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Mechanical harvesting in traditional olive orchards: oli-picker case study

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Abstract. Olive harvesting is one of the most laborious and expensive agricultural practices. Indeed, it absorbs 50% of the product value, and this is due to the continuous increasing of labour from one hand and to the lake of labourers from the other hand. Traditional olive orchards are characterized by the presence of large, century old trees and a very low planting density. These conditions make it difficult to plan sustainable and highly productive harvesting models, and therefore require the employment of partially or fully mechanized harvesting systems. In this context, experimental trials were carried out in a traditional olive orchard, situated in Calabria (Southern Italy), in order to assess technical and economic aspects of a commonly used harvester named oli-picker. This machine allows olive harvesting from tree canopy thanks to a spiked cylindrical comb mounted on a hydraulic articulated arm. Particularly, data about operational working time as well as working productivity were collected for technical purposes, whereas economic evaluation considered harvesting cost expressed in terms of cost per hour, cost per unit of product (1 kg of olives) and average cost per hectare. The obtained results highlighted that working productivity referred to the operative time, was 0.37 trees h^{-1} $worker^{-1}$, while the cost per kg of harvested olives was 0.20 € kg^{-1}. From the conducted study, it emerges that encouraging results may be reached by mechanizing harvesting operation even in century old orchards.

Key words: Olive orchard, mechanization, oli-picker, harvesting costs.

INTRODUCTION

Olive growing represents a key sector for the entire Mediterranean Basin. It contributes to the natural landscape formation, and has been largely spread in natural systems at least from the IV millennium B.C. to the anthropic period, both as wild variety 'oleaster' *Olea europea var. sylvestris* and as cultivated one *Olea europea var. sativa* (Zohary et al., 2012). In Calabria, Southern Italy, olive orchards are spread over 188 thousand hectares and produces more than 140 thousand tons of oil per year (ISTAT, 2013). This patrimony is of a noticeable importance, however, it is characterized by a high variability, due to the co-existence of extensive orchards with few trees per hectare and intensive ones having more than 600 trees per hectare.

Most of these orchards do not enable to reach high and constant yields from qualitative and quantitative point of view due to their traditional structure. Indeed, big century old trees with irregular layouts and scaled fruit ripening characterize them. This determine a low unitary productivity, high production costs and consequently the marginalization of extended areas with low levels of adaptation, conversion and mechanization (Sola-Guirado et al., 2014).

Due to their historical, monumental and landscaping importance, as well as to the existing regulation limitations, it is difficult to carry out the conversion of these orchards into new intensive ones (Famiani et al., 2014). Therefore, it is hard too to settle efficient and economically sustainable mechanized models for most of olive farms present in the territory.

However, it is still possible to obtain good quality olive oil from these olive trees if harvesting techniques from the canopy substitute olive harvesting from the ground (Vieri & Sarri, 2010; Castro-García et al., 2012; Deboli et al., 2014; Leone et al., 2015). In fact, this type of olive growing belong to the latest PGI 'Oil of Calabria' for which a transitory protection regime is currently in vigour at a national level.

In this context, experimental trials were carried out in a century old olive orchard situated in Calabria, where trunk shakers are difficult to use due to trunk diameter, in view to assess technical and economic aspects of a commonly used mechanical beater (oli-picker, Mipe Viviani s.r.l.) mounted on a tractor for olive harvesting from the canopy.

MATERIALS AND METHODS

Experimental trials were carried out on 10 trees of 'Grossa di Gerace' cultivar, which represents the typical cultivar of the Ionian versant of Reggio Calabria. It is featured by a high vigour and an assurgent growth. The trees had the same dimensional and morphological features and were planted on a 12 x 12 m layout. Dimensional features of olive trees, canopy volume determined according to C.O.I. method (International Olive Council, 2007), fruit detachment force (FDF) and total yield per tree are reported in Table 1.

Table 1. Parameters of olive trees (median±interquartile range)

Trunk circumference (cm)	Trunk height (m)	Canopy diameter (m)	Tree height (m)	Branches (n)	Canopy volume (m^3)	FDF (N)	Total yield per tree (kg)
340 ± 45	1.6 ± 0.3	11.3 ± 1.6	5.0 ± 0.4	4 ± 1	332.4 ± 114	4.5 ± 0.8	190 ± 60

Harvesting was carried out using the oli-picker Mipe Viviani s.r.l. having 820 kg of mass. It consists in a spiked cylindrical comb mounted on a hydraulic articulated arm of seven meters long, which can turn around its axle providing the brushing action that allow olive detachment (Fig. 1). The oli-picker was mounted in the back of a 40 kW agricultural tractor that moved only when the entire production of the tree is harvested. Two operators composed the harvesting site. The first one drived the tractor, while the second one was responsible of net handling.

In order to asses harvesting site working productivity referred to the operative time, working time of each carried out operation was measured according to CIOSTA requirements (Bolli & Scotton, 1987). The operative time includes the effective time during which the activity is carried out as well as the accessory time needed for moving and excludes the idle time.

Furthermore, technical and economic data were recorded. An estimation model based on Miyata (1980) was applied in order to calculate the machinery cost per hour (e.g., agricultural tractor cost) and the equipment cost (e.g., oli-picker), taking into account also the operator-machine labour cost.

Figure 1. Mipe Viviani Oli-picker Olidb08 during harvesting trials.

Fixed costs (e.g. interest, insurance and depreciation) and variable ones (e.g. fuel and oil consumption of tractor, maintenance and labour cost) were considered as operating costs. The harvesting costs expressed in terms of cost per hour, cost per unit of product (1 kg of olives) and average cost per hectare were determined.

In order to determine the harvesting cost per 1 kg of olives, the total cost per hour was divided by the harvesting yield per hour. Furthermore, the harvesting cost per kg was multiplied by the harvesting yield per hectare to calculate the average cost per hectare.

