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Integrating olive grove maintenance and energy biomass recovery with a single-pass pruning and harvesting machine

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ABSTRACT

In Italy, olive tree groves may offer up to a million tonnes of dry biomass per year as pruning residue. Searching for a cost-effective way to tap this potential, the authors tested a new machine, capable of recovering pruning residue at the same time as pruning. The pre-commercial prototype was tested on four different plots and compared to a simpler tractor-base mechanical pruning unit. The authors conducted detailed time-studies in order to determine machine productivity and residue recovery cost. The integrated machine can treat between 0.2 and 0.6 ha h^{-1}, producing between 0.33 and 1.03 tonnes of fresh residue $hour^{-1}$. Its integrated residue recovery function does not slow the pruning, which actually proceeds faster than with the tractor-base unit, due to the more efficient multiple-disc cutting bar. The marginal cost of residue recovery hovers around 40–45 € fresh $tonne^{-1}$. However, the new machine must not be considered just as a biomass harvester, but rather as a mechanical pruning unit with an integrated biomass recovery function. Its main benefit derives from the capacity of performing a very effective mechanical pruning, and the residue recovery function is a secondary benefit yet unavailable on standard pruning machines. Its deployment must be seen in the context of a general effort to modernize olive grove management and to develop an integrated biomass production system, rather than as a further attempt to build a specialised biomass supply chain.

1. Introduction

Energy biomass can be sourced from existing agricultural residue, which offers a strategic benefit wherever it is impractical to convert cropland to energy crop cultivation [1] and the disposal of such residue is expensive or problematic [2].

Besides, agricultural residue does not accrue any growing costs and could be tapped at a relatively low price, if effective collection systems were deployed. In particular, olive tree pruning residue has already been targeted as a main source of lignocellulosic biomass, especially in the Mediterranean Sea basin, where olive groves cover almost 9 million hectares [3]. In Italy alone, the annual amount of residue derived from the pruning of olive groves, vineyards and other orchards has been estimated to 2.85 million tons, net of the amounts already recovered for traditional utilization [4]. Such a massive and concentrated availability would be suitable for industrial utilization, such as co-firing [5] and bioethanol production [6],

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which explains why pruning residue generally plays an important role in any analysis of biomass availability conducted in the Country [7]. In particular, the surface grown with olive trees amounts to over 1 million hectares [8] and generates at least 1 oven dry ton (odt) of pruning residue per hectare and year [9].

Since a few years, a number of machine manufacturers have been offering dedicated implements for collecting pruning residue. These machines generally derive from conventional mulchers, equipped with a storage bin or with a blower, the latter designed to direct the flow of comminuted residue to an accompanying trailer. Such implements are relatively cheap, and are designed for being towed or carried by farm tractors in the 50–70 kW class. For this very reason they cannot achieve industrial performance, and their productivity is commonly in the range of 1 green tonnes per hour [10] or about 0.6–0.8 ha per hour [11]. Such a low productivity level may compromise the economic sustainability of the operation, unless the work is conducted with surplus resources obtained at marginal cost. Besides, the rear-mounted design of these units implies that the tractor must straddle the windrowed residue, which is particularly difficult when the pruning has been concentrated in tall windrows, as a consequence of heavy pruning. Then, two main alternatives remain available: a) resorting to powerful industrial harvesters with frontal collection devices, which can overcome both the productive and the structural limits of lighter tractor-mounted machines and achieve gross productivities in excess of 5 green tonnes per hour [12] or b) integrating pruning residue collection and processing with some other operation, so that its recovery is obtained at a marginal cost. Ideally, one could integrate pruning and pruning residue collection in a single operation performed with a suitable mechanical unit. In specialised industrial orchards, pruning is the most expensive task after harvesting, and represents between 20 and 40% of the overall management cost [13]. For this very reason, pruning is being mechanized, just like harvesting. The effect is obtained with reciprocating cutter-bars, applied to standard agricultural tractors [14]. This way it is possible to reduce labour consumption from 80 to 15 worker hours per hectare [15]. Furthermore, mechanical pruning does not seem to produce inferior results to manual pruning, whose supposed superiority is merely aesthetic, especially if harvesting is also mechanized [16]. In fact, if harvesting is performed mechanically with tree shakers, then mechanical pruning offers a significant advantage [17].

Recently, the Italian manufacturer Favaretto has developed an integrated harvester (Speedy-cut) capable of performing both pruning and pruning residue harvesting in a single pass. This machine may offer a cost-effective solution to pruning and pruning residue recovery, and has attracted much attention. Therefore, the goal of this study was to determine the performance of this machine with scientific methods, offering reliable estimates for its productivity and cost. Furthermore, the study aimed at determining whether pruning residue collection and processing does slow down the main pruning operation, so that a realistic marginal cost of pruning residue recovery can be calculated.

2. Materials and methods

In its present version, the machine consists of a four-wheel-drive self-propelled carrier, powered by a 150 kW diesel engine. A multiple-disc cutting bar is mounted on a hydraulic boom hinged on the right side of the carrier. The bar is divided in two segments by an articulation, so that its shape can be adjusted to fit the trees and the job. A collection tub is placed under the bar and in front of the machine, to receive the prunings as they are cut. A belt conveyor at the bottom of the tub feeds the prunings to a swinging-hammer grinder placed just under the driver's cab. Removable screens can be placed between the grinder and the bottom of the grinding chamber in order to produce even-sized fragments. Ground residue is then moved to a 5 m^3 tilting bin by a combined auger and ladder conveyor. The bin is placed on the rear end of the machine, so that the load can be easily dumped on the ground or into suitable containers (Figs. 1 and 2).

Tests with the Favaretto Speedy-cut were conducted at 3 different sites in Central Italy, representative of the main working conditions found in the Italian olive tree groves (Table 1). The study was designed to evaluate machine productivity and to identify the most significant variables affecting it. The data collection procedure consisted of a set of detailed time-motion studies conducted at the cycle level, where the harvesting of a full row was considered as a complete cycle. In general, detailed time studies are more discriminating than shift-level studies and can detect smaller differences between treatments [18]. Cycle times were defined and split into time elements [19] considered to be typical of the functional process analyzed: this was done with the intent of isolating those parts of a routine that are dependent on one or more external factors in order to enhance the accuracy of the eventual productivity estimate [20]. In particular, four main elements were identified and separated, namely: pruning-collecting, turning, unloading, delays. All time elements and the related time-motion data were recorded with Husky Hunter® hand-held field computers running Siwork3 time-study software [21]. Output was determined by measuring the volume of all chip containers produced during each test, and by taking sample containers to a certified weighbridge. Moisture content

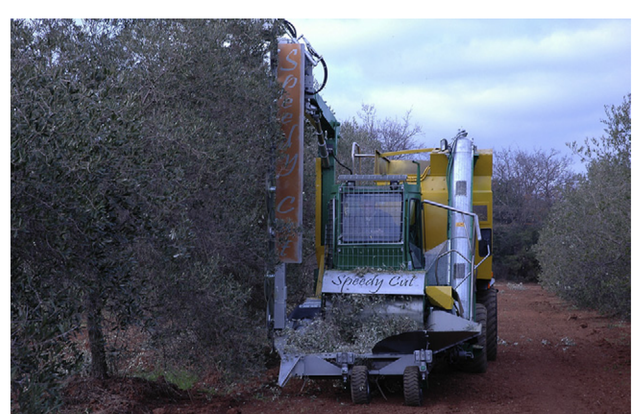

Fig. 1 – A picture of the machine at work.