DESIGN AND EVALUATION A HAND-HELD MACHINE FOR OLIVES HARVESTING

Younis, S. M.[1], K. M. Abdelbary[2], S. A. ELMesery [3] and A. A. Abdelahady[4]

ABSTRACT

The cost of harvesting olive is probably the major factor in determining whether or not there will be an economically successful season for most farmers. Manual harvesting of fruit accounts for 30 to 60% of the total production costs. The aim of the present study was to design, construct and evaluate a hand-held harvester for olive tree. With the purpose of increasing the mechanization level of the harvest operation and permitting the production of high quality oil; the design was based on the following criteria: using local raw materials in the manufacture of the equipment. Providing simple design and easy in operation. The design is made considering all the mechanical, agronomical and economical aspects involved in this issue. The first step consists in the design of the shacking device used for the separation of the olives from the plant, the next step is the design of the supporting structure, including the arms and the frame; finally there is a description of moving parts of the machine. To evaluate the machine performance, a factorial experiment with complete randomized design in five replications was conducted, the factors being shaking frequency (900, 1250 and 1600 rpm), shaking period (1,2and 3 min) and Three varieties of olives (Krotina -kornaki-Manzanalo) varieties oil, varieties of table to study the effect of the use of different speeds in (rpm) and operating period in (min) on harvesting productivity and damage percent were evaluated. The highest harvesting productivity was at 1600 (rpm) and 3 (min), Low damage percent were evaluated at 900 (rpm) and 3 (min), machine achieved highest productivity and Low damage with Kornaki.

Keywords: *Mechanical harvesting, hand held olive harvester, methods of harvesting, accelerations, shaker, vibration, olives, transmission energy*.

[1] **Prof., Agric. Eng. Dept., Fac. of Agric., Cairo Univ., Giza, Egypt.**
[2] **Assistant Prof., Agric. Eng. Dept., Fac. of Agric., Cairo Univ., Giza, Egypt.**
[3] **Researcher Prof., Water Relations and Field Irrigation Dept., National Research center.**
[4] **Agricultural Specialist, Water Relations and Field Irrigation Dept., National Research Center.**

INTRODUCTION

Olive (***OleaeuropaeaL***) is one of the oldest cultivated fruits since its fossilized leaves dating to around 37,000 years ago have been discovered on the Aegean island of Santorin. The olive belongs to the ***Oleaceae*** family, which comprises of 29 genera and the genera ***Oleo*** is one of them with 35 species **(Heywood, 1978)**.

The olive tree is a characteristic plant of the Mediterranean region cultivated for the production of the oil extracted from its fruits, the olives it is one of the most congeal trees and can exceed 2000 years of age; it prefers a warm and dry climate, therefore we can find the oldest ones were the climate remained stable over the centuries, mostly near the sea (**Mirzabe, *et al.*, 2013**). **Özarslan *et al.*, (2001)** reported that hand harvesting is currently at about 50% of the total production costs and 50-60% of the total labor requirement is used for harvesting operations. The world production of olive was 20,344,342 tons. The major producer countries are Spain, Italy, Greece, Turkey, Morocco, Syria, Tunisia, Egypt, Algeria, Portugal and others, **(FAO,2013).**

Fruit harvesting is divided into two categories: manual and mechanical harvesting. Manual harvest costs generally 30- 60 % of the total cost **(O'brien et al., 1986)**

The Egyptian olive production cultivation was about 563,070 tons produced from 202,743 Feddan (1 Feddan =0.42 Hectare), most of which are processed mainly as table olive and the rest is extracted to olive oil, (**Ministry of Agriculture and Land Reclamation, 2013).**Fifty to sixty percent of total production cost issued for harvesting operations **(Özarslan et al., 2001)**. Also in Egypt harvesting operation costs about 0.5–0.75 LE/Kg.

Fruit mechanical harvesting has taken two forms: (1) mechanical aids that provide hand pickers with some assistance and (2) machines that do the harvesting operation. The fruit harvesting machines are varied according to the fruit detachment theories (such as shaking, cutting, combing, etc.), which suit crop type. The main objective of this study was to design and evaluate a hand held machine for harvesting olive. Therefore, the present work was established to investigate the following issues:

1. Designing hand-held harvester.
2. Evaluating its performance.

Manual harvest of olives is one of the most expensive operations in the table olives production, but the use of the electric hand-guided machines triples the productivity. **(Deboli *et al*., 2014)**

Di Giovacchino *et al*., (2002) reported that the direct picking of olive from the tree is necessary avoiding the gather from the ground. In fact, in ground gathering, the detachment time of the single fruit cannot be controlled, because it be dropped from the plant several days before its harvest.

Visco *et al*., (2004) demonstrated that fruits with a shorter peduncle were more amenable to mechanical harvest. It was the combination of tree height, pendulous, apical bearing habit, far from the tree trunk, and light fruit weight that generates, particularly for table olive production, the major problem of mechanical olive harvesting technology; were generating sufficient fruit removal force, (FRF) properly transmitted to the olive abscission zone, to remove the olive fruit without damage. Generally, when fruit is still green the FRF is 800-1000 g or 10 N. It drops markedly at maturity and much more slowly thereafter… etc.

Mailer *et al*., (2005) reported that the most popular method today to determine the optimal harvesting date, developed and used by the International Olive Oil Council (IOOC), is the maturity index (MI), which is based on the pigmentation of the olive fruit.

Deboli *et al*., (2014) mentioned that the picking operation of olives requires, like in other cultivations, a high mechanization level in order to reduce the production costs of high quality oil.

González-Montellano, *et al*., (2014) reported that the direct picking from the tree is necessary avoiding the gather from the ground. In fact, in ground gathering, the detachment time of the single fruit cannot be controlled, because it be dropped from the plant several days before its harvest.

El-Otmani, (2003) mentioned that in Morocco, fruit harvest is done by hand, taking maximum care to avoid any damage to fruit that could result in decay. Mechanization plays a strategic role in the planning of olive groves and in choosing the cultivars and the tree training system.

