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MODIFICATION AND EVALUATION OF HAND-HELD HARVESTERS FOR OLIVE FRUITS.

El-Iraqi, M. E. ; S. E. El Khawag and T. R. Awais
Agric. Eng. Res. Inst., Agric. Res. Center, Egypt

ABSTRACT

The main objective of this study is to modify the real effectiveness of two imported hand-held harvester types namely; olive lancer with a vertical straight rotor head and olive comb harvester with a fruit collecting bag to increase the harvesting productivity and efficiency with high quality olive fruits; in addition to reduce the high cost and risks of manual harvesting method. Both harvester types were evaluated before and after modification compared with manual harvesting method of olive fruits in terms of labor productivity, harvesting efficiency, harvested fruit quality, energy requirements and harvesting cost.

The obtained results may be summarized as follows:

- Modification and use of the olive lancer type harvester for harvesting Shimlaly and Tofahy olive fruit varieties gave a remarkable increment percentage in labor productivity by about 5-7 times higher with respect to manual harvesting method. Also, it can be save the harvesting manpower requirements by about 90-130% and reduce the total harvesting cost by about 185-245% comparing with manual harvesting cost.
- The use of hand-held modified olive comb harvester increased the labor productivity by about 1-2.5 times, saved the harvesting manpower requirements by about 190-260% and saved the harvesting cost by about 135-195%, for harvesting Shimlaly and Tofahy olive varieties, respectively comparing with manual harvesting method.
- These results means that the use of hand-held olive harvesters could be reduced the amount of labors or time needed to carry out the olive harvesting operation in the best period and obtain the best harvested fruits quality. In addition to make the introduction of hand-held olive harvesters easier, feasible and more economical especially when used for other purposes to run devices such as scissors and saws to mechanize tree pruning.

INTRODUCTION

Martin (1994) reported that the olive harvest technology can be broadly divided into hand held machines and larger machines mounted on tractors or on self propelled units. Technically, hand held harvesting units are harvest aids. The units are usually pneumatic, can extend an operator's reach by 4 m and remove fruit with a vibrating motion of the comb, or by clamping on the branch and shaking. Using either a pneumatic, hand held combing unit, or a clamping shaking unit a single operator can harvest 300–450 kilos per day, before fruit collection. This is at least 50 kg per day better than the best hand harvest laborers.

O¨ zarslan, *et al*. (2001) concluded that harvesting is the final step in field production of an olive crop. Therefore, it consider is one of the most important practices and the most expensive aspect in olive cultivation

because of the high costs associated with the process. In the hand harvesting method of olive, they pick the fruits one by one, or beat the tree limbs with a pole causing them to fall. Canvases or nets are placed under the tree to collect the fallen fruits. However, this type of harvesting is time consuming and involves intensive labor (about 50–60% of total labor requirement is used for harvesting operations). In addition, it results in high level of fruit damage.

Michelakis (2002) concluded that the higher cost and slow rate of hand harvesting make mechanical harvesting desirable. Therefore, up to now, in several olive producing countries, a number of studies have been carried out to mechanize fruit harvesting and as a result several machines are now available on the market. However, the application of mechanical harvesting of olive is quite limited worldwide. Among them, the most common are the trunk shakers and hand-held machines. Trunk shakers are usually very effective for harvesting in intensive olive groves able to give a high production, but their price is relatively high. Hand-held machines are small, versatile devices that can easily fit the different training systems of the trees and their price is relatively low.

Abdeen *et al*. (2006) reported that greater use of manual combs to detach the olives and spread suitable size nets under the trees to collect the harvested olives should be promoted in order to improve the harvesting productivity of the workers (10-20%). They added that the introduction of hand-held machines for olive harvesting should be promoted in order to reduce the manpower requirement that is not always easily available and also to be able to concentrate harvesting in the best period to obtain high oil quantity and quality.

RIRDC (2008) reported that there are two main types of hand held harvesting equipment of olive fruits: Branch shakers and Combing machines. Both groups of machines can be powered by different kind of engines or electric motors. The fruit is fallen into bags or to nets around trees then collected into a crate. The fruit picked in this way typically shows very little damage and it is relatively free from foreign matter (soil, branches, leaves, etc.). This is particularly suitable for table olives. The main limitations of this technique are picking of the upper part of the trees and its cost and manual labor requirements. This manual technique is not limited to any particular tree shape. While, the lower and wider canopies are best suited for the reasons stated above.

Deboli and Calvo (2009) indicated that the hand harvesting method is considered one of the major expenses of olive production which may reach the 50-70% of the obtained cultivation revenue, with a productivity that is not higher than the 15 kg/h for each operator.

Ferguson *et al*. (2010) concluded that the major reason for developing mechanical olive harvesting is the high cost of hand harvesting which was approximately 50-65% of the gross return per ton in California's San Joaquin Valley. They added that, olive harvest technology can be broadly divided into hand held machines and larger machines mounted on tractors or on self propelled units. These units remove fruits with harvest productivity of 300-450 kg/day, before fruit collection better than the best hand harvest laborers. However, most olive harvesters fall into two general categories based upon

the principle of removal. They either clamp and shake the trunk or branches, or have canopy contact vibrator heads with rods that extend into the canopy.

Problem statement and Objective

In the last decades, a large number of new olive orchards have been planted in Egypt (about 158,058 fed.) which produce about 449,009 ton (AOAD, 2009). Almost of these olive orchards are harvested by hand from the trees (sometimes also using sticks to beat the crown) with relatively low labor productivity (6-20 kg/h per labor) and the total labor necessary is very high. Moreover, manual harvesting is tiring and the use of ladders gives rise to high risks of labors falling. As a result, the manpower requirements for olive harvesting will also increase and it may become difficult to find sufficient labors to harvest the olives at the optimum harvesting conditions.