Table 2 reports the operating costs items of harvesting work site considered in the economic analysis, according to the following assumptions:

- work remuneration was evaluated in terms of opportunity cost and was equal to the employment of temporary workers for manual (net handling) and mechanical operations (Strano et al., 2015), by adopting current hourly wage (including social insurance contributions). Particularly, qualified workers were employed for mechanical operations, considering a compensation of 9.46 € h^{-1}, while the salary for generic workers was considered equal to 5.31 € h^{-1}.

– purchase price of 500 € ha^{-1} and an economic life of 5 years were considered to calculate the net costs.
– machine salvage value was estimated as demolition material selling (steel and iron) equal to 10% of the initial purchase cost.
– interests on capital goods (machines and nets) were calculated by applying an interest rate equal to 2%.

Table 2. Operating costs of harvesting work site

COST ITEMS	Symbol	Source
Machinery (tractor) value (€)	MV	Price list
Equipment (oli-picker) value (€)	EV	Price list
Total value (€)	TV	MV + EV
Salvage value (€)	SV	% di TV
Power (HP)	P	Technical manual
Interest rate (%)	r	Market survey
Economic life of machinery (years)	EL_1	Technical manual
Average annual machine use (h $year^{-1}$)	AMU	Field survey
Average daily machine use (h $year^{-1}$)	DMU	Field survey
Fuel price (€ l^{-1})	FP	Price list
Oil price (€ kg^{-1})	OP	Price list
Fuel consumption (l h^{-1})	FC	Field survey
Oil consumption (kg h^{-1})	OC	Field survey
Area occupied by the machine (m^2)	A	Technical manual
Price per m^2 (€ m^2)	PA	Local market
Nets value (€)	NV	Price list
Economic life of nets (years)	EL_2	Technical manual
Generic worker (n)	Wg	Field survey
Qualified worker (n)	Wq	Field survey
Average wage per hour (€ h^{-1})	HWg HWq	Collective Labour Agreement
Variable Costs per hour		
Fuel consumption cost (€ h^{-1})	FCC	FC*FP
Oil consumption cost (€ h^{-1})	OCC	OC*OP
Maintenance (€ h^{-1})	MR	Field survey
Worker labour cost (€ h^{-1})	OMC	(HWg*Wg) + (HWq*Wq)
Total variable costs per hour	**THVC**	**FCC+OCC+MR+OMC**
Annual Fixed Costs		
Interests on capital goods (€ $year^{-1}$)	I	((TV+SV+NV)/2) * r
Depreciation (€ $year^{-1}$)	DR	$(TV-SV)/EL_1 + NV/EL_2$
Insurance (€ $year^{-1}$)	IR	Field survey
Space cost (€ $year^{-1}$)	SC	A * PA * (0.03)
Total fixed costs per year (€ $year^{-1}$)	**TAFC**	**I+DR+IR+SC**
Total fixed costs per hour (€ h^{-1})	**HFC**	**TAFC/AMU**
TOTAL HARVESTING WORK SITE COST PER HOUR (€ h^{-1})	**THC**	**HFC + THVC**

RESULTS AND DISCUSSION

Elaborated data revealed a working productivity equal to 0.37 trees h^{-1} worker^{-1} corresponding to 80 kg h^{-1} worker^{-1} during the achieved trials. Harvesting efficiency expressed as the ratio between mechanically harvested olives and total olives present on the canopy exceeded 96%.

Employing the same harvesting machine, on big olive trees having a production varying between 15 to 30 kg per tree, Almeida & Peça (2012) obtained a work rate of 13 to 24 tree per hours with four workers. Whereas Famiani et al. (2014) obtained a working productivity equal to 95 kg of harvested olives h^{-1} worker^{-1}, corresponding to 1.3 trees h^{-1} worker^{-1}. They also obtained a productivity of 60 kg harvested olives h^{-1} worker^{-1} (equal to 0.6–0.7 trees h^{-1} worker^{-1}) when olive harvesting was achieved by mean of the oli-picker and hand-held pneumatic combs, and 130 kg of harvested olives h^{-1} worker^{-1} (equal to 1.7 trees of h^{-1} worker^{-1}) when the oli-picker was associated to a reversed umbrella.

Economic outputs obtained from the analysis showed a total hourly cost of harvest working site equal to 31.86 € h^{-1} with a higher incidence of variable costs (27.39 € h^{-1}), especially due to labour costs. Fixed costs were equal to 4.47 € h^{-1}. The average cost per hectare was of 2.906,63 € ha^{-1}, while the cost per kg of harvested olives was equal to 0.20 € kg^{-1}. This latter is lower than the cost obtained by Almeida & Peça (2012), which ranged between 0.3–1.1 € kg^{-1}, as well as that obtained by Famiani et al. (2014) which was equal to 0.28 € kg^{-1}, using the same harvesting machinery, with different conditions of plant productivity and worker number.

From productive point of view, it emerges that encouraging results may be reached by mechanizing harvesting operation even in century old orchards that provide high yields when suitably managed considering the whole agricultural practices. This allows, to concentrate harvesting operations in a brief period and to obtain higher quality olive oil (Giuffrè, 2014) than that obtained from the harvested olives from the ground.

CONCLUSIONS

The rising requirement to modernize olive and olive oil sector, which assisted during the recent year to the development of new growing models (Giametta & Bernardi, 2010; Tous et al., 2014), make it necessary to recover and valorise traditional orchards that still provide high yields thanks to their accurate management. The conservation of this patrimony that plays a multifunctional role is guaranteed only if a careful planning of machinery employment to accomplish the diverse agricultural practices, especially harvesting, is carried out.

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Authors contributed equally to the present work.

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