Harvesting olive methods can be classified to: manual methods and mechanical methods according to (**Hegazy 2009)**.

Hand picking may represented about 80% of the total lab our time required for producing olives in an olive grove and 50–70% of the cost of the harvested olives. This is the reason why hand picking is disappearing and is being replaced by hand-held harvesting machines or mechanical systems. **(Claudio, .2014).**

The basic rule to remove the fruit is shaking all the fruit wheel movement working to increase the internal energy of the fruit (F=ma) remains getting this energy with shaking even be greater than the power of keeping the tree of the fruits fall down. (**Brient et al., 1986).**

$$\mathbf{F = MA} \qquad (1)$$

Where:

F: Force detachment fruits, (Newton).

M: Mass of fruits, (Kg).

A: The acceleration to move, (m/s^2).

Tsatsarelis *et al*., (1984) reported that the factors that affected the fruit detachment were attachment force, fruit weight, maturity, variety, geometry of the fruit (length of peduncle and volume), pruning of the tree, and specifications of the shaker.

O'brien *et al*., (1986) mentioned that the factors affecting the mechanical harvesting of tree fruit were frequency, amplitude, direction of shaking, detachment type and fruit size and pull force to fruit weight ratio.

Younis et al. 1992, studied the effect of three levels of shaking frequency (300, 400 and 500 rpm), three levels of shaking strokes (4, 8 and 12 cm), three levels of shaking duration time (60, 120 and 180 sec) and the harvesting date on the harvesting percentage of olives and energy requirements.They found that the energy required to give 90% of harvesting percentage was obtained to be 5.1 kW.h/ton of olive fruits, at

12 cm stroke, 90 sec shaking duration time, 350 rpm shaking frequency and late harvesting.

Ghonimy 1997, found that the optimum fruits removal percentage of olives with minimum limb damage can be realizing when shaking is applied at 120 mm amplitude, 600 rpm frequency and 0.56 min shaking time with spraying AL sol at 1500 ppm concentration and 2.1 min without spraying. **Ghonimy, (2003)** stated that some factors affecting the vibration and mechanical harvesting of tree fruit as follows:

Vibration: the motion of a body or system that was repeated after a given interval of time. Period; the time interval the vibration to repeat itself; Frequency; the number of cycles of motion per unit of time. ; Amplitude; the maximum displacement of the body or some part of the system from the equilibrium position. Cycle; each repetition of entire motion complete during the period. Natural frequency; the frequency of a system undergoing free vibrations. If a body is suddenly disturbed in some manner.

MATERIAL AND METHODS

a. **Experimental layout**.

The experiments were carried out in the Experimental Farm of Agricultural Production and Research Station (APRS), National Research Centre (NRC), El Nubaria Province, El-Behaira Governorate, Egypt (latitude 30.8667 N, and longitude 30.1667 E).

The experiment were designed by Randomized Complete Blok design with the following arrangement of treatments:

(1) Three different speeds (900-1250-1600), (rpm)

(2) Three different operating period (1-2-3), (min)

(3) Three varieties of olives (Krotina -kornaki- Manzanalo) varieties oil,varieties of table

B. Machine Description

Figure (1 and 2) and Table (1) showed the design of the machine and its specifications. The design was based on the following criteria:

- Using local raw materials in the manufacture of the equipment.
- Providing simple design and easy in both operation and maintenance.

To achieve the objective, the study was implemented through the following steps:

1. Drawing a simplified initial design and calculating the stresses in accordance with the design equations.
2. Choosing the components of the machine,
3. Manufacturing and implementation of the first prototype.
4. Improving the first prototype and testing it in field under different operating conditions.
5. Technical and Economical evaluation for the final prototype of the machine.

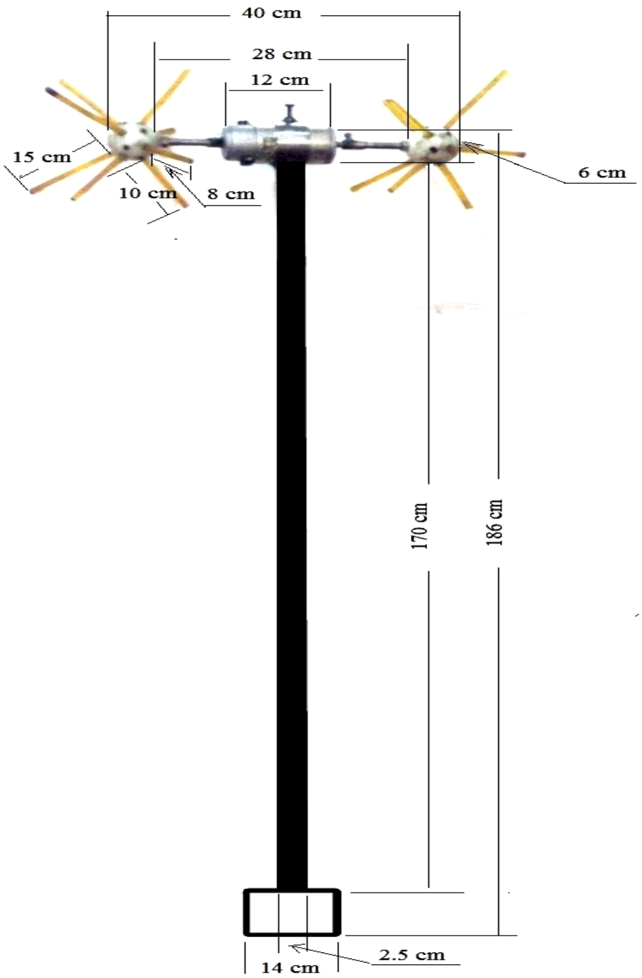
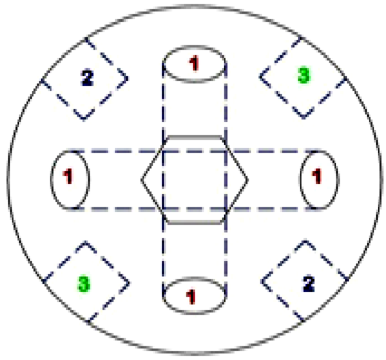


Fig. 1: Front view of hand-held harvester.



