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MECHANICALLY-AIDED HARVESTING OF ARTICHOKE WITH AN ELECTRICALLY PROPELLED PROTOTYPE

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ABSTRACT Harvesting operations account for as much as 40% of the total production costs in Globe Artichoke. The edible heads are harvested exclusively by hand, machine harvesting being hindered by an extended harvest maturity. Many passes through the fields are required over the season to complete the job. The pickers move through the rows cutting the mature heads and placing them in sacks carried along the field. Work efficiency can be increased employing machinery to move the produce in the rows and out of the field. A variety of over the row high ground clearance equipment can be employed to aid artichoke harvest (tractor, self-propelled machinery, conveyor belt). To improve labour efficiency an electrically propelled over-the-row harvesting prototype was developed at the CRA-ING “Agricultural Engineering Research Unit”. The machine is operated by the use of foot controls, so that the operator can pick artichokes while driving over the row and accumulates produce on a wide loading platform. In field tests, hand and machine-aided harvesting were compared. After adequate training the driver learns to pick at the same rate of ground harvesters, thus improving the ratio of pickers on total field workers and consequently reducing work time (h/ha) up to 40%. Time loss due to field stops and to walking non-working distance for unloading the sacks is avoided. The hourly productivity (n° heads/h) of the crew in mechanically aided harvest is 73% higher than in hand harvesting. On the whole, harvesting yield is improved by a 65%.

Keywords: Harvest, Machine-aided, *Cynara cardunculus*.

INTRODUCTION On a global scale, artichoke (*Cynara cardunculus* L. subsp. *scolymus* Hayek) is ranked third among horticultural crops, following tomato and potato. Italy is the world’s largest producer of globe artichoke, accounting for almost 40% of the total world production, with a cultivated surface of about 50 thousand hectares and total produce of about 520 thousand tons (Istat, 2008). Puglia, Sicily and Sardinia are the three main Italian regions, summing together 90% of surface and 60% of production. In recent years, the surface area under artichoke cultivation has had a negative trend in Italy, production having remained stagnant since the end of last century.

The cultivation of artichoke requires a considerable amount of manual labour for carrying out the numerous cultural practices necessary throughout the growing season. Among these, harvesting is the most labor-intensive activity, representing 40 to 60 percent of the growing costs (Dellacecca et al., 1979). The harvesting period for this crop will go on for many weeks due to the extended time over which all the flower buds in the field will reach harvest maturity, besides the edible heads must obtain the preferred market size before being picked. The differences among plant growth rates in the field and the differences among artichoke varieties adopted by farmers may furthermore accentuate the extension of the maturation period. Artichoke harvest involves high labour need, furthermore, for the reason that the same field must be harvested frequently, especially during the peak season going on from March through May, for a total of more than 15 passes before the harvest is completed.

Artichokes are harvested entirely by hand, cutting the edible heads from the plant with a knife, also paying a special attention for safeguarding the new buds coming out of side sprouts. The head can be harvested leaving either a short or a long stem, meaning with less or more leaves. With the long stem product, measuring up to 25 cm, harvesting operations and product transportation are more complicated because of the bigger volumes of vegetation and the higher working time involved (Panaro, 1982).

Crop management and cultivation techniques show a great variability between different Italian growing locations. Artichoke farms differ for total surface extension, field dimension, row length and plant spacing. Other important differences are related to the characteristics of road network of farms, the distance from field to the processing facilities. All of these aspects are important for choosing how to handle the produce and the type of farm mechanization needed, in particular for machine-aided harvest.

MATERIALS AND METHODS Since the 1980's, agricultural mechanization research has worked to achieve prototypes for integral harvesting of artichoke, but no applicable solution has been produced yet (Arrivo et al., 1979; Arrivo et al., 1979). The analysis of the harvesting techniques used mostly in the main Italian artichoke growing areas, showed a lot of technical and economic aspects that could be improved adopting new technologies (Colorio et al., 2007). Working on these topics, researchers at the CRA-ING (Italian Council for Research in Agriculture - Agricultural Engineering Research Unit) have designed, constructed and conducted experiments with an electric traction prototype that can optimize the employment of manpower for harvesting artichokes.