In this regard, the main objective of this study is to modify and evaluate the real effectiveness of two imported hand-held harvester types for harvesting olives fruits comparing with manual harvesting method, to increase the labor harvesting productivity and efficiency which makes it easier to concentrate the harvest in the period of maximum product quality to better meet the qualitative standards demanded by the international markets. In addition to reduce the high cost of manual harvesting method and minimize the high risks due to using ladders by introducing more suitable lower price of hand-held machines for the economic and availability of Egyptian manpower conditions with respect to larger machines.

MATERIALS AND METHODS

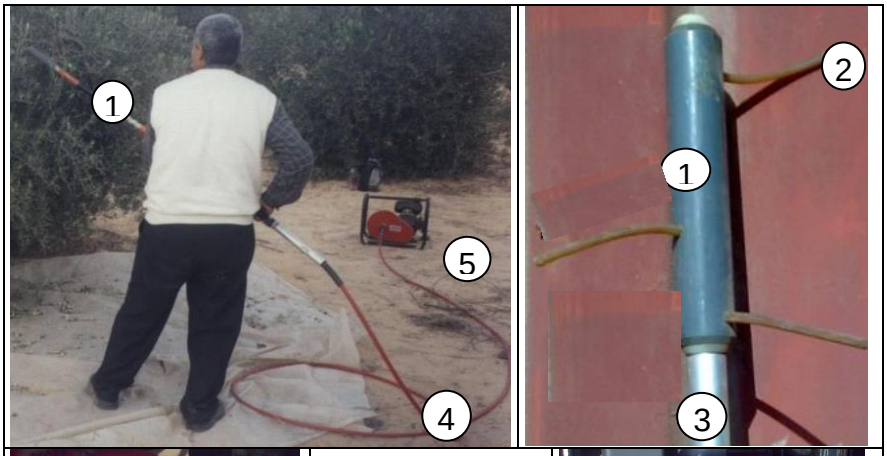
Materials

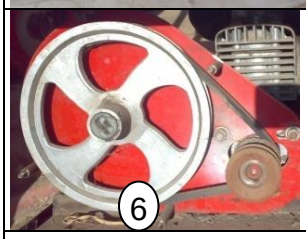
In this study, two imported hand-held harvester types namely; olive lancer type harvester with a vertical straight rotor and olive comb harvester with a fruit collecting bag were modified and evaluated compared with manual harvesting method for the harvesting olive fruits. The modification and fabrication of lancer and comb harvesters were carried out at the some private workshops in El-Mansoura and Damnhour cities, Egypt, in 2008. The construction, working method and modification process investigated of each harvester may be explained as follows:

Olive lancer type harvester

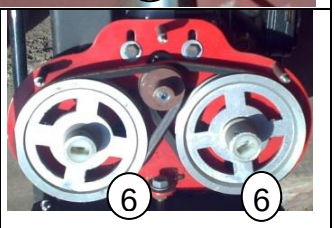
Construction

The hand-held olive lancer type harvester is Italy made, Model MD-4582. It has four main components as shown in Fig. (1) namely, lancer rotor head, carrier pipe, power transmission cable and engine. The lancer rotor head (26 cm length and ϕ 5cm) is a vertical straight type and equipped with 4 flexible rubber fingers (13 cm length) which distributed on the circumference of the rotor head. The rotor head was fixed on the upper end of the carrier pipe (150 cm length and ϕ 5cm) using a ball bearing. The flexible power transmission cable (10 m length) was passed through carrier pipe to transmit the engine power to the rotary lancer head. The used engine was a Mitsubishi gasoline engine, 4-stroke, air cooled, with maximum power output of 1.47 kW at rating speed of 4,000 rpm.





1. Lancer rotor head
2. Rubber fingers
3. Carrier pipe
4. Power transmission cable
5. Engine
6. Output rotors



Single output rotor (before modification)

Double output rotors (after modification)

Fig. (1): General view of the olive lancer harvester and its components

Working method

The working method of olive lancer harvester is so simple, whereas, the operator connects the flexible power transmission cable between engine and the rotor lancer head through carrier pipe and catch the olive lancer carrier by his hand and positioning it to the olive shots and branches as shown in Fig. (1). Then operating the rotor head which detach the olive fruits due to the hitting impacts produced by rubber fingers of lancer rotor head to fall in the cloth net spreading on the ground down and around the olive tree.

Modification process

The single output rotor of the engine was modified to duplicate its output to two rotor as shown in Fig. (1) which provided with 2 lancer rotor heads working together in the same time for harvesting one olive tree using 2 labors to reduce the harvesting time and save manpower requirements and harvesting cost.

Olive comb harvester

Construction

The construction of the imported hand-held olive comb harvester contains five main components namely; comb case, comb finger, comb throat, fruit tube and collection bag as shown in Fig. (2). The comb case is fabricated from PVC material as a half circle shape with depth and width about 15 cm and 16 cm, respectively. The curved side of comb case is closed

while the straight one is opened. The upper end of comb case is provided with two fixed fingers of PVC material. The finger length is about 5 cm and figures spacing about 4 cm (not adjustable). However, the lower end of comb case is connected with comb throat with inner diameter about 10 cm and length of 30 cm to connect the comb case with fruit tube. The fruit tube is fabricated as a telescopic plastic tube with 10 cm inner diameter to transmit harvested olive fruits from comb case to collecting bag. While, the fruit collection bag is fabricated from special cloth material to contain about 15-20 kg of olive fruits and equipped with hang hand.