Plan Fingers holder

Fig. 2 Fixing finger position arrangement on the ball

1. Finger position (8) cm, 2. Finger position (10) cm, and 3. Finger position (15) cm

Table 1. Technical specifications of the hand-held harvester:

Description	
Type of movement	Rotary members -vibration
Type of head	Thermoplastic spheres with 16elastic sticks of different length
Motor	High power 12 -24V 300 Watts
Initial length	186 cm (up to 3-4m with extension
Weight	4 kg (without cable)
Extension	Optional extension 0.5 and 1.0m (with transmit ion axle)
Cable length	14 m for generator use
Average consumption	7A
Power	300 W
Pole Fixed	2

This equipment allows the olives detachment thought the vibrating action of the rotary members inserted at the top of the rod. It is fed by tension of 12 or 24V. Elastic sticks of different length. The alternating length of the sticks doubles the vibration on the olive tree and guarantees maximum performance The majority of the fruits found in a depth of no more than

15 cm based on that were selected fingers of different lengths harvest There are (four fingers of a length of 15 cm) to reach the maximum depth of fruits and (8 fingers 10 cm) to reach the majority of fruit (4 fingers 8 cm) to reach the extreme places up. Different lengths lead to an interlocking fingers machine with branches. Putting the fingers at different angles so as to work aren't all leaves of the tree without leaving the fruits is not harvested.

c. Measurements:

1- *Contact Tachometer*

Was used to determine speed rotation of the ball, with range of 0.5 to 19,999 rpm Surface Speed (m/min.): 0.05 to 1,999.9 m/min.

2-Force Gauge (5kg, 20 kg wide capacity, high Resolution, accuracy) *was used to measure detachment force of olive.*

3- Damage percent (%) = $\frac{\text{damage olive harvested}}{\text{Total olive harvested}}$

4- The productivity was measured (g/min) at the season olive for each treatment.

RESULTS AND DISCUSSION

In this research the design and testing the performance of hand-held portable machine to harvest olives and powered were studied .The effect of the use of different speeds in (rpm) and operating period in (min) on harvest productivity and damage percent were evaluated.

Productivity and damage percent of (*Krotina*) variety:

Table (2) and Figures (3, 4, 5; 6) illustrate the effect of the machine velocity and operating period on harvest production and damage percent for type of olive (Krotina).(It could be arranged in the following descending order1600>1250rpm>900rpmand 3min>2min>1min, respectively.) The highest and lowest values of machine productivity were achieved at 1600rpm at 3min, and 900 rpm at 1min, respectively. The differences were significant among all replicates and means values. The increase percent in harvest production between 1600rpm and 900rpm recorded 27.98 %. On the other hand the increase percent in harvest production between operating periods 3min and 1 min recorded 63.65 %.Meanwhile the effect of machine velocity and operating period on damage percent, It could be ranked in the following descending order 1600rpm>900rpm > 1250rpm and 3min >2min>1min, respectively. The highest and lowest values of damage percent were achieved at 1600rpm at 2min, and 900 rpm at 1min, respectively. The differences were significant among all replicates and means values. The increase percent in harvest damage percent between 1600rpm and 1250rpm recorded 56.92%. On the other hand the increase percent in harvest damage between operating periods 3min and 1 min recorded 43.06%. The increasing percent show that there was a positive effect on harvest production in case of operating the long period 3min, but there was a negative effect on.at the highest velocity 1600rpm harvest damage percent.

Table (2) Effect of the machine velocity and operating period on harvest production and damage percent for type of olive (*Krotina*) without spraying.

Velocity (rpm)	**Period (min)**	**Machine Production (g)**	**Damage percent (%)**
900	1	486i	4.87fg
	2	809f	4.87fh
	3	1170c	4.56hi
1250	1	520h	5.21f
	2	908e	6.19d
	3	1431b	5.92e
1600	1	573g	15.8b
	2	1108d	14.8c
	3	1742a	18.53a
LSD 0.05		**9.3**	**0.40**

Note: Numbers followed by different letters means that treatment has significant difference at ($P<0.05$)

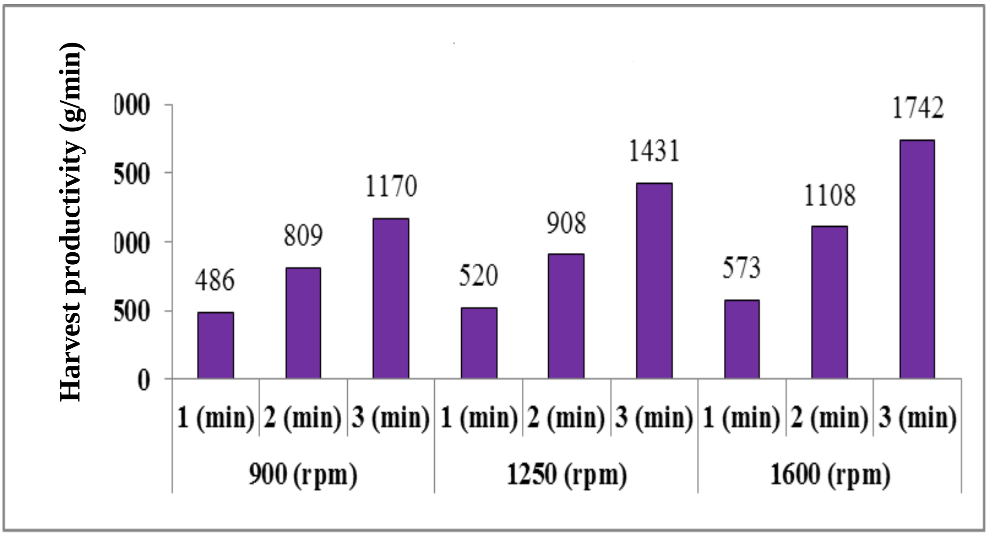


Fig. (3) Effect of the machine velocity and operating period on harvest production for variety of olive (*Krotina*).

