Innovations in Mechanization and Control Systems of Production in Olive Sector

[1]B. Bernardi, [2]F. Giametta and [1]G. Sciarrone

[1]Univ. of Reggio Calabria, Agricultural Engineering Department, 89122 Reggio Calabria, Italy.

[2]Univ. of Molise, S.A.V.A. Department, 86100 Campobasso, Italy.

bruno.bernardi@unirc.it, ferruccio.giametta@unimol.it, giuseppe.sciarrone@unirc.it

ABSTRACT

The rapid and sweeping changes occurred in the last few years in the world have been crucial driving forces behind the evolution of olive growing practices on a global scale. These drives to change are gradually modifying the traditional olive growing scenarios thanks to the successful advent of a modern mechanized and specialized olive orchard cultivation where resource efficiency improvements and production cost reduction have become mandatory. In particular, the olive growing innovation process is based on a model referred to as “super intensive”, whose main advantage lies in highly-efficient mechanized harvesting operations performed uninterruptedly by means of the same grape harvesters long used to collect grapes. At renewal that affects models cultivation joins the growing attention paid to quality control and food safety are crucial in order to increase the competitiveness of products and improve the level of acceptance of same by consumers. "Traceability" is the key word today on the food scene, presenting as a tool of competitiveness and rationalization of production systems and enhancement of quality productions. The present study is intended to explore both olive growing innovation process and its quality control systems, by a series of tests conducted in Spain and in Italy. The results obtained have shown that super intensive olive orchard cultivation presents clear advantages in terms of abatement of hours of work, which is meant to contain costs and reach appropriate levels of productivity while safeguarding olive quality. It appears also that, in response to growing demands for food security and enhancement of food production, a system of traceability can ensure accuracy and speed of transmission of a guarantee of quality.

Keywords: Super intensive olive growing, grape harvesters, traceability, food safety, Italy.

1. INTRODUCTION

The increased interest in state-of-the-art olive growing systems on the part of olive growers all over the world is accounted for by the need to satisfy the demands of a more and more competitive global market. In particular, the olive growing innovation process is based on a model referred to as “super intensive”, which is characterized by an elevated planting density (up to and over 2,000 plants/ha) whose main advantage lies in highly-efficient mechanized harvesting operations performed uninterruptedly by means of the same grape harvesters long used to collect grapes.

The form of training generally thought to fit better than the others to this new olive growing model is made of plants with a central axis slightly taller than 2 m, which can however reach up to 4 m of height, with the final 1.5 m portion flexible enough to avoid damage by the harvester.

The length of the lateral branches, which usually depart from the central axis at a height of 0.50-0.70 m from the ground and are oriented in parallel with the row, gradually decreases from the basis to the top of the crown. Such form of monocone training must be then modified over time through appropriate pruning operations meant to reduce the size of tree crown and obtain flat surfaces responding better to the requirements of grape harvesters. This system normally uses a spacing of about 1.35-1.50 m between trees and about 3-4 m between rows. Within three years of planting, tree crowns literally close the spaces between trees forming a sort of uninterrupted hedge-like row. If appropriately fertilized and irrigated, plants start bearing fruit within two years, maximum three years of planting (Rallo *et al.*, 2006).

This model of cultivation, which could be conceived as a short-term investment (assuming a life span of 15-20 years for this kind of plantings), is based on the assumption that only an integral mechanization of the harvesting operations is likely to guarantee olive growing maximum economic efficiency: the grape harvesters worksite is, in fact, made of just two workers, one driving the harvester and the other in charge of the trailer destined to collect and handle harvested olives (Giametta G., 2006). The notion of subsistence olive growing, on which traditional olive growing relies, has to come to terms with a the new notion of income olive growing which is meant to contain costs and reach appropriate levels of productivity while safeguarding olive quality.

Theme of this last great interest, given the numerous scandals that have affected the agri-food sector in recent years and which led to the attention of public opinion fundamental concepts as quality, food safety and origin of products and terms such as traceability chain of processing. “Tracking” is meant to be the path of information that follows a product both upstream and downstream the production process throughout the entire production chain, from the raw materials to the products ready to be marketed. Often you have to give traceability roles which in reality is only in part. It must not be confused with traceability communication to the consumer product information.