1. Comb case
2. Comb fingers
3. Comb throat
4. Fruit tube
5. Collectin bag

Fig. (2): General view of imported hand-held olive comb harvesters.

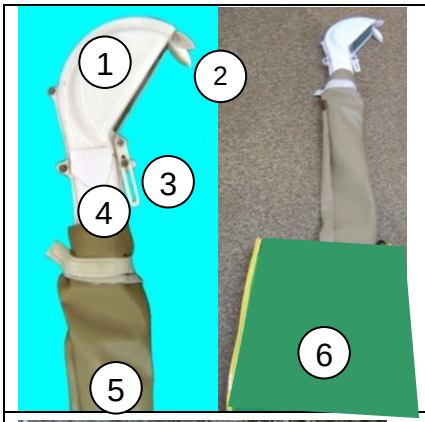
Working method

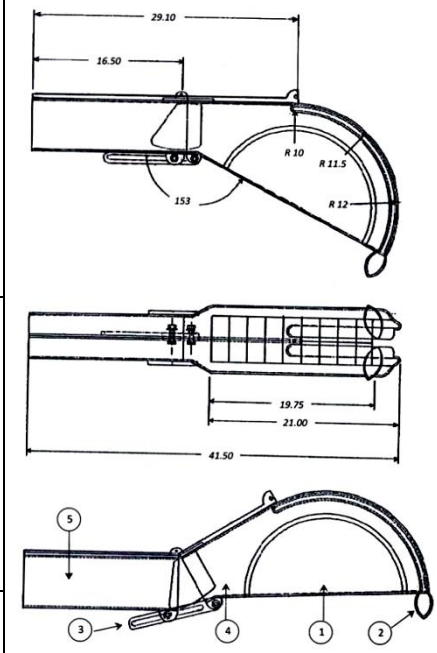
The operator catches the comb harvester from its throat by one of his hands and grasps the olive branches with the comb fingers then pulled the comb downward starting from the upper point of olive branch, to detach the fruits from its shots/branches and picked it in comb case to fall in collection bag which carried on the labor shoulder. After the collecting bag is full with olive fruits, the operator empty it in the fruit box and continue the harvesting operations.

Modification process

The modification process were carried out on the imported hand-held olive comb harvester after its evaluation under Egyptian olive farms for solving its harvesting problems and increasing its performance. The main modification items taken into consideration on the imported hand-held olive comb harvester are shown in Fig.(3) and summarized as follows:

1- Increase the comb case dimensions (width and depth) and make fingers spacing is adjustable to suit different olive variety characteristics.
2- Make the comb angle between the comb case and its throat is adjustable to suit different harvesting labors tall and olive tree heights .
3- Increase the inner diameter of comb throat to 15 cm and replace the telescopic plastic comb tube with the other one fabricated from local cloth material with increase its inner diameter to 15 cm to avoid the fruits and leaves blocking.





1. Comb case
2. Comb fingers
3. Comb angle adjuster
4. Comb throat
5. Fruit tube
6. Collectin bag

Fig. (3): General view and schematic drawing of modified olive comb harvester.

Performance evaluation and measurements

The performance evaluation experiments of olive lancer and comb harvesters were carried out during harvesting olive *Shimlaly* variety (for oil purpose) and olive *Tofahy* variety (for table purpose). The imported olive lancer harvester with single rotor and modification one with double rotors were evaluated based on labor productivity, ton/h at three rotational speeds of 800, 900 and 1000 rpm (12.98, 14.60 and 16.23 m/s). As the structure and speed of lancer rotor head were same for both import and modified lancer type harvesters, therefore the modified lancer only was evaluated based on harvesting efficiency, %, energy requirements, kW.h/ton and fruit quality (cleaning efficiency,% and fruit damage,%) at same rotational speeds of 800, 900 and 1000 rpm. However, imported and modified olive comb type harvesters were evaluated based on labor productivity, ton/h; harvesting efficiency, %; energy requirements, kW.h/ton and fruit quality (cleaning efficiency,% and fruit damage,%) using four different labors for harvesting both olive varieties under study comparing with olive manual harvesting

method. The harvesting operations were done at some private olive farms (Nobaria new reclaimed lands) in 2009 and 2010 at the commercial maturity where the fruit just beginning to develop color.

Olive fruit properties

The physical properties includes fruit dimensions (length & diameter), weight and volume, in addition to the mechanical properties such as firmness and detachment force were measured for *Shimlaly* and *Tofahy* olive varieties fruits.

Olive tree characteristics

In olive orchards under study, some tree characteristics were determined by measuring the diameter & height of crowns and the total height of the tree. Other characteristics such as height of 1st branch, tree spacing, layers of fruit distribution and its percentage on the tree crown were measured.