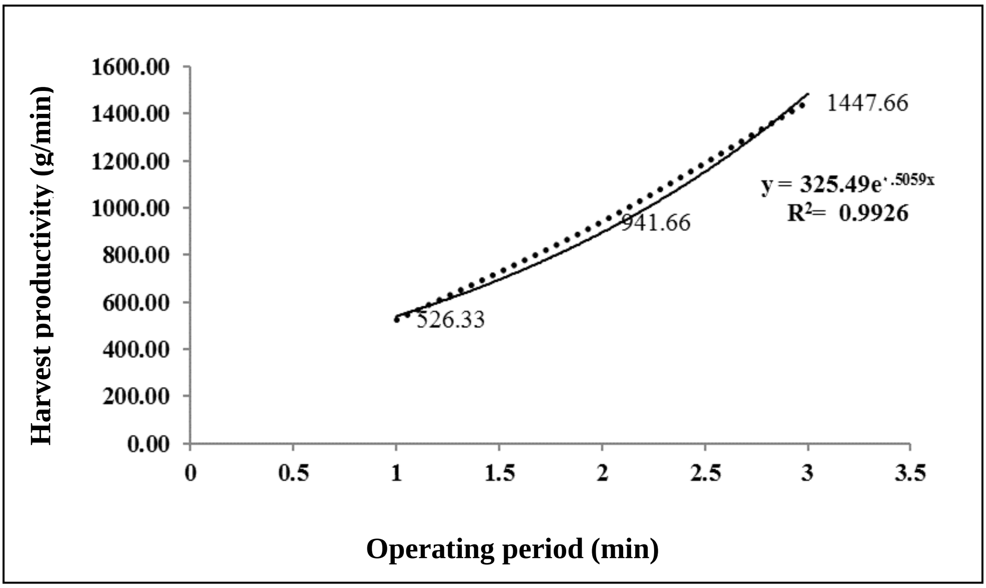


Fig. (4) The relationship between the operating period and harvest productivity for variety of olive (*Krotina*).

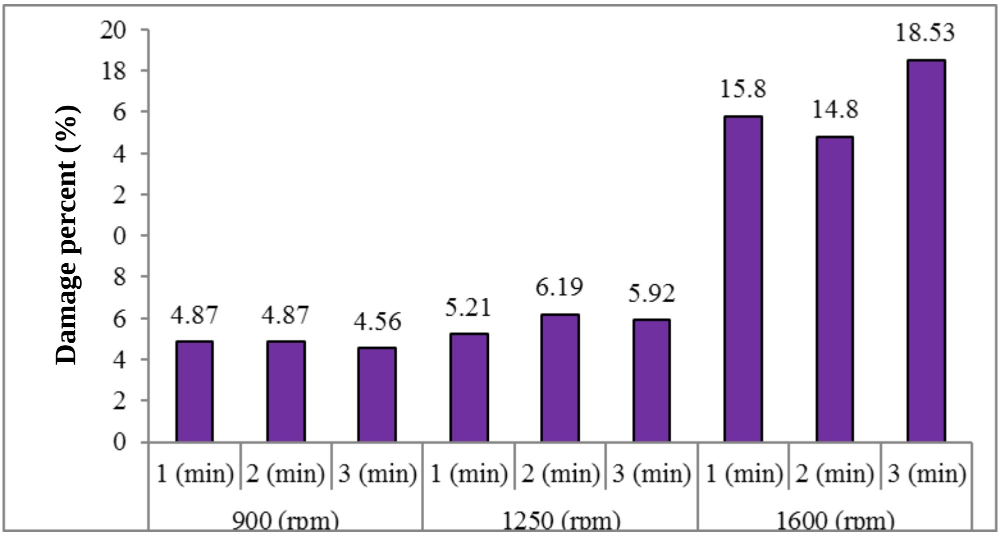


Figure (5) Effect of the machine velocity and operating period on damage percent for type of olive (*Krotina*) without spraying.

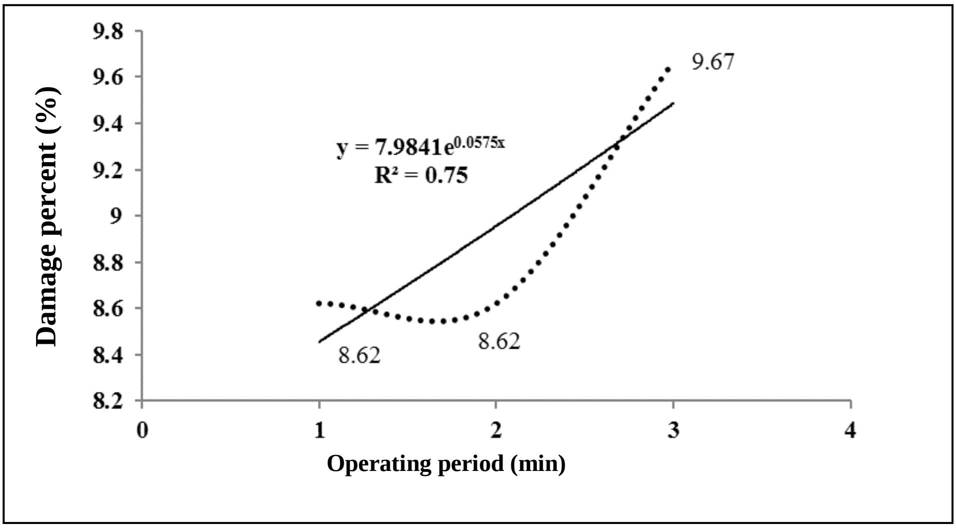


Fig. (6) The relationship between the operating period and harvest damage percent for olive type (Krotina) without spraying.