It is very important for tracing the identification of companies that have participated in the training of each unit of output and therefore in charge of it. Communicating a method of production, geographical origin, category or composition of a product, they talk about labelling (Peri *et al.*, 2000). In this work will use the definition of traceability given by the Italian Academy of Georgofili: “Chain traceability means identifying all the businesses contributing to the production of a food product. Such identification relies on monitoring the flows of materials from farm to fork”.

The present study is intended to explore both productivity and work capacity of two of the most commonly used grape harvesters, in a view to assessing their harvesting performance by a series of tests conducted in Andalucía and in Cataluña and to implement a tracking system to be applied to control of olive production in Calabria (Italy), to monitor the entire chain and establish the efficiency of information about the origin of the product.

2. MATERIALS AND METHODS

In Andalucía tests were conducted at experimental olive groves where comparative analyses were jointly carried out in terms of varieties (Thesis A) and density (Thesis B), by the

University of Cordoba, IFAPA (Instituto Andaluz De Investigación y Formación Agraría, Pesquera y Alimentaria) and the company Todolivo (De la Rosa *et al.*, 2006). Thesis A was focused on a comparative analysis between the following varieties: “Arbequina” (Agromillora selection), “Arbequina IRTA-I 18”, “Arbosana”, “Koroneiki” and “Fs-17” (Barranco *et al.*, 2004; Fontanazza *et al.*, 1998); all these varieties had the same planting distance of 3.75 m x 1.35 m (1975 plants/ha). Table 1 shows the main technical features of the areas tested. Thesis B focuses on the comparison of 10 different planting densities (from 780 to 2,581 plants/ha with a spacing from 3.1 m to 5.7 m between rows and from 1.25 m to 2.25 m between trees) in “Arbequina” variety (Agromillora selection) olive groves. Both the sizes and the technical features of the planting densities under study are reported in Table 2.

In Cataluña tests were instead conducted in a five-year old olive grove located in Reus (Tarragona), which had been planted with “Arbequina” variety (“Agromillora” selection) olive trees (Tous *et al.*, 2006). The olive grove in question has a 1.50 m x 3 m planting distance, a plant density of about 2,500 plants/ha. Table 3 give the parameters of the plants present on the surface tested (0.43 ha).

The harvesters utilized during the tests, Grégoire G120 SW in Andalucía and New Holland Braud VX 680 in Cataluña (Figure 1 and 2), make use of the technology used to harvest grapes from widely spaced rows of vines with some essential modifications that turn them in olive harvesters: an increased number of shakers for them to be adapted at best to the productive area of the hedge-like rows of the olive groves in question, the addition of a conveyor immediately before the picking tunnel to help row introduction into the tunnel itself. The width of this latter can also be adjusted to the width of the “hedge” which is expected to increase in time.

Figure 1. Grégoire G 120 SW at work.

Figure 2. New Holland Braud VX 680.

The worksite is made of two workers, one driving the grape harvester and the other in charge of the trailer from the rows to the oil mill (Giametta G. *et al.*, 2006). The assessment of the time taken by the different operations envisaged by the tests under consideration has been made under C.I.O.S.T.A. ranking requirements, i.e. tests were considered to start when the harvester was positioned opposite to the row to begin harvesting operations, and to end when the product was fully unloaded.

The parallel study conducted about traceability of Calabrian olives, was based initially on finding Olive farms widely representative of the territory concerned, in order to define the contents, objectives and boundaries of the system, through the descriptions reach the chain, of ingredients, path main raw material and companies that contribute to the process.