Labor harvesting productivity

The average value of labor harvesting productivity (ton/h) using different labors comparing with olive manual harvesting method was calculated based on the total harvesting time required for detecting olive branch, detaching fruits, collecting it in the fruit bag/box and the lost time in moving harvesting tools between olive trees and branches, in addition to the time required to empty full fruit bags.

$$Labor\ productivity,\ ton/h = \frac{1}{Total\ harvesting\ time,\ h/ton}$$

Olive harvesting efficiency

The olive harvesting efficiency is defined as the percent of fruit removed from the total crop on the tree. The detached olive fruits on a cloth net spread under the trees or in the fruit bags were collected and weighed (W_t). At the end of harvesting operations all olives remaining on the olive crown were harvested manually and weighed (W_m). Also the fruit fallen on the ground out of the collecting net/bag were collected and weighed (W_g). The fruit harvesting efficiency was determined using the following equation according to **O**¨ zarslan *et al*., (2001) and Erdog˘an *et al*., (2003) :

$$Harvesting\ efficiency,\% = \frac{W_t}{W_t + W_m + W_g}\ x\ 100$$

Harvested olive fruit quality.

Four types of olive fruit samples were taken from the harvested fruits using different harvesting methods under study with three replications to calculate the cleaning efficiency (%) and mechanical fruit damage (%) which they represents the fruit quality. The percentage of foreign materials such as olive leaves and other branch parts which found in the harvested fruits for each harvesting method using different olive varieties under study were determined to calculate the cleaning efficiency as an indicator of fruit quality. However, the other quality indicator of harvested olive fruits was evaluated by calculating the percentage of the damaged fruits due to hitting impact from harvesting tools and dropping it out of the collecting net or bag. The damage

percentage was rated as bruising (skin not broken) and mechanical (skin broken).

Energy requirement

The energy requirement for harvesting of *Shimlaly* and *Tofahy* olive fruits using two types of olive harvesters under study comparing with traditional harvesting method were estimated on the basis of the following equations:

$$Energy\ requirement\ (kW.h/ton) = \frac{Power\ required\ (kW)}{Productuvity\ (ton/h)}$$

The manpower output for harvesting work was assumed as 0.1 kW according to Witteny (1988). However, the mechanical power consumed was estimated according to ASAE (1997) based on the total amount of fuel consumed to operate the modified lancer harvester at the highest rotational speed of 1000 rpm during harvesting olive fruits.

Estimation harvesting

The harvesting cost (LE/h and LE/ton) of *Shimlaly* and *Tofahy* olive fruit varieties using lancer and comb harvesters as a mechanical methods comparing with manual harvesting methods were estimated to realize the economic objective of this study. The manual harvesting cost was determined based on the average labor harvesting productivity (ton/h) and labor wage LE/h using the following equation:

$$The\ total\ manual\ harvesting\ cost\ (LE/ton) = \frac{labor\ cost\ (LE/h)}{Labor\ productivity\ (ton/h)}$$

Concerning the economical feasibility of using hand-held lancer harvester for olive harvesting, some estimation assumptions and analysis have been carried out considering a cost of purchase of a modified lacer harvester with 2 rotor heads + all the required accessories of about 7000 LE with life expectancy 7 years, 500 operating hours per year. The manpower cost was calculated based on the fact that one laborer was required to properly operate the machine and 30 LE/day (8 hours/day). The annual capital consumption which included the depreciation and the interest costs was estimated at 25% of the machine cost. While, the remaining elements of fixed costs (taxes and housing) were annually assumed to be 2% of the machine cost. The cost of repair/maintenance was estimated at 2% of the machine cost per 100 hours of operation, 0.41//h fuel consumption, 0.9LE// fuel cost and 30% of fuel cost for oil cost (Hunt, 1983). The olive lancer harvesting cost was determined at the optimum rotor head speed of 900 rpm.

$$The\ total\ mechanical\ harvesting\ cost\ (LE/h) = Fixed\ cost\ (LE/h) + Operation\ cost\ (LE/h)$$

However, the assumption bases of 500LE purchase cost with life expectancy 3 years and 200 operating hours per year were taken into consideration during estimation the harvesting cost of comb harvester.

RESULTS AND DISCUSSION

Olive fruit properties and tree characteristics

The average and standard deviation (SD) values of the physical and mechanical properties of olive fruits for both Shimlaly and Tofahy varieties

were measured, calculated and summarized in Table (1). The obtained results indicated that the average values of the length, diameter, volume and weight of the Tofahy olive variety were found to be relatively higher than obtained for the Shimlaly olive variety fruits. However, the average values of firmness and detachment force for Shimlaly variety (26.19 and 11.4 N) higher than obtained for Tofahy variety (21.73 and 9.65 N) respectively.

Table (1): Physical and mechanical properties for investigated varieties of olive fruits.

Measurements	*Shimlaly*		*Tofahy*	
	Av.	SD	Av.	SD
Length, mm	18.14	1.20	25.71	6.27
Diameter, mm	12.48	0.61	28.43	5.24
Volume, mm	1.73	0.36	13.52	3.18
Weight, g	1.61	0.24	14.83	2.34
Firmness, N	26.19	5.11	21.73	6.67
Detachment force, N	11.40	4.17	9.65	2.81

The characteristics of olive tree crown and fruit distribution percentage on the tree layers were measured and calculated for Shimlaly and Tofahy olive varieties as shown in Fig. (4). The average values of tree height, tree crown diameter and tree spacing were 3.10m, 3.15m and 5.5×5.5 m, respectively for Shimlaly and Tofahy olive varieties. However, the highest fruit distribution percentage of 60 and 64% were found at circumference of tree crown in 1st layer and the lowest fruit distribution percentage of 15 and 13% were in 3rd layer for Shimlaly and Tofahy olive varieties respectively as shown in Fig. (4).