Productivity and damage percent of (*Manzanilo*) variety:

Table (3) and Figures (7, 8, 9; 10) illustrate the effect of the machine velocity and operating period on harvest production and damage percent for type of olive (*Manzanilo*). (It could be arranged in the following descending order 1600rpm>1250rpm>900rpm and 3min>2min>1min, respectively). The highest and lowest values of machine productivity were achieved at 1600rpm at 3min, and 900 rpm at 1min, respectively. The differences were significant among all replicates and means values. The increase percent in harvest production between 1600rpm and 900rpm recorded 30.31 %. On the other hand the increase percent in harvest production between operating periods 3min and 1 min recorded 64.42 %. The effect of machine velocity and operating period on damage percent, It could be arranged in the following descending order 1600rpm > 900rpm > 1250rpm and 3min >1min>2min, respectively. The highest and lowest values of damage percent were achieved at 1600rpm at 2min, and 900 rpm at 1min, respectively. The differences were significant among all replicates and means values. The increase percent in harvest damage percent between 1600rpm and 1250rpm recorded 58.82%. On the other hand the increase percent in harvest damage between operating periods 3min and 1 min recorded 42.86 %.The increasing percent revealed that there was a positive effect on harvest production in case operating the long period 3min, but there was a negative effect to on. At the highest velocity 1600rpm harvest damage percent.

Table (3) Effect of the machine velocity and operating period on harvest production and damage percent for type of olive (*Manzanilo*) without spraying.

Velocity	Period	Machine Production (g)	Damage percent (%)
900 rpm	1 min	438i	6.48g
	2 min	797f	5.15i
	3 min	1062d	7.00e
1250 rpm	1 min	489h	7.13d
	2 min	901e	5.95h
	3 min	1412b	6.58f
1600 rpm	1 min	546g	16.52b
	2 min	1084c	15.03c
	3 min	1666a	19.56a
LSD 0.05		7.7	0.14

Note: Numbers followed by different letters means that treatment has significant difference at (P<0.05)

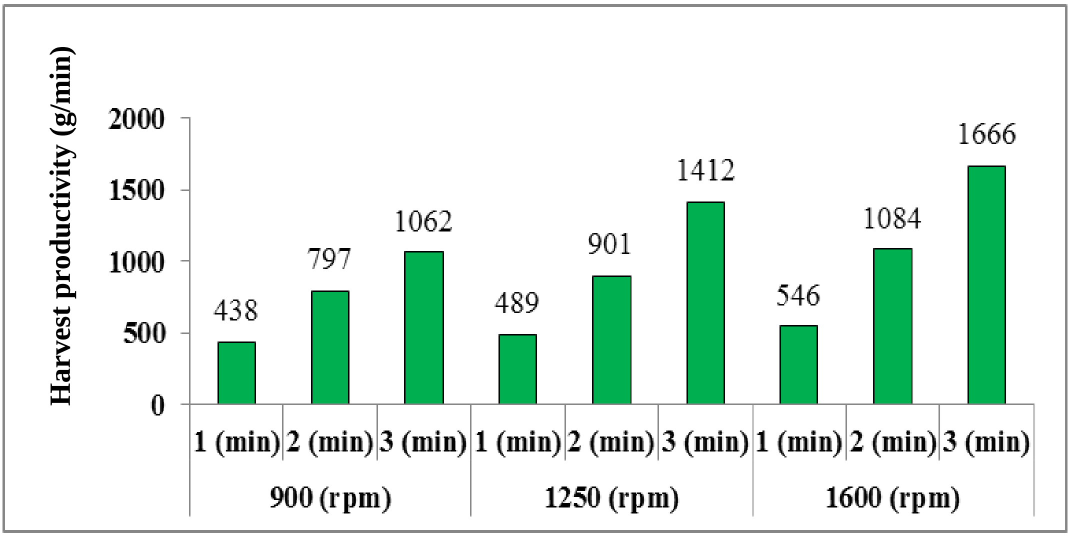


Fig. (7) Effect of the machine velocity and operating period on harvest productivity for variety of olive (*Manzanilo*).

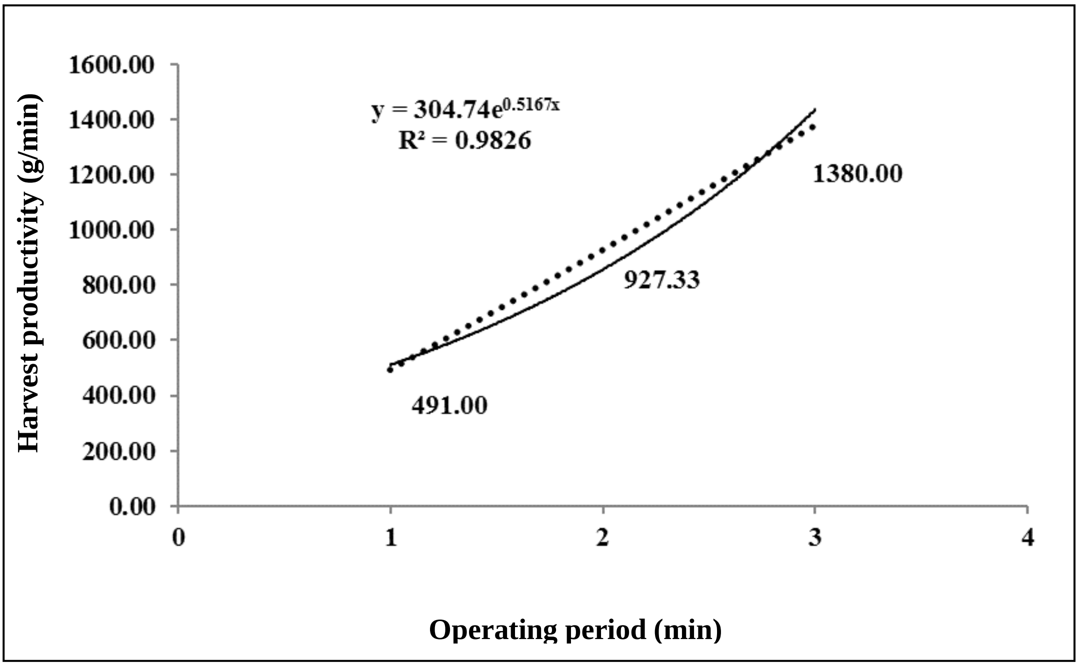


Fig. (8) The relationship between the operating period and harvest production for type of olive ((*Manzanilo*) without spraying.