Table 1. Comparison of the average sizes of the five varieties studied

Variety	Plant Height [m]	Crown Height [m]	Crown Diameter [m]	Crown Volume [m^3]	Tested rows [n]	Row Length [m]
Arbequina	4.00	3.30	2.00	10.16	3	50
FS-17			1.97	9.84	3	32
Arbosana			2.00	10.16	3	49
I-18			1.97	9.84	3	46
Koroneiki			1.96	9.75	3	34

Table 2. Comparison of the average sizes of the different planting distances studied (cv. "Arbequina" Agromillora selection)

Density [p/ha]	Plant Height [m]	Crown Height [m]	Crown Diameter [m]	Crown Volume [m^3]	Rows Distance [m]	Trees Distance [m]	Test Rows [n]	Row Length [m]
780	4.00	3.30	1,96	9.75	5.70	2.25	4	32
909			1.96	9.75	5.50	2.00		34
952			1.97	9.84	5.25	2.00		36
1143			1.97	9.84	5.00	1.75		35
1203			1.96	9.75	4.75	1.75		33
1481			1.96	9.75	4.50	1.50		32
1569			2.00	10.16	4.25	1.50		33
2000			1.83	8.51	4.00	1.25		29
2254			1.83	8.51	3.55	1.25	3	28
2580			1.96	9.75	3.10	1.25	3	21

Table 3. Technical features of the surfaces tested

Elements	Unit of measurement	Value
Plant Height	[m]	2.40
Crown Height	[m]	1.70
Crown Diameter	[m]	1.30
Crown Volume	[m^3]	2.10
Test rows	[n]	5.00
Row length	[m]	284
Plants per row	[n]	189

The traceability of chain has been applied to every unit of output materially and individually identifiable: the management of production processes has been applied "in batches," so you can check for each daily production, all operations (before and after) that contribute to training in the event that the form mechanization and organization of farm remains unchanged. One of the major criticalities in the model of traceability under study occurs at the time of raw material (olives) processing at the oil mill where sometimes olives can mix with other non traced olives, i.e. drupes with different features (acidity, number of peroxides, etc.) that can happen to mix with more valuable lots. Therefore it has been decided to implement a system meant to check that the raw materials arriving at the oil mill are those actually processed there. This kind of check has been performed by analysing samples from the different lots unloaded at the oil mill at different times and in various modalities in line with the logic given in figure 3.

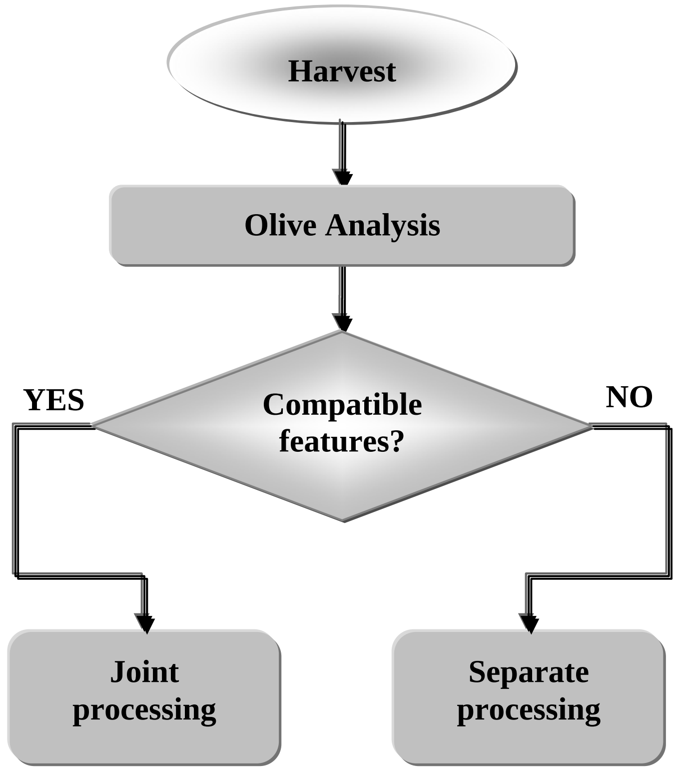

Figure 3. Logic scheme of the processing procedure.