Small farms largely harvest by hand, without using any machinery inside the planted field. Vehicles are used along the headland for transferring the produce towards the processing facilities. Field crew workers carry out two distinct duties: some of them will pick the buds and others will move the product out of the field employing shoulder carried packs (Fig. 1). Alternatively each worker is independent, having his own sack for carrying along the buds. When the sack is full, the worker will walk to the end of the row for unloading. Product may be stored either in bins, previously located at each end of the planted field, or it could be accumulated on the loading platform of a vehicle, for further transportation.



Figure 1. Traditional hand harvesting.

The agricultural machinery mostly used by artichoke growers in Italy are particular “over the row” tractors, designed with a very high ground clearance for carrying the produce in line (Fig. 2).



Figure 2. “Over the row” tractor with rear and front frames to hold bins.

By any means artichokes are harvested by hand while the workers walk along the rows, picking out the mature buds and cutting them off the plant. Workers then accumulate the gathered artichokes on the containers carried by the tractor. Different kinds of containers can be used for transporting the crop. Working time can be optimized using more than one tractor at a time, that can alternate in the field, so that an empty one will immediately replace the fully loaded tractor leaving the field. With this kind of organization, inactive periods for field workers, due to tractor transfer for unloading, will be avoided.

This harvesting method employs tractor drivers and field workers. Driver obviously don't pick artichokes. If the total productivity of the field crew (intended as the personnel that actually picks the product) is divided by the total number of workers involved, the resulting per capita yield is progressively reduced as the number of non picking workers increases. To improve the ratio between harvesting personnel and total crew members, with the aim of reaching a value closest to 1, researchers at CRA-ING developed the electric traction prototype so that the driving and picking tasks could be performed contemporarily.

The new prototype has a functioning principle that is derived from a commercial electric traction vehicle used for harvesting asparagus, the same concept was also used by the manufacturer for harvesting zucchini (Fig. 3).

The first tests for harvesting artichoke with a mechanical aid were carried out using the commercial zucchini harvester. The commercial model was purposely modified for the tests, a tipping container was added in the back end of the machine, made with a steel frame and fabric walls, for accumulating the produce. The self moving frame had two seats placed on both sides and aligned with the wheels. The vehicle had two rear drive wheels powered by electric motors and two front steering wheels, moved by foot controls. As the machine moved through the rows, the two workers picked the buds from the row in the middle and from the two side rows (Fig. 4).



Figure 3. General view of the zucchini harvester arranged for harvesting artichoke.



Figure 4. Zucchini harvester moving through the field in harvest.

The first tests showed that it was quite uncomfortable for the operators, seated in the particular position, to pick all of the artichokes from the side rows, because the vegetation in the row is wide (up to 1 meter) and they can't reach all the way across. These preliminary results suggested further and substantial changes in the prototype design.

In the new project the frame was considerably modified: only one seat was placed at the centre of the machine, the ground clearance was increased, a big volume tipping platform was placed in the back for holding the produce. The seat's height can be adjusted by means of an electric cylinder for vertical linear movement, for a better work position. The steering controls are made using two pedals hinged to a secondary frame, that is directly attached to the seat (Fig. 5). The pedals are linked to the wheels by means of steering rods that are joined together behind the seat, thus avoiding placing obstacles in front of the seat.

Behind the seat, a big tipping platform has been positioned, having a volume bigger than to 2 m³. The big loading capacity was necessary for reducing stops during the harvest. The trapezoidal shape studied for the platform, facilitates loading and unloading operations. Other changes regarded the wheels, choosing tires with wider footprints to improve stability and traction in wet soil conditions.



Figure 5. First tests with the new CRA-ING prototype.

In the tests, harvesting in a mechanically-aided way using this newly developed prototype was compared to the traditional hand harvesting. In our trials hand harvest was identified as Plot A and mechanically aided harvest was identified as Plot B (Fig. 6). In both cases a crew of five members was used for carrying out the trials.