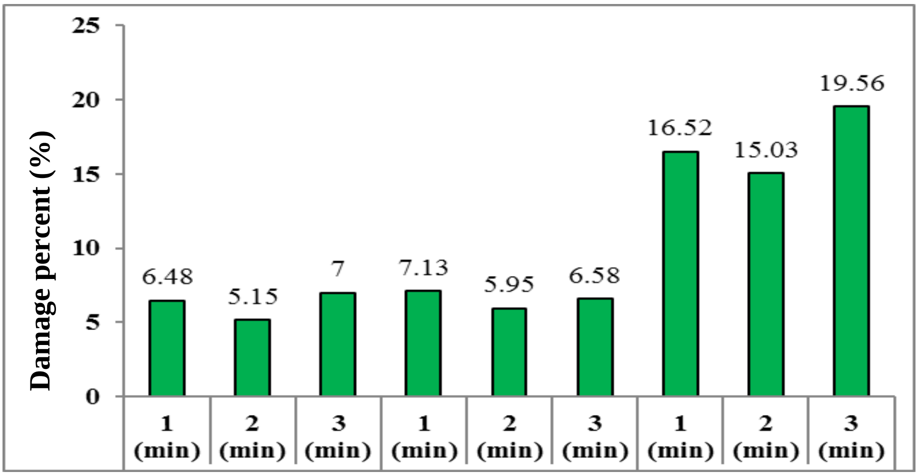


Fig. (9) Effect of the machine velocity and operating period on damage percent for type of olive (*Manzanilo*) without spraying.

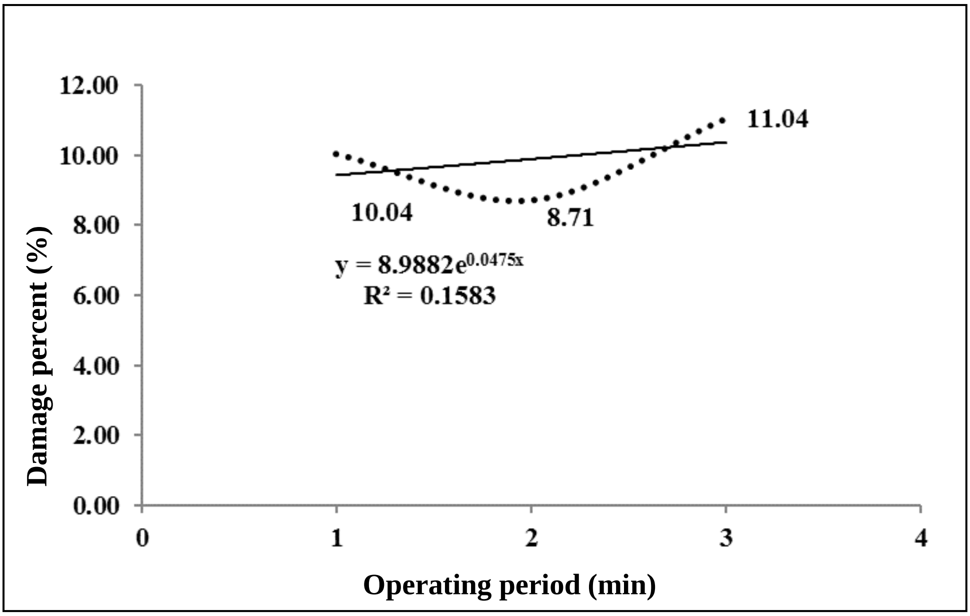


Fig. (10) The relationship between the operating period and harvest damage percent for olive type (*Manzanilo*) without spraying.

Productivity and damage percent of (*Kronaky*) variety:

Table (4) and Figures (11, 12, 13; 14) illustrate the effect of machine velocity and operating period on harvest production and damage percent for type of olive (***Kronaky***) .It could be arranged in the following descending order 1600rpm>1250rpm>900rpm and 3min>2min>1min, respectively. The highest and lowest values of machine productivity were achieved at 1600rpm at 3min, and 900 rpm at 1min, respectively. The differences were significant among all replicates and means values. The increase percent in harvest production between 1600rpm and 900rpm recorded 41.38 %. On the other hand the increase percent in harvest production between operating periods 3min and 1 min recorded 65.84 %. The effect of machine velocity and operating period on damage percent, It could be arranged in the following descending order 1600rpm > 900rpm > 1250rpm and 3min >1min>2min, respectively. The highest and lowest values of damage percent were achieved at 1600rpm at 2min, and 900 rpm at 1min, respectively. The differences were significant among all replicates and means values. The increase percent in harvest damage percent between 1250rpm and 1600rpm recorded 3.23%. On the other hand the increase percent in harvest damage between operating periods 1min and 3 min recorded 9.77 %. The increasing percent revealed that there was a positive effect in harvest production in case using the long period 3min but the short period 1 min has a negative effect on damage percent, and there was a positive effect to on. At the highest velocity 1600rpm harvest damage percent but the middle velocity1250rpm has a negative effects on damage percent.

Table (4) Effect of the machine velocity and operating period on harvest production and damage percent for type of olive (*Kronaky*) without spraying.

Velocity	Period	Machine Production (g)	Damage percent (%)
900 rpm	**1 min**	777i	5.40e
	2 min	1489f	4.90d
	3 min	2297d	4.47h
1250 rpm	**1 min**	959h	5.15f
	2 min	1894e	5.12g
	3 min	2808b	4.62i
1600 rpm	**1 min**	1302g	4.83b
	2 min	2694c	4.72a
	3 min	3788a	4.86c
LSD 0.05		**10.5**	**0.05**

Note: Numbers followed by different letters means that treatment has significant difference at (P<0.05)