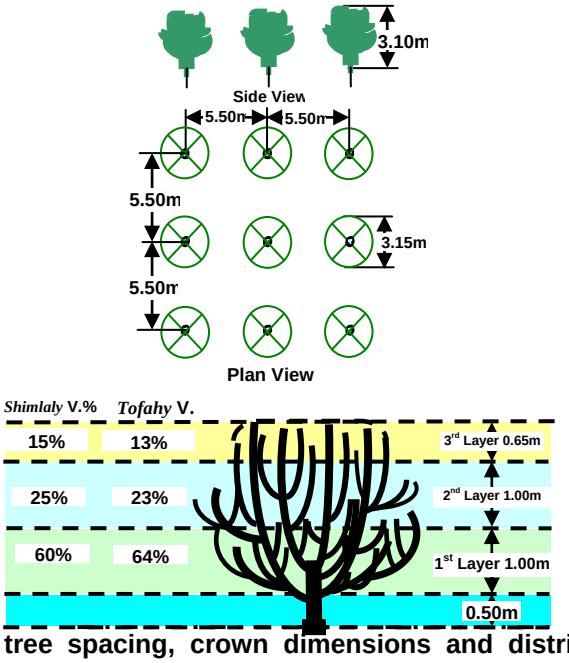


Fig. (4): Olive tree spacing, crown dimensions and distribution fruit layers on the tree.

Evaluation of hand-held olive lancer type harvester

Labor harvesting productivity

The average values of labor harvesting productivity using olive lancer type harvester for Shimlaly and Tofahy olive varieties with single output rotor (before modification and double output rotors (modified one) are illustrated in Fig. (5). The results showed that the average values of worker productivity were 0.089, 0.118 and 0.084 ton/h for harvesting Shimlaly variety in comparison with 0.122, 0.139 and 0.107 ton/h for harvesting Tofahy variety using olive lancer type harvester with single output rotor at 800, 900 and 1000 rpm, respectively. While, in case of using the modified lancer type harvester with double output rotors, the productivity values were 0.094, 0.127 and 0.088 ton/h for harvesting Shimlaly variety comparing with 0.130, 0.151 and 0.113 ton/h for harvesting Tofahy variety at 800, 900 and 1000 rpm rotational speed, respectively. However, the obtained values of labor productivity were 0.015 and 0.021 ton/h using manual harvesting method for Shimlaly and Tofahy varieties, respectively. In other words, modification of the olive lancer type harvester for harvesting Shimlaly and Tofahy fruit varieties gave a remarkable increment percentage in labor harvesting productivity by about 5-7 times higher with respect to manual harvesting method. This means that the use of hand-held lancer type harvester reduced amount of labors and time needed to carry out olive harvesting operations in the best period and obtain the best harvested fruits quality.

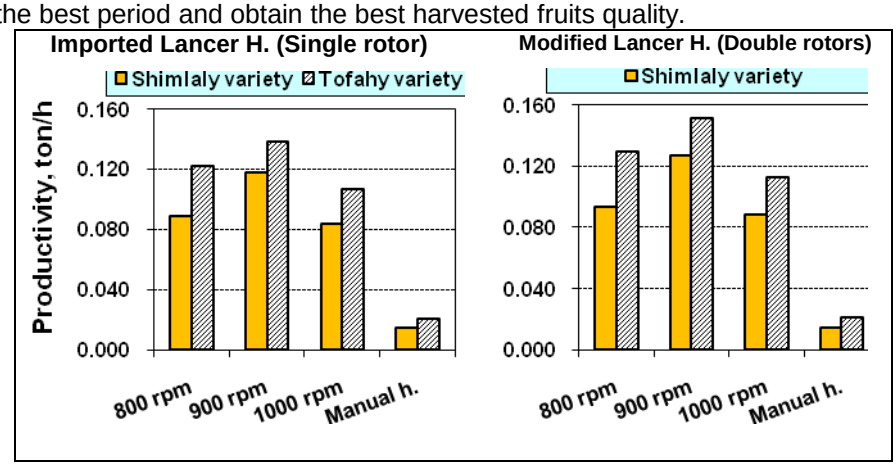


Fig. (5): Labor productivity sustained with olive lancer type harvester compared with olive manual harvesting method.

Regarding to the effect of rotational speed of the modified lancer type harvester on the labor productivity, the results showed that increasing the rotational speed from 800 to 900 rpm increased the labor productivity from 0.094 to 0.127 ton/h and from 0.130 to 0.151 ton/h for harvesting Shimlaly and Tofahy varieties, respectively. However, by increasing rotational speed from 900 to 1000 rpm decreasing the labor productivity from 0.127 to 0.088 ton/h and from 0.151 to 0.113 ton/h for harvesting Shimlaly and Tofahy varieties, respectively. The reasons behind these results may be due

insufficient hitting impact action to detach olive fruits by lower speed of 800 rpm and due to over hitting impact action by higher speed of 1000 rpm which results in throw some of olive fruits away from collection net, consequently, increasing the collection time and decreasing the productivity. Therefore, it could be concluded that the rotor speed of 900 rpm is consider the best speed to operate the modified lancer harvester for harvesting olive fruits.

It could be observed also, the labor productivity for harvesting Tofahy olive variety was higher than that obtained for harvesting Shimlaly olive variety when using imported or modified lancer type harvesters at any given rotational speed. These results may be due to the high weight of Tofahy fruits and its low detachment force compared with Shimlaly olive variety. The increment percentages in labor productivity for harvesting Tofahy than Shimlaly variety were 36.83, 17.66 and 27.38% using imported lancer harvester comparing with 38.14, 19.30 and 28.60% using modified lancer type harvesters at 800, 900 and 1000 rpm, respectively.

