Mechanical Pruning Tests and Economic Analysis in Spanish Intensive Olive Growing Systems

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Abstract
Modern olive cultivation development is closely connected to the mechanization of pruning operations which, together with harvesting, influence considerably olive-tree yields and productions quality. The objective of the present study is to assess performances, and economic aspects, of mechanized pruning operation in spanish intensive olive-groves. The intensive cultivation system (density of 250-600 trees/ha) is still very effective, and in order to make it more competitive, there is an increasing interest towards pruning interventions made using machines able to carry out both topping and hedging. Tests, carried out in Spain concern two different olive-groves cultivated in pots and in monocone. The technical results of this study will be used to carried out an economic analysis aims to assess the convenience of mechanical innovations in olive farm. The economic efficiency will be evaluated in terms of saving in labour, to investigate the economic validity of technological innovations in olive growing, based on the criteria of intensive fully mechanized cultivation. The obtained advantages through the employment of machines able to carry out topping and hedging, and speed pruning operations, are notable. Indeed, it is possible to prune a hectare of olive-grove in about one hour, as it is demonstrated by the working operating capacity brought out during the tests. The economical analysis carried out shows that the use of these machines is particularly interesting since it allows to effectuate a cultural intervention often neglected because of its high costs.

Keywords: mechanization, pruning operations, economic analysis

Introduction

The world olive growing situation presents a complicated outline, where the distinctive aspects concern the spreading of an olive growing characterized by high production costs and low productivity. Inside this scenery it is very important to support a process of modernization which can allow the passage from the traditional growing systems to others which involve a specialized and intensive olive cultivation, with a larger number of trees per hectare, a stronger use of modern agricultural techniques together with a higher level of mechanization.

During the 70s, consequently to the crisis of the traditional olive cultivation, which started in the half of the 50s with the rural emigration and become more marked in the 60s for the competition of other vegetable oils, the so-called "new olive-cultivation" started in Europe. The aim of this "intensive" new olive cultivation was to realize plantations fit for the mechanical harvest with trunk shaker, characterized by a precocious production and higher productivity. Spain was one of the first countries which adopted these modern cultivation techniques, by increasing planting densities of olive-groves with 500 plants/ha (Rallo *et al*.,

2006). At the beginning of the 90s, a new olive cultivation technique developed in Cataluña, with the use of the superintensive model allowed to have 2000 and over plants per hectare. This density was considered impossible, until then, for a centuries-old species as olive is; in fact it was employed only for apple and pear trees on dwarfing rootstock and for peach-trees afterwards (Loreti, 2007). While the superintensive model is spreading all over the world very quickly, although all the matters about its sustainability, the "intensive" cultivation system, with plants grown in pots and in more modern "single cone" forms is still very effective and, in order to make it more competitive, there is an increasing interest towards pruning interventions which can be made using machines able to carry out both topping and hedging (Lodolini *et al*., 2006).

In this work, carried out in Spain, are reported the results relative to the first year of mechanical pruning tests, carried out in intensive olive cultivation systems. The aim of this research was to evaluate the achieved performance and make a comparison in terms of productivity and quality with the previously done work. During the tests, operational time assessment was carried out according to the formalities provided for by C.I.O.S.T.A. classification.

Materials and methods

The tests, carried out in Spain (Reus) concern two different olive-groves: **Olive-grove A** cultivated in pots and **Olive-grove B** cultivated in single cone. Both systems, made up of thirteen-year-old "Arbequina" plants (selection Agromillora), present flat position, North-South direction and are provided with drop fertirrigation. The olive grove cultivated in pot has planting density of meter 4.50 x 3.50 (635 plants/ha), plants of 3.15 m high and crowns of 0.70 m from the ground; the single cone olive grove has a planting density of m 4.50 x 3.00 (741 plants/ha), plants of 3.20 m high and crowns of 0.90 m from the ground. The dimensional and technical characteristics of the tested areas are reported in table 1.

The work equipment is made up of the single worker operating the pruning machine. The beginning of each survey is the moment when the machine is in front of the row ready to start the pruning and the final point is when the work in the tested areas ends. In both olive-groves the intervention scheme, elaborated on a triennial base, envisages for the first year the cut of a single hedge along the rows to be carried out with a double passage of the machine.