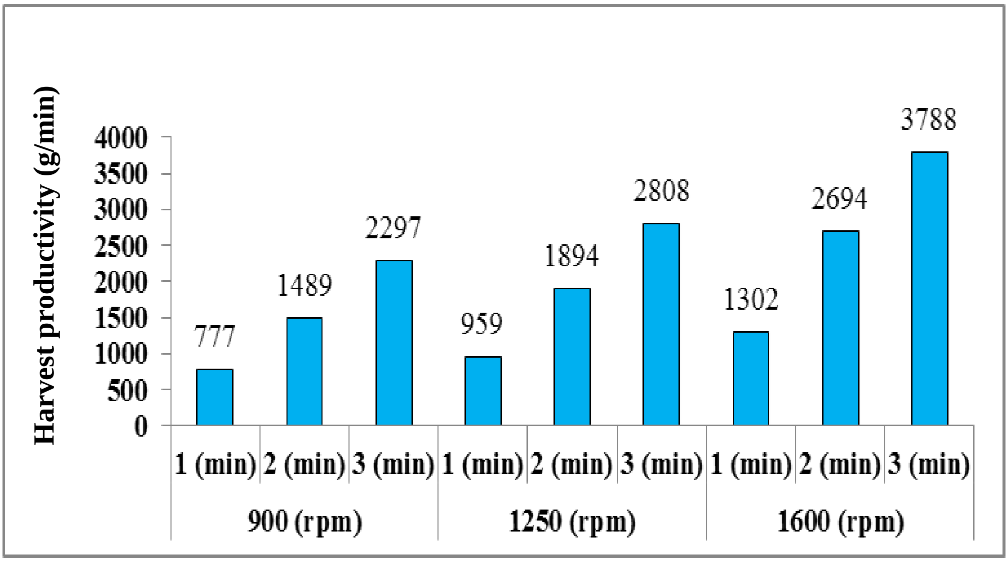


Fig. (11) Effect of the machine velocity and operating period on harvest productivity for variety of olive (*Kronaky*).

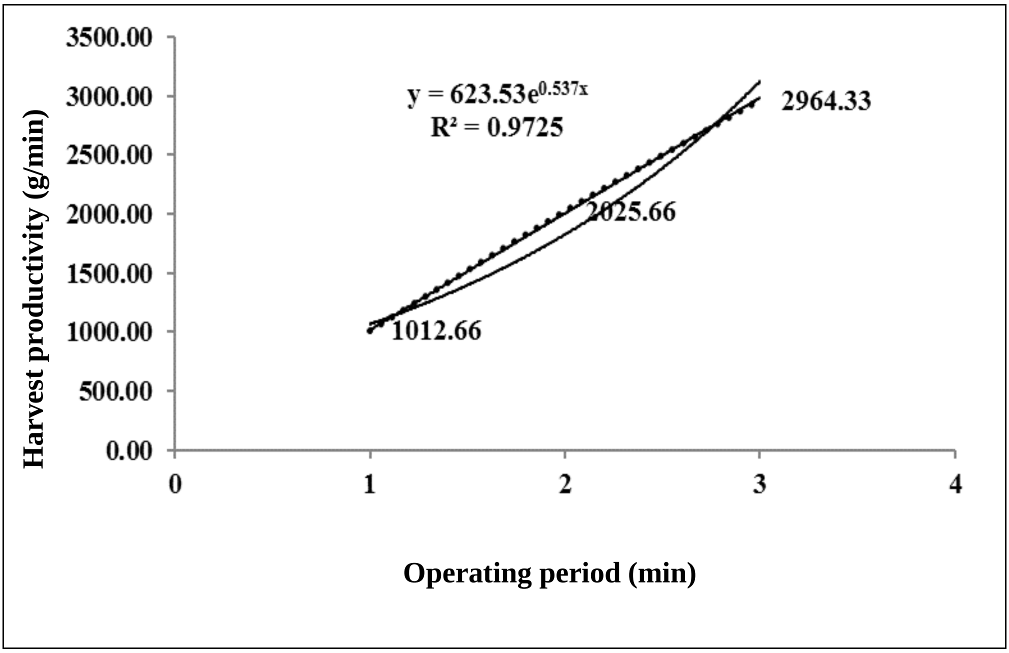


Fig. (12) The relationship between the operating period and harvest production for type of olive (*Kronaky*) without spraying.

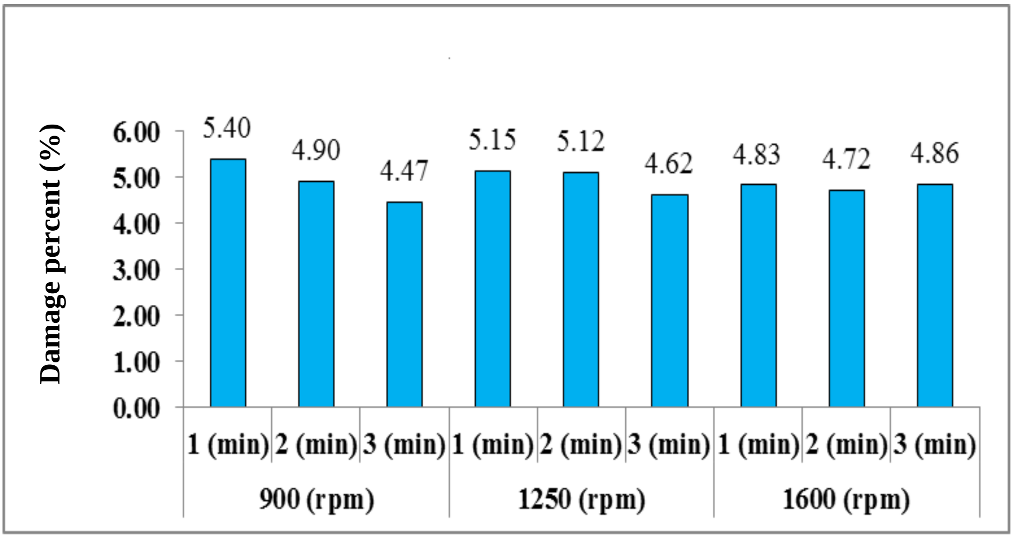


Fig. (13) Effect of the machine velocity and operating period on damage percent for variety of olive (*Kronaky*).

