state that the observed lower yields were not due to a generalized decrease in yield on every of the 30 trees of the sample, but inexplicably due to the fact that 25% in 2001 (23% in 2003) of the trees of the plot did not produced. Over the period of eight campaigns the average yield for mechanical pruning (36.4 kg tree^{-1} yr^{-1}) was significantly ($P < 0.05$) higher than for manual pruning (30.1 kg tree^{-1} yr^{-1}). These results relative to the potential of mechanical pruning as a method for reducing labor dependence, without negative influence in production, are in line with the results obtained by Pastor and Humanes (1998) in Andaluzia-Spain.

There are significant differences ($P < 0.05$) between years in harvesting efficiency and in the vibrating time (Table 3), reflecting noncontrolled aspects like different tractor operators and fruit maturity at harvest. Vibrating time was significantly ($P < 0.05$) influenced by the interaction years × pruning treatments (Table 1). With the exception of 2 yr (1998 and 2003) there were no significant differences ($P < 0.05$) between manual pruning and mechanical pruning in vibrating time.

With the exception of 2004, no significant differences ($P < 0.05$) were found on olive yield for mechanical pruning and for mechanical+manual (Table 2).

Over the period of eight campaigns the average yield of mechanical pruning (36.4 kg tree^{-1} yr^{-1}) was no significantly different ($P < 0.05$) from mechanical+manual pruning (34.1 kg tree^{-1} yr^{-1}). These results were also observed by Pastor and Humanes (1998), although differences in the methodology used, but leading to the common conclusion that a manual complement simultaneous with mechanical pruning brings no sensible advantage in terms of yield.

Furthermore, in every one of the eight harvesting campaigns no significant differences ($P > 0.05$) in harvesting efficiency was observed between mechanical pruning and mechanical + manual pruning. There were significant differences ($P < 0.05$) between years in the vibrating time (Table 3), reflecting noncontrolled aspects like different tractor operators and fruit maturity at harvest. Only in the campaign of 2004 (Table 4) the vibrating time required by mechanical + manual pruning was significantly ($P < 0.05$) higher than the time required by mechanical pruning.

The mechanical pruning obtained a pruning rate of 487 trees h^{-1} man^{-1} compared to the 20 trees h^{-1} man^{-1} for manual pruning leading to a potential advantage in costs, is less dependent on worker's skills and brings flexibility to the year-round planning of the olive grove. These results are valid for flat olive groves, free of obstacles and should be regarded valid for a pruning machine with a cutting bar wide enough to cut each tree in a single pass. If more than one pass is required the pruning rate will be reduced to less than half the present value (Peça et al., 2002). It is also envisaged that a deeper cut of the canopy will reduce the pruning rate. It is relevant to find the same pruning rates in manual pruning and in mechanical+manual pruning. This may be regarded as a lack of training of the labor employed toward the more selective approach required by mechanical+manual pruning. The reduction in pruning rate brought by the manual complement mean that advantages in management flexibility and costs are lost; Giametta and Zimbalatti (1994) refers mechanical pruning rates of 34 trees per man hour. The substantially lower work rates can be explained by a narrow cutting bar and a more complex cutting pattern imposed on trees, with lateral vertical cuts as well as topping.

It is assumed that there will be different responses according to different olive production systems (tree density, tree training, varieties, irrigation, etc.) meaning any new pruning method must be assessed according to the realities of each production system. Although it was observed that after mechanical pruning trees can be kept without pruning for longer periods, it is currently accepted that a manual intervention is required to free the canopy from excessive nonproductive wood (Pastor

Table 3. Influence of years after pruning olive trees on shaker performance in terms of harvesting efficiency (percentage of fruit removed) and vibrating time (s tree^{-1}).

Year after pruning	Harvesting efficiency	Vibrating time
Pruning year	88.6b†	5.0d
first	96.4a	7.2c
second	80.9cd	11.2b
third	79.9cd	7.6c
fourth	80.2cd	7.0c
fifth	72.3e	10.4b
sixth	83.2c	9.8b
seventh	76.4de	23.5a

† Means followed by the same letter are not significantly different by Duncan multiple range test at the 5% level.

Table 4. Influence of the interaction years after pruning olives trees × pruning treatment shaker vibrating time (s tree^{-1}).

Treatment	1997	1998	1999	2000	2001	2002	2003	2004
Manual	4.7j†	6.1hj	10.6cd	7.4gh	6.0hj	11.1cd	8.4eg	21.6b
Mechanical	5.6ij	8.3fg	12.1c	7.7gh	7.3gi	10.1de	11.1cd	22.6b
Mechanical + manual	4.9j	7.2gi	11.0cd	7.8gh	7.7gh	10.1d	9.9df	26.4a

† Means followed by the same letter are not significantly different by Duncan multiple range test at the 5% level.

and Humanes, 1998). Opportunity for this manual pruning and periodicity is currently addressing further investigation to analyze its implication on yield and harvesting efficiency.

These tests indicate that after mechanized pruning (horizontal cut at the uppermost part of the canopy) trees can be kept for at least 8 yr without any significant loss in olive yield per tree and no effect in harvesting efficiency, therefore reducing costs.

Selective manual complement to the mechanized pruning, performed in the same year, does not provide any further advantages in olive yield nor in shaker performance and consequently increasing production costs.

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