The first passage provides a cut with an average inclination of 20-25° off the vertical and an average depth of about 0.70 m in the crown; the second passage provides a cut with an inclination of 10-15° off the horizontal. This scheme envisages the same intervention on the opposite hedge in the second year, while in the third year the topping, together with a manual final touch, is envisaged. The pruning machine employed, mounted towards the front on a 40 kW self-propelled fork-lift truck, is comprised of a series of two couples of sharp toothed wheels with a diameter of 0.60 m e 0.65 m, placed on the same supporting shaft (figure 1). These hydraulically operated wheels are made of tempered steel and have teeth in widia plates in order to facilitate the work; they have a rotation speed of 2.000-2.500 cycles/min and are able to cut branches with a diameter of over 8 cm without problems.

Table 1. Dimensional and technical characteristics of the tested areas.

Tested areas		**Olive Grove A**	**Olive Grove B**
Dimensional characteristics before pruning			
Elements	Measurement Unit	Value	
Plants height	[m]	3.15	3.20
Crown longest diameter	[m]	3.80	3.60
Crown shortest diameter	[m]	2.40	2.33
Crown volume	[m^3]	6.10	7.13
Avenue width	[m]	0.70	0.90
Dimensional characteristics after pruning			
Plants height	[m]	3.15	3.20
Crown longest diameter	[m]	3.15	3.05
Crown shortest diameter	[m]	2.40	2.33
Crown volume	[m^3]	4.83	4.27
Avenue width	[m]	1.35	1.45
Olive grove technical characteristics			
Age	[years]	13	13
Density	[p/ha]	635	741
Tested rows	[n]	4	4
Row average length	[m]	147	210
Plants per row	[n]	42	70
Work equipment	[n]	1	1

Figure 1. Pruning machine used during the tests

Results

Table 2 reports the data about working times collected during the first year of tests for both olive groves. These data show that the working operating time (TO) is, on the average, equal to 0.94 h/ha, the additional time (TA) is equal to 0.10 h/ha, while the dead time (TM) is equal to 0.35 h/ha.

Table 2. Collected data about times during mechanical pruning tests for both theses

Olive Grove	TE [h/ha]	TA [h/ha]	TO [h/ha]	TM [h/ha]	TU [h/ha]
A	0.77	0.10	0.87	0.40	1.03
B	0.97	0.10	1.01	0.30	1.39

Note:
TE = Effective time TA = Additional time TO = Operating time TM = Dead time TU = Usage time

These data about times demonstrate working productivity and efficiency whose values are reported in table 3, show that the average advance speed of the pruning machine along the rows is equal to 2.60 km/h; so the working capacity referred to the operating time is 1.12 ha/h for olive grove A and 0.94 ha/h for olive grove B.

Table 3. Data about working capacity and productivity collected during the tests

Taken away wood		Pruned branches diameter		Pruning machine advance speed	Working capacity	
		< 4 cm	> 4 cm		Referred to TO	
[kg/plant]	[t/ha]	%		[km/h]	[ha/h]	[t/h]
Olive grove A						
6.3	4.0	70	30	2.88	1.12	4.48
Olive grove B						
3.5	2.6	65	35	2.27	0.94	2.45

The quantity of taken away wood is equal to 6.3 kg/plant in olive grove A e 3.5 kg/plant in olive grove B, with an average value of 3.3 t/ha. The diameter of 68% of pruned branches is, on the average, shorter than 4 cm.

Economic analysis

In olive cultivations, pruning is the second demanding practice just after harvesting from an economic point of view, as it generally accounts for 20-40% of annual production costs, depending on its type and frequency (Lodolini *et al.*, 2006). Therefore, in order to reduce production costs, considering, the increasing of agricultural labour cost and the scarcity of skilled labour, it is necessary to apply mechanized techniques for pruning and harvesting (Gucci *et al.*, 2000).