Figure 6. Machine aided harvest crew

In plot A, three workers hand harvested the mature buds and two workers carried baskets on their backs for accumulating the artichokes. Each one of the three pickers walked along and picked from one row, the resulting working width for the crew was 4.8 m, with a distance between rows of 1.6 m.

In plot B, five workers are employed. Four workers walk along the rows, two on each side of the electric powered prototype. The machine drives over a row and the driver picks the mature heads. In this case the resulting working width for the crew was 8 m.

For both plots a suitable number of bins was previously distributed on both ends of the field, so that the produce could be unloaded once out of the row. Otherwise, if the back

carried baskets would be filled before completing the row, the shortest journey could be chosen each time for reducing walking distances (Fig. 7).



Figure 7. Unloading the artichokes into bins.

RESULTS AND DISCUSSION The two different harvesting methods, hand harvesting for plot A and machine-aided harvesting for plot B, were compared in tests performed in a field having typical characteristics for the central Italian regions (Table 1). The harvesting crew in both cases counted 5 members, in plot A only three persons actually picked the product while the other two carried the baskets. In the other case all of the workers picked a row each, therefore the working width for plot A was 40% smaller than in plot B.

The individual productivity of the pickers, intended as the number of mature heads picked in a minute, is practically identical (Table 2). Pickers in plot A work side by side with the basket carrier, therefore handling the product is faster, for this reason the individual productivity was slightly higher.

The hourly productivity of the crew is much higher in the mechanically-aided harvest. The reason, clearly, is almost exclusively attributed to the fact that, in the hand harvest plot, 40% of the total employees are occupied not for picking but for moving the product with the baskets out of the field where the bins are positioned. With the use of the mechanical aid all the workers, included the driver, have a very elevated productivity. A further difference in the productivity data is due to the time losses that are higher in plot A. In fact, the pickers stop working many times, waiting for the product to be carried and unloaded in the bins. In plot B, fewer time is needed for dumping the artichokes at the end of the field (Fig. 7). This excessive increase of the time losses makes the adoption of such a job organization totally irrational, while in the mechanically-aided harvest the increase in crew productivity is 73%.

In the electric prototype the loading autonomy is rather insufficient because of the limited dimensions of the dump body. The electric traction gives a maximum speed of 2,7 km/h, for this reason the machine takes a lot of time for travelling non-working distances. This specific characteristic has contributed to a slight increase in the plot B time loss.

Table 1. Characteristics of test plots.

Parameters and characteristics		Plot A	Plot B
Crop Spacing	m	1.6 x 0.9	1.6 x 0.9
Row length	m	170	170
Total work crew	n°	5	5
Total pickers	n°	3	5
Rows harvested each passage	n°	3	5
Test field dimension	m ²	816	1360

Table 2. Average values of the harvesting tests.

Parameters		Plot A	Plot B
Actual Working width (1 picker/row)	n° rows	3	5
Average field yield	n° buds/ha	10.100	10.450
Individual productivity	n° heads/min	16,3	15,8
Time loss	%	19	13
Crew hourly productivity	n° heads/h	2376	4110
Increase in crew productivity	%	-	73
Actual working time	h/ha	4,21	2,54
Reduction in work time	%	-	40

CONCLUSIONS The principal advantage of the mechanically-aided system is that the operator that drives the machine can also harvest the product. The results confirm that the harvesting ability of an experienced operator is comparable to that of the hand workers.

A rational organization of the work crew employed in the mechanically-aided system requires the combination of a worker on board of the machine and at least two operators that pick from the adjacent rows. In this case the three workers perform the job normally carried out by four persons in manual harvest, with a 25% manpower reduction.

The results obtained in the harvesting tests with the prototype have highlighted the real possibility of achieving a significant increase in labour productivity. The low travelling speed of this prototype is a limiting factor. A good work organization consists in the use of the electric vehicle only for the harvest phase, unload the machine at the end of the field.

Other advantages of the electric traction system are represented by in the absence of harmful exhaust gasses, low noise level, low energy expenditure. Besides the vehicle has a modest purchase cost and maintenance is simple and economic.

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