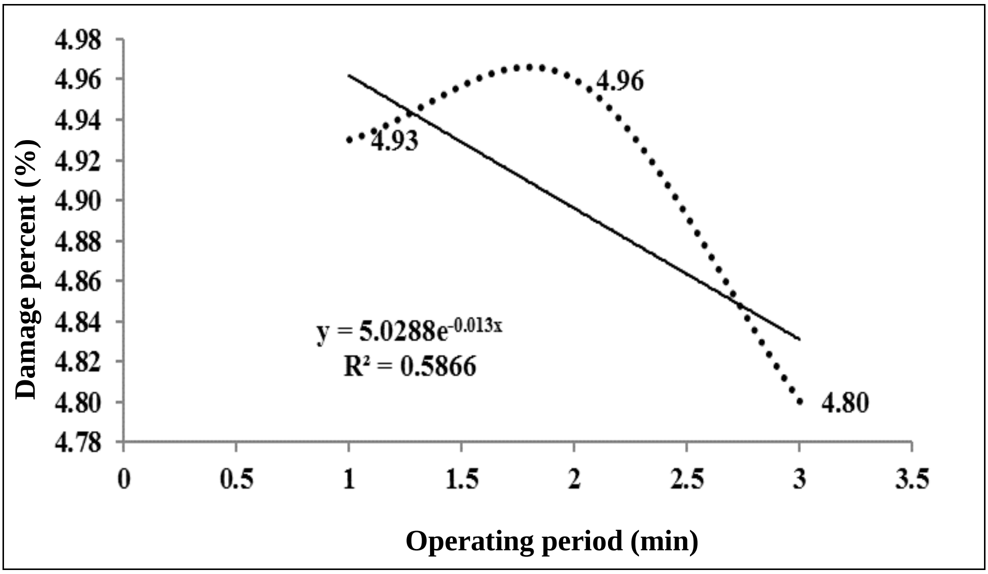


Fig. (14) The relationship between the operating period and harvest damage percent for olive variety (*Kronaky*) .

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الملخص العربي

تصميم وتقييم آلة محمولة لحصاد الزيتون

سامى محمد يونس[١] ، خالد محمد عبدالبارى[٢] ، ثروت عبد السميع الميسيرى[٣]
و احمد عبدالعاطى عبد الهادى[٤]

يعتبر الزيتون من أهم محاصيل الأستزراع في الأراضي الصحراوية المستصلحة لما تتميز به من قدرة علي تحمل الجفاف والملوحة والنمو في مختلف أنواع الأراضي ومقاومة الطبيعة والمناخ مما يسمح بزراعته لإستثمار مساحات كبيرة من الأراضي الشاسعة التي يصعب إستغلالها في زراعة كثير من أنواع المزروعات لأخري وتتركز زراعة الزيتون في دول حوض البحر المتوسط حيث يبلغ إنتاج هذه الدول حوالي ٩٣% من الإنتاج العالمي وتعتبر مصر إحدي هذه الدول التي أهتمت بزراعة الزيتون في الأونة الأخيرة.

[١] أستاذ الهندسة الزراعية، قسم الهندسة الزراعية، كلية الزراعة ـ جامعة القاهرة.
[٢] مدرس ـ قسم الهندسة الزراعية، كلية الزراعة ـ جامعة القاهرة.
[٣] أستاذ باحث العلاقات المائية والري الحقلي، قسم العلاقات المائية، المركز القومي للبحوث.
[٤] أخصائي زراعي، قسم العلاقات المائية والري الحقلي، المركز القومي للبحوث.

ويعتبر الحصاد اليدوي طريقة قليلة الجدوي الأقتصادية حيث تمثل تكاليف الحصاد بهذه الطريقة ما بين ٥٠-٦٠ % من التكاليف الكلية للعمالة وحوالي ٥٠% من تكلفة المنتج النهائي .

وللحصاد اليدوي كثير من المشاكل تتركزفي الفقد الكبير في المحصول وإنخفاض معدل إنتاجية العامل بالإضافة الي الأضرار التي تحدث للأفرع نتيجة الضرب بالعصي وإستخدام الخطاطيف لحصاد ثمار الزيتون لذلك فإن الحصاد الميكانيكي يعتبر طريقه جيدة ومناسبة لتخفيض نسبة الفقد وتقليل تكاليف الانتاج. ونظرلأهمية الحصاد الميكانيكي فقد تناول هذا البحث الأتي :

١. تصميم ألة حصاد محمولة.
٢. رسم النموذج الأولى للألة واختيار الاجزاء الرئيسية المكونه لها.
٣. تنفيذ وتصنيع النموذج الأولى للألة.
٤. اختبار وتقييم النموذج الأولى واستكمال التعديلات التى ظهرت نتيجة الاختبار.
٥. تصنيع واختبارالنموذج النهائى للألة حقليا تحت ظروف تشغيل مختلفة.

وقد تم إجراء التجارب الحقلية بمحطة التجارب والبحوث الزراعية التابعة للمركز القومي للبحوث - منطقة النوبارية - محافظة البحيرة، وذلك لدراسة تأثير السرعات المختلفة للآلة (٩٠٠- ١٢٥٠ -١٦٠٠ لفة/دقيقة) وفترات التشغيل المختلفة (١-٢-٣ دقيقة) لثلاثة أصناف من الزيتون (كروتينا- كورناكى - مانزانيللو) علي الإنتاجية ونسبة الثمار التالفة.

ومن خلال البحث تم الحصول علي أعلي إنتاجية عند السرعة (١٦٠٠ لفة/الدقيقة) وفترة تشغيل مقدارها ٣ دقائق كما تم الحصول علي أقل نسبة للتالف عند سرعة (٩٠٠لفة /الدقيقة) وفترة تشغيل ٣ دقائق كما أن الآلة حققت أعلي إنتاجية في الثمار لنوع الزيوت كروناكي عند السرعة (١٦٠٠ لفة/الدقيقة) وفترة تشغيل مقدارها ٣ دقائق.

الكلمات الدالة *: الحصاد الميكانيكي، حصادة زيتون محموله باليد، طرق الحصاد، التعجيل، هزاز، الاهتزاز، الزيتون، نقل الطاقة.*