According to statistical data available from the Spanish Department of Environment and Rural and Marine, in 2008, the national average wage by categories (euro/day) was represented by the following values: 50.10 euro/day for skilled labor and 35.60 euro/day for not skilled one. The present study carries out a comparative analysis between manual and mechanical pruning costs, considering data from both, literature (Fontanazza *et al.*, 1998; Pastor *et al.*, 2006; Sillari *et al.*, 1998; Zimbalatti *et al.*, 2009) and experimental tests. The cost of manual pruning effectuated by a labour constituted by three men using chainsaws represents a total amount of 177,7 €/ha. On the other side, mechanical pruning which was effectuated just by one operator

driving the machine (tests A and B), and completed by a final manual touch, costed 79,44 €/ha (average of the two tests). In conclusion (table 4; figure 2), it can be affirmed that with mechanical pruning it is possible to economize approximately the 55,3% of pruning labour costs in olive cultivations.

Table 4. Data about working capacity and productivity collected during the tests

	Manual Pruning	**Test A**		**Test B**	
		Mechanical pruning A	*Manual final touch A*	*Mechanical pruning B*	*Manual final touch B*
Work rate (h/ha)	22.70	1.03	7.57	1.39	7.57
Pruning labour costs (€/h)	7.83	5.56	7.83	5.56	7.83
Pruning labour costs (€/ha)	177.7	5.73	59.25	7.73	59.25
Total labour costs (€/ha)	**177.7**	**17.19**	**59.25**	**23.20**	**59.25**

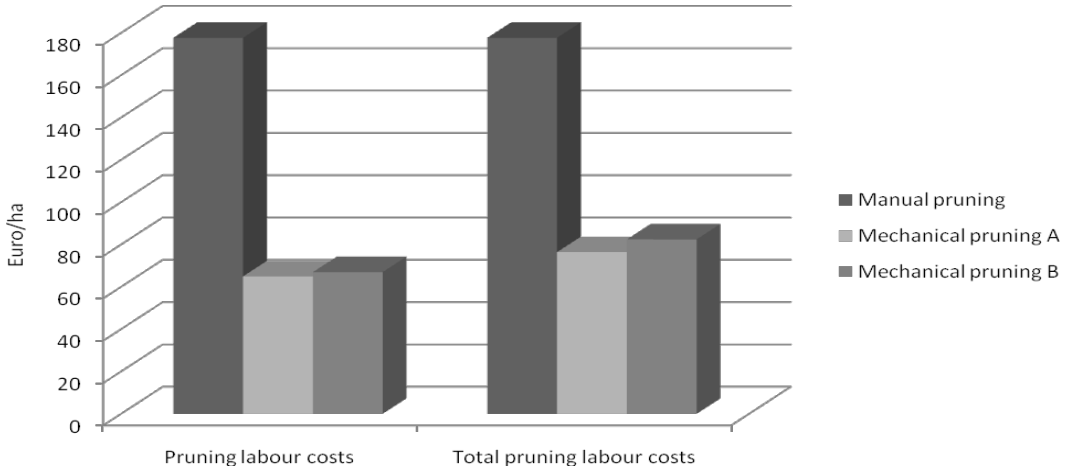

Figure 2. Comparison between pruning labour costs

Conclusions

Mechanical pruning employment in the intensive olive grove, besides cutting down the costs, it is reduced to a uniform cut of the tree-crown which can be carried out without particular problems (Giametta *et al.*, 1997). The cut efficiency of these machines is obvious, so that it is possible to prune a hectare of olive-grove in about an hour. This pruning system is particularly fit for single cone cultivations.

As concerns pot cultivations, for the different opening of branches, the machine operator could have some problems in case of drastic pruning, since he could inadvertently cut whole branches. This could undermine the tree structure and make manual pruning interventions necessary in order to restore the cultivation kind chosen. Moreover mechanical pruning is not selective, since useful and useless wood is removed; so a reduction of buds, with a consequent fall of production, can occur. However, since this is only the first year of experiments, final remarks about olive vegetative/productive aspects cannot be expressed, yet. All these indications can be available only after further, thorough studies. It is easy to foresee

that the mechanization of pruning operations will be very successful in the future, since it is an effective solution to carry out this expensive, but important, cultivation practice.

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