3. RESULTS AND DISCUSSION

Regarding to the mechanized harvesting tests in super intensive olive orchard cultivation, tables 4, 5 and 6 give distribution data in terms of operational times per surface units (TO), productivity, and work capacity. In Andalucía, thesis A indicates that the lowest harvester operation time (TO) (4.1 h/ha) has been registered for the Arbequina I-18" variety; the "Arbosana" and "Arbequina (Agromillora selection)" varieties follow with slightly higher values. Thesis B highlights instead that harvester operation time (2.6 h/ha) has been registered for densities of 780 plants/ha and 909 plants/ha. Iddle time turns out to be neglectable compared to the hours of operation the grape harvesters used in both theses. The results obtained in terms of harvest efficiency indicate yields of 13.4 t/ha with a work productivity of 0.09 ha/hop for thesis A, whereas in thesis B the same parameters were 8.6 t/ha in terms of harvest yield and 0.14 ha/hop in terms of work productivity. Production losses, i.e. the amounts of drupes remained on the branches and therefore not processed by the harvester, were on the order of 8%. The results of the tests performed in Calatuña have allowed to assess a time of operation per unit of surface (TO) of 2.3 h/ha and in terms of harvest efficiency, the yield obtained was 8.5 t/ha. Hence the work capacity of the harvester turned out to be 0.45 ha/h, while the work productivity was 0.22 ha/hop. Drupe loss was on the order of 6%.

Table 4. Average values of the parameters assessed and harvesting capacities - Thesis A

Variety	TE [h/ha]	TA [h/ha]	TO [h/ha]	Yield [t/ha]	Work Capacity In terms of TO [ha/h]	Work Capacity In terms of TO [t/h]	Work Productivity In terms of TO [ha/hop]	Work Productivity In terms of TO [t/hop]
Arbequina	3.5	1.7	5.2	9.1	0.19	1.76	0.10	0.88
FS-17	5.8	2.5	8.3	11.9	0.12	1.40	0.06	0.70
Arbosana	3.1	1.5	4.6	18.0	0.22	3.89	0.11	1.95
I-18	3.0	1.1	4.1	8.3	0.24	2.03	0.12	1.02
Koroneiki	4.7	1.7	6.4	19.4	0.15	3.00	0.08	1.50

Note: TE = actual working time TA = accessory time TO = operation time

Table 5. Average values of the parameters assessed and harvesting capacities - Thesis B

Density	TE [h/ha]	TA [h/ha]	TO [h/ha]	Yield [t/ha]	Work Capacity In terms of TO [ha/h]	Work Capacity In terms of TO [t/h]	Work Productivity In terms of TO [ha/hop]	Work Productivity In terms of TO [t/hop]
780	1.9	0.7	2.6	6.3	0.38	2.34	0.19	1.17
909	1.7	0.9	2.6	6.0	0.39	2.54	0.20	1.27
952	1.9	0.8	2.7	7.4	0.36	2.70	0.18	1.35
1143	2.1	1.0	3.1	7.3	0.32	2.27	0.16	1.14
1203	2.2	1.0	3.2	7.6	0.31	2.33	0.16	1.17
1481	2.7	1.1	3.8	8.4	0.26	2.22	0.13	1.11
1569	2.8	1.0	3.8	8.7	0.26	2.30	0.13	1.15
2000	3.1	1.5	4.6	10.4	0.22	2.26	0.11	1.13
2254	3.4	2.2	5.6	11.6	0.18	2.09	0.09	1.04
2580	3.8	2.2	6.0	12.0	0.17	1.98	0.09	0.99

Table 6. Average values of the parameters measured and harvesting capacities in Cataluña

TE [h/ha]	TA [h/ha]	TO [h/ha]	Yield [t/ha]	Work Capacity In terms of TO [ha/h]	Work Capacity In terms of TO [t/h]	Work Productivity In terms of TO [ha/hop]	Work Productivity In terms of TO [t/hop]
2.1	0.2	2.3	8.4	0.45	3.80	0.22	1.90

About the traceability system, it has been decided to implement a computer system meant to process the data entered by each operator of the olive chain and turn them into useful information addressed to consumers according to the scheme illustrated in figure 4 (Takato *et al.*, 2004). The traceability software proposed is in line with the logic of art. 18 of EC Regulation 178/2002 and enables to document all the chain activities, thus allowing businesses to demonstrate their compliance with the rules in force in terms of traceability (EC Regulation 178, 2002).