Harvesting efficiency

The average values of harvesting efficiency due to using modified lancer type harvester at different rotational speeds under study with respect to manual harvesting method for Shimlaly and Tofahy varieties are summarized in Table (2). The obtained results in both olive varieties indicated that the slightly lower harvesting efficiency obtained using lancer type harvester with respect manual harvesting method, can be attributed to the fact that the crown of both varieties were relatively dense and so it was not easy to work with the lancer harvester in all parts of the tree crown. Also, decreasing or increasing the rotational speed of lancer harvester than 900 rpm decreased the harvesting efficiency. Therefore, the best results nearest of manual harvesting efficiency can be obtained using lancer harvester at 900 rpm for harvesting both Shimlaly and Tofahy varieties.

Table (2): Effect of using modified olive lancer harvester on harvesting efficiency, % comparing with manual harvesting method.

	Lancer harvester speed			Manual method
	800 rpm	900 rpm	1000 rpm	
Shimlaly Variety	85.30	94.99	87.84	95.19
Tofahy Variety	81.47	89.36	83.58	93.81

Harvested olive fruit quality

Cleaning efficiency

The average values of the cleaning efficiency using modified olive lancer type harvester at 800, 900 and 1000 rpm for harvesting Shimlaly and Tofahy varieties comparing with manual olive harvesting method were summarized in Table (3). These results showed that the cleaning efficiency decreased by increasing the rotational speed of rotary harvester. The cleaning efficiency obtained by using lancer type harvester was slightly lower with respect manual harvesting method and the best results nearest of manual cleaning efficiency can be obtained using lancer harvester at 900 rpm for harvesting both Shimlaly and Tofahy varieties.

Table (3): Effect of using lancer type harvester on fruit quality comparing with manual harvesting method.

		Lancer harvester speed			Manual method
		800 rpm	900 rpm	1000 rpm	
Cleaning efficiency, %	Shimlaly Variety	98.60	97.92	96.16	99.38
	Tofahy Variety	98.49	97.61	95.13	99.11
Fruit damage, %	Shimlaly Variety	7.75	9.09	17.31	5.31
	Tofahy Variety	11.33	13.83	20.18	7.18

Fruit damage percentage

The effect of using modified lancer type harvester for harvesting Shimlaly and Tofahy olive varieties on the mechanical fruit damage percentage comparing with manual method are summarized in Table (3). The obtained results indicated that an increase in the rotational speed of lancer harvester results in an increment percentage in the fruit damage percentage with harvesting both given olive varieties. However, the values of fruit damage percentage were higher with harvested Tofahy fruits than Shimlaly fruits at any given rotational speed of lancer harvester. Also, the fruit damage percentage values in harvested olive fruits by manual method were found to be lower than that harvested using lancer harvester at any given rotational speed.

Energy requirements

The average values of energy requirements for harvesting Shimlaly and Tofahy olive varieties were 2.96 and 2.48 kW.h/ton, respectively using modified lancer type harvester, comparing with 6.90 and 4.74 kW.h/ton using manual harvesting method for harvesting Shimlaly and Tofahy olive varieties, respectively. This means that the use of hand-held olive lancer type harvester saved the manpower requirements for harvesting olive fruits by about 90 to 130 %.

Estimation harvesting cost

The average values of estimation olive harvesting cost (LE/h) were found to be 9.4 and 3.8 LE/h for using modified lancer harvester and manual harvesting method, respectively for both Shimlaly and Tofahy olive varieties. However, the average values of estimation harvesting cost (LE/ton) were 74.20 and 62.20 LE/ton using modified lancer harvester at 900 rpm for harvesting Shimlaly and Tofahy olive varieties, respectively comparing with 258.60 and 177.70 LE/ton using manual method. From these results it could be reported that using hand-held modified lancer harvester for harvesting olive fruits reduced the harvesting cost by about 248.30 and 185.60% with respect of manual harvesting cost.

Evaluation the olive comb harvester

Labor harvesting productivity.

The effect of using imported and modified olive comb harvesters on the labor harvesting productivity for Shimlaly and Tofahy varieties comparing with manual harvesting method are illustrated in Fig.(6). The obtained results showed that the average values of labor productivity using imported olive comb harvester were 0.038 and 0.043 ton/h comparing with 0.053 and 0.062 ton/h using modified olive comb harvester for harvesting Shimlaly and Tofahy varieties, respectively. However, it were 0.015 and 0.021 ton/h using manual harvesting method for Shimlaly and Tofahy varieties, respectively.

These results cleared that using both imported and modified olive comb harvesters gave an increment percentages in labor productivity for harvesting any given olive variety comparing with manual harvesting method. Using imported olive comb harvester instead of manual method for harvesting Shimlaly and Tofahy varieties increased the labor productivity by 160.65 and 103.65%, receptivity. Moreover, modification of the imported olive comb harvester gave a remarkable increment percentage in labor harvesting productivity about 262.45 and 192.51% for harvesting Shimlaly and Tofahy varieties, respectively with respect to manual method.