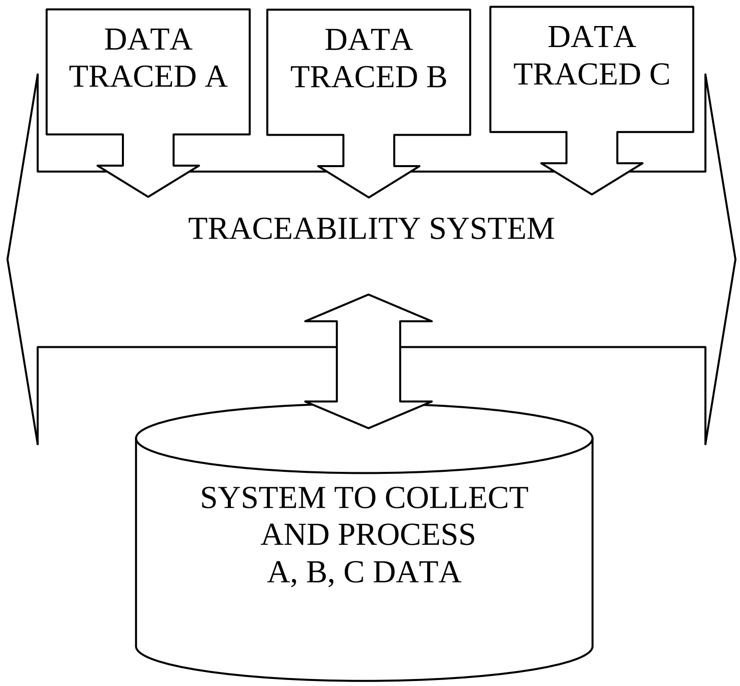

Figure 4. Representation of the data processing modality.

The system adopted allows to describe and document, to organization, methodology, techniques and tools utilized to plan and monitor activities; to resources and responsibilities in terms of the quality of the product. Information on all products can be processed and transferred into barcode labels or, via the web, onto customized collective portals.

A computer system is presently being developed which is expected to coordinate the flows of information on farming chains traceability; to allow the backtracking of each individual lot of produce; to indicate the accompanying documents (barcodes included) required to identify the lots in question; to manage the chain logistics (travel of the traced lots across the various operators). After data input, the software processes a 14-digit barcode which encompasses all the data of the product, from the lot of origin to the oil mill processing operations.

This barcode allows for a rapid data scanning and acquisition by means of a laser gun scanner Barcode scanners mimic keystrokes entered via a keyboard: after deciphering the barcode they pass the information on to the computer where it is displayed the software can be used also on individual workstations. The database, which is structured in an user-friendly format, (see Figure 5) can be exported to other databases containing real-time updated information to be processed, printed or published in the web.