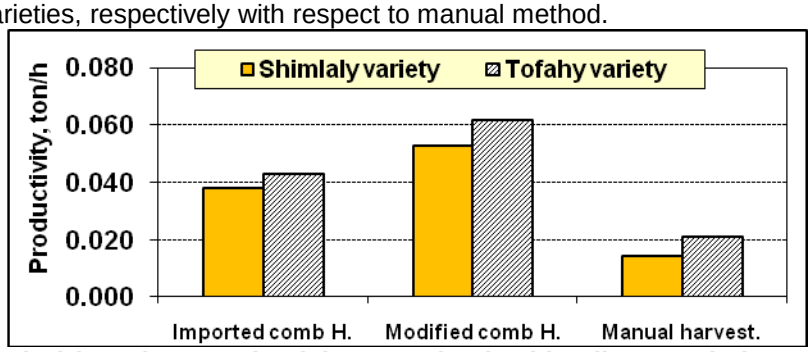


Fig.(6): Labor productivity sustained with olive comb harvester compared with olive manual harvesting method.

Regarding to the effect of using modified comb harvester with different labors for harvesting olive fruits, the results showed that there is a remarkable variance in labor productivity among different labors under study. The labor productivity was ranged from 0.050 to 0.057 with an average of 0.053 ton/h for harvesting Shimlaly variety and ranged from 0.057 to 0.068 with an average of 0.063 ton/h for harvesting Tofahy variety.

Harvesting efficiency

The effect of using the imported and modified olive comb harvester on the harvesting efficiency of *Shimlaly* and *Tofahy* varieties comparing with manual method is summarized in Table (4). The results showed that the manual harvesting method gave the highest harvesting efficiency values of 96.11 and 93.76% followed by 86.14 and 83.22 % when using the modified olive comb harvester and followed by 74.13 and 71.64% when using the imported olive comb for harvesting *Shimlaly* and *Tofahy* olive varieties, respectively. This means that the harvesting efficiency obtained when using imported or modified comb harvester was lower than that obtained by olive manual harvesting method. These results may be due the fact that the crown of both varieties were relatively dense and so it was not easy to separate some olive branches by comb fingers which increase the percentage of remaining fruits on the tree.

Using the modified olive comb harvester results in an increment percentage of (39.00 and 43.64 %) in the harvesting efficiency for harvesting *Shimlaly* and *Tofahy* varieties, respectively. This results may be due to the applying some modification on the comb figures spacing which increase its ability for different olive volumes and varieties.

Fruit quality

Cleaning efficiency

The cleaning efficiency percentages of harvested olive fruits using hand-held imported and modified comb harvesters comparing with olive manual method are summarized in Table (4). The obtained results indicated that using manual method gave the highest values of cleaning efficiency (96.03 and 95.41%) for harvesting *Shimlaly* and *Tofahy* olive varieties, respectively. However, the average values of cleaning efficiency using modified comb harvester (92.05 and 90.19%) were higher than that obtained when using imported comb harvester (86.15 and 84.08%) for harvesting *Shimlaly* and *Tofahy* olive varieties, respectively. This result may be due to increase the number of leaves separated with the harvested fruits in comb harvester. The modification of imported comb harvester increased the cleaning efficiency values by about of 6.85 and 7.27 % for harvesting *Shimlaly* and *Tofahy* varieties and rise the cleaning efficiency nearest to the manual method.

Table (4): Effect of using olive comb harvester on fruit quality comparing with olive traditional harvesting method.

	Imported comb		Modified comb		Manual method	
	Shimlaly	***Tofahy***	***Shimlaly***	***Tofahy***	***Shimlaly***	***Tofahy***
Harvesting efficiency %	74.13	71.64	86.14	83.22	96.11	93.76
Cleaning efficiency, %	86.15	84.08	92.05	90.19	96.03	95.41
Fruit damage, %	15.31	17.18	10.75	13.33	8.09	9.83

Fruit damage percentage

The mechanical damage percentages in olive fruits during harvesting *Shimlaly* and *Tofahy* varieties using the imported and modified comb harvesters comparing with manual harvesting method was calculated and recorded in Table (4). These results showed that using modified olive comb harvester instead of imported one decreased the fruit damage percentage from 15.31 to 10.75 and from 17.18 to 13.33% comparing with 8.09 and 9.83% using manual harvesting method for *Shimlaly* and *Tofahy* varieties, respectively.

Energy requirements

Using modified olive comb harvester instead of imported harvester decreased the values of energy requirements for harvesting Shimlaly olive variety from 2.64 to 1.90 kW.h/ton with respect to 6.90 kW.h/ton using manual method. The corresponding values for harvesting Tofahy olive variety were decreased from 2.33 to 1.62 kW.h/ton with respect to 4.7 kW.h/ton using manual method. This means that the use of hand-held modified comb harvester saved the manpower requirements for harvesting olive fruits by about 190 to 260 %.

Estimation harvesting cost

The average value of estimation harvesting cost using modified comb harvester was found to be 4.6 LE/h combared with 3.8 LE/h using manual method for harvesting Shimlaly or Tofahy olive varieties. However, the average values of estimation harvesting cost for Shimlaly olive fruits using

imported and modified comb harvesters were 121.2 and 87.2 LE/ton, respectively comparing with 258.60 LE/ton using manual method. The corresponding values for Tofahy olive fruits were 106.7 and 74.3 LE/ton using imported and modified comb harvesters, respectively comparing with 177.7 LE/ton using manual method. These results means that using hand-held modified comb harvester saved the harvesting cost of Shimlaly and Tofahy olive fruits by about 196.5 and 139.3%, respectively with respect of manual harvesting cost.