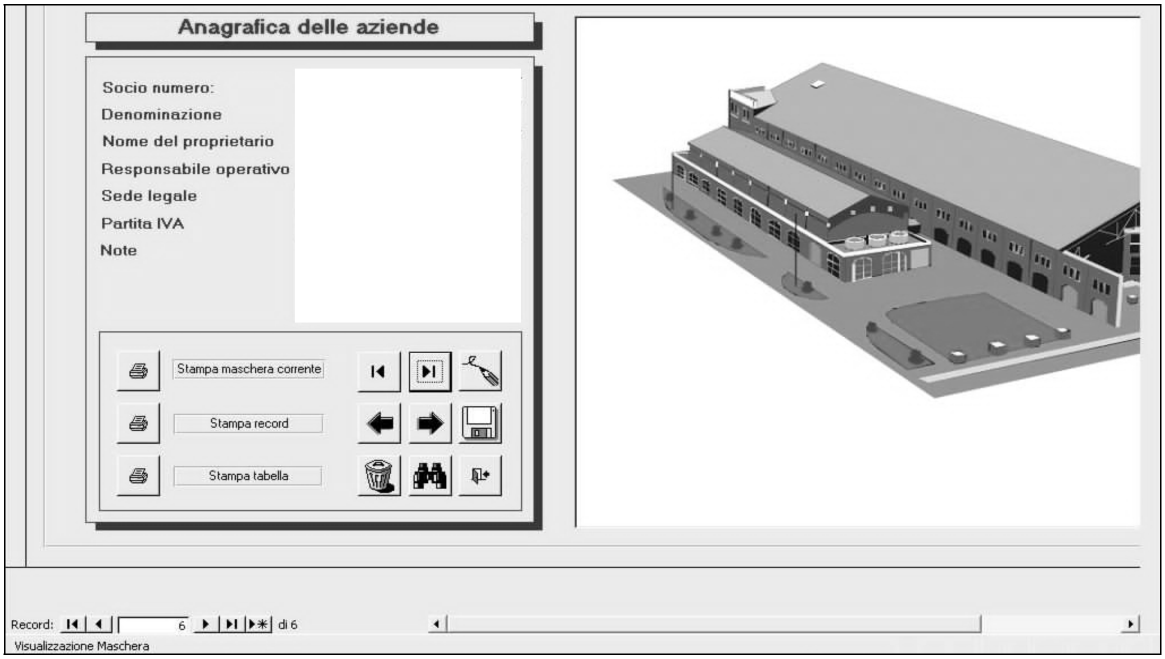

Figure 5. Software display during data loading.

4. CONCLUSIONS

The super intensive model, which responds to issues linked to chronic shortage of labor and to the need to contain production costs, is likely to revamp that portion of obsolete and non cost-effective practices which are no longer competitive in the olive growing sector, is however resulting in a "global revolution in olive tree cultivation techniques" (Loreti, 2007).

Among the main issues emerged it is worthwhile mentioning the challenging identification of the best suited varieties to such cultivation model in view of the requirement of keeping plants vigor under control to allow the passage of harvesters, although the Arbequina I-18 seems to be the variety best suited to super intensive cultivation, as the work times assessed for this variety during the tests performed turned out to be the lowest.

The results obtained highlight that for higher densities a better yield corresponds to an increase in the time required to accomplish harvesting operations. In addition, as olive groves age, decreases in yield occur for higher densities which are ascribable to a decreased level of illumination. This phenomenon does occur especially in the presence of favorable growth conditions and of disproportionate relations between the height and the width of the hedge-like row. Therefore the ideal number of plants per hectare remains to be established together with the minimum investment required to obtain the best of productivities.

Another interesting factor is the impact that the length of the individual rows is likely to have on the operation of the harvesters in question. The presence of rows of contained length (42 m on average) has had a negative impact on the harvester work capacity due to the resulting increase in accessory times. As a result a significant increase in terms of harvester operation efficiency can be obtained by designing the systems in question in a view to predisposing them to an integrated harvesting system, i.e. increasing the length of rows and containing logistic problems (narrow dirt lanes, poor road system, elevated slopes). Experimental studies aimed to establish several fundamental parameters of super intensive cultivation are presently being conducted to express a final judgment on the model in question also in terms of ideal varieties and planting densities. One such parameters has to do with the economic (in addition to "biologic") duration of the crops and the best form of management of the hedge-like row in the different phases of vegetative development.

Among the issues relating to the implementation of the traceability chain system, a first crucial moment is the sharing of issues such as the definition of the product or component relevant, management and material flows involved. Traceability is not in fact draw all that is possible, but what is useful and necessary (Peupert et al, 2003). Establish a system of traceability means to carry out a series of choices about the parameters to be defined internally (products, raw materials, environmental conditions of storage); to relevant information that the company wants to be able to recover, both upstream and downstream; the partners involved.

Once defined the perimeter of the traceability system and information to be transported along the supply chain, is therefore necessary to ask the question of which instrument should be adopted to reproduce the information (identification) and transfer (communication). Finally, it is important to note that handling errors and registration make it unidentifiable products. The present study, therefore, has the main purpose of eliminating all sources of risk by studying the many stages of processing.

A detailed analysis of the productive processes has been made possible through the definition of the so-called "dynamic lot": a unit of product processed (either directly or indirectly) in a time unit (usually a day), as a function of the peculiarities of the olive growing farms involved (orographic features, level of mechanization, etc.). The data obtained have allowed to implement a specific software which allows for a comprehensive monitoring of all the processing and production phases: to acquiring data (input) related to the olive growing sector under study; to implementing (output) innovative labelling systems (barcode labels) that enable workers to process information very rapidly and obtain exhaustive data concerning the origin of the product in question.

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The authors have contributed equally to the present work.