Conclusions

- Modification and use of the olive lancer type harvester for harvesting Shimlaly and Tofahy fruit varieties gave a remarkable increment percentage in labor productivity by about 5-7 times higher with respect to manual harvesting method. Also, it can be save the harvesting manpower requirements by about 90-130% and reduced the total harvesting cost by about 185-245% with respect of manual harvesting cost.
- The best results of harvesting efficiency, cleaning efficiency and fruit damage percentage nearest to that obtained with manual harvesting can be achieved using lancer harvester at 900 rpm for harvesting both Shimlaly and Tofahy varieties.
- The use of hand-held modified olive comb harvester increased the labor productivity by about 1-2.5 times, saved the harvesting manpower requirements by about 190-260% and saved the harvesting cost by about 135-195%, for harvesting Shimlaly and Tofahy olive varieties, respectively comparing with manual harvesting method.
- Modification of imported comb harvester increased the harvesting efficiency by about 39.00 and 43.64 % and the cleaning efficiency by about of 6.85 and 7.27 % for harvesting Shimlaly and Tofahy varieties.
- Using modified olive comb harvester instead of imported one decreased the damage percentage from 15.13 to 10.75 and from 17.18 to 13.33% comparing with 8.09 and 9.83% using manual method for Shimlaly and Tofahy varieties, respectively. These percentages could be neglected in regarding to the saving in labor productivity and total harvesting cost especially with Shimlaly olive variety which was harvested for processing purpose to produce olive oil.
- These results means that the use of hand-held olive harvesters could be reduced the amount of labors or time needed to carry out the olive harvesting operation in the best period and obtain the best harvested fruits quality. In addition to make the introduction of hand-held olive harvesters easier, feasible and more economical especially when used for other purposes to run devices such as scissors and saws to mechanize tree pruning.

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تطوير وتقييم نماذج آلية لحصاد ثمار الزيتون

محمود السيد العراقى– صفوت الدسوقى الخواجة – طاهر رشاد عويس
معهد بحوث الهندسه الزراعية – مركز البحوث الزراعية

الهدف الرئيسي من هذا البحث هو تقيم نماذج آلية لحصاد ثمار الزيتون وتطويرها محليا لتلاءم ظروف حصاد أصناف الزيتون فى مصر بغرض زيادة إنتاجية عامل الحصاد وتقليل تكاليف عملية الحصاد والحصول على ثمار عالية الجودة تصلح لأغراض التصدير بالإضافة إلى تقليل المخاطر التي يتعرض لها عامل الحصاد من استخدام مساعدات الحصاد مثل السلالم والتسلق على الأشجار.

أجريت تجارب تطوير وتقييم نموذجي الحصاد: 1- الرأس الدوارة ذات الأصابع المطاطية (Lancer type harvester) 2- مشط الحصاد (Comb harvester) مقارنة بطريقة الحصاد اليدوي لحصاد صنفي الزيتون شملالى (لغرض إنتاج الزيت) وصنف تفاحي (لغرض إنتاج زيتون المائدة) وقد تم تقييم نموذج الرأس الدوارة ذات الأصابع المطاطية المستورد والمطور عند ثلاث سرعات دورانية 800، 900، 1000 لفة/دقيقة لحصاد صنفي الزيتون شملالى وتفاحي بينما تم تقييم مشط الحصاد المستورد والمطور باستخدام أربعة عمال مختلفة لحصاد صنفي الزيتون شملالى وتفاحي

وكانت أهم النتائج المتحصل عليها كما يلي:-

- أدى تطوير واستخدام نموذج الرأس الدوارة ذات الأصابع المطاطية فى حصاد ثمار صنفي الزيتون تحت الدراسة إلى مضاعفة إنتاجية عامل الحصاد بحوالى 5-7 مرات والتوفير فى متطلبات الطاقة البشرية اللازمة للحصاد بحوالى 90-130% والتوفير فى تكاليف الحصاد بحوالى 185-245% مقارنة باستخدام طريقة الحصاد اليدوية.
- أوضحت التجارب أن أفضل النتائج المتحصل عليها لكفاءة الحصاد ، وجودة الثمار المحصودة (كفاءة النظافة فى الثمار + نسبة الضرر الميكانيكي للثمار) والقريبة من مثيلاتها بالحصاد اليدوى كانت باستخدام نموذج الرأس الدوارة المطور عند سرعة 900 لفة /دقيقة لحصاد كل من الصنفين شملالى وتفاحي.
- أدى تطوير واستخدام مشط الحصاد المطور فى حصاد ثمار صنفي الزيتون تحت الدراسة إلى مضاعفة إنتاجية عامل الحصاد بحوالى 1-2.5 مرة والتوفير فى متطلبات الطاقة البشرية اللازمة للحصاد بحوالى 190-260% والتوفير فى تكاليف الحصاد بحوالى 135-195% مقارنة باستخدام طريقة الحصاد اليدوية.
- أدى تطوير مشط الحصاد المستورد إلى ارتفاع كفاءة الحصاد و اقترابها من كفاءة الحصاد اليدوي وكذلك ارتفاع جودة الثمار المحصودة ممثلة فى ارتفاع كفاءة النظافة وانخفاض نسبة الضرر الميكانيكي.
- تشير هذه النتائج إلى إمكانية انتشار استخدام نماذج الحصاد المساعدة تحت الدراسة فى حصاد ثمار الزيتون للتغلب على مشكلة ندرة عامل الحصاد وخاصة فى الأراضى الجديدة مع رفع إنتاجيته للحصاد بجودة ثمار عالية وتكاليف تشغيل منخفضة .

قام بتحكيم البحث

أ.د / على السيد ابو المجد	**كلية الزراعة – جامعة المنصورة**
أ.د / محمد قدرى عبد الوهاب	**كلية الزراعة – جامعة الزقازيق**