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Development of a Simple Tool Provided with a Sensor for Harvesting Citrus Fruits

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ABSTRACT

The present paper aims to develop a simple tool provided with a sensor to be used for harvesting citrus fruits. The developed harvesting tool consists of telescopic tubes, a harvesting device provided with a sensor, a dry battery, a fruit tube and a collection basket. The developed tool was based on validating the correct stem- cutting position, safeguarding the fruits from harm, and preventing the fruits from down via the fruit tube. Two types of fruit trees were used. In order to better understand how certain operating parameters affect the performance of the proposed harvesting tool, experiments were carried out. These parameters are: cutting disc speeds of 9.81, 13.74, 17.66 and 21.59 m/sec and cutting disc teeth numbers of 60, 80 and 100 teeth. The developed harvesting tool was assessed in terms of the following: consumed power, energy requirements, total fruit losses, harvesting cost, and productivity of the harvesting instrument. According to the trial findings, the Washington navel orange and Sour orange had the highest values of harvesting tool productivity and efficiency at 285 and 315 kg/h and 96.0 and 97.5%, respectively. While the lowest level required power and the specific energy values were 36. 10 W and 35. 02 and 0. 125 W h/Mg for the previously mentioned two types. The lowest values of harvesting cost are 42.80 and 38.72 "EGP/Mg for the same mentioned two types of fruits.

***Keywords**: Sensor, teeth, tool, and disc.*

INTRODUCTION

The fruit and citrus trees, as food for human sources and an important pillar of the national income, are one of the basic elements for agricultural production in bridging the food needs resulting from population growth and the increasing demand for its products. In addition, the fruit and citrus trees provide a lot of raw materials for the food industry and the medical and cosmetics. So, the production expansion of fruit trees became of great economic. The expansion in the agriculture fruit trees has been accompanied by the development of methods of pruning and harvesting, including the mechanism ways to end the pruning process and harvest quickly and easily with high quality. When developing such fruit harvesting machines, broken twigs or branches fruiting or scratch fruits that lead to corruption must be taken into account

Sanders (2005) mentioned that 35 to 45 percent of the overall cost of production goes into citrus harvesting. As a result, increasing the effectiveness of this particular process has a significant impact on the viability and profitability of the business. The old-fashioned hand harvesting technique is labour- and money-intensive. High-quality fruit selection is greatly desired since it drives up the price of fruit by supplying the best fruit, and none of the mechanical systems under investigation were found to be able to select fruit with the same level of excellence as manual picking. In order to lower the cost of manual picking, it also provides the findings of research into further strategies for increasing manual picking productivity. Additionally, cutting was described by Srivastava et al. (2006) as a technique that results in the mechanical breakdown of plant stems and/or leaves; as a result, the strength and structure of plant materials are of interest. Engineering characteristics of plant parts are less well understood than those of more widely produced items. Although some engineering studies of plant materials have been seen as materials with fibres of high tensile strength orientated in a common direction and linked together by material of considerably lesser strength, structurally speaking, the stems engineering materials such as steel. Hermans, (2008): stated that over fifty years ago, the mature stage was the precursor of harvesting utilising very tall/long ladders while carrying or carrying a basket. Falls from this pose a significant danger of death. Low-stemmed trees have been standard for several fruits since the 1960s. In comparison to standing on a tall ladder, trees with lower legs offered a more effective, quicker harvest and a more comfortable working position. Ravetti (2008): There were a side-by-side shaker (Haslett Harvesting), a grape harvester (New Holland/Braud), a modified coffee harvester (Haslett Harvesting), and two specialised machines using beating systems (Gregoire 133V) or rotating heads with flexible fingers (Colossus). Operation speed, canopy and trunk damage, fruit removal efficiency, and operating expenses are some of the traits that have been evaluated. Large over-the-row harvesters like Colossus and side-by-side shakers are two competing solutions for cutting down trees the size of an entire canopy. El-Iraqi et al. (2010) created a simple auxiliary tool for mechanical mango harvesting. These prototypes include a telescoping tube, a fruit collection tube, and various cutting mechanisms. One disc cutter had a gasoline motor, while the other had a diesel engine, a lead hook, electric shears, and an electric drive The findings revealed that fruits with the least amount of damage were the ones with the least amount of harm. Electric shears, electric disc cutters, and mechanical disc cutters were used by (3-4) %, (4-5) %, and (5-6) %, respectively. According to Peilin Li et

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al. (2011): traditional harvesting in the horticultural business involves 'handpicking' techniques to take dozens to hundreds of fruits, such as citrus fruits, from various positions on the individual fruit trees. It is well knowledge that large-scale fruit harvesting is still inefficient and expensive. Mechanical harvesting methods have been researched and put into practise to help horticulture firms operate more profitably and efficiently. However, they frequently mutilate fruits when picking them. To ensure fruit quality, effective fruit removal techniques must be developed. Three different manual mango pickers were evaluated by Roger et al. (2016): the pull, trigger, and modified trigger with a scissors blade controlled by a steel wire to cut the stems. When compared to a traditional mango picker with a capacity of 22 fruits/min, the results show that the capacity of the trigger and pull types was 12 and 21 fruits per minute, respectively. Mohamed (2017): stated that the fruit stems were not sliced by the circular plan discs. Additionally, increasing the linear speed of the cutting saws increases the overall cutting percentage. The picker was successful in harvesting mango fruits at an optimal linear speed of 8.34 m/s using modified circular saws with 100 sharp edge teeth and double discs overlapping by 5 mm, and the counter blade position is under the discs, giving a correct cutting percentage of 95% and only 5% undercut stems. Comparing the average (productivity, total fruit injured ratio) for the manual picking and the innovative picker, there were (22 fruit/min, with damage ratio of 52.74%), the use of the innovated picker decreased the fallen fruits ratio, injured fruits ratio, and latex fruit ratio by (84.89%, 64.55%, and 84.25%) respectively and increased the right harvested fruits by 49.03%. Given that the picker's productivity was average (20 fruits per minute with a damage ratio of 7.28%), the farmer would have to sell 52.74% of the crop at a low price as a result of the damaged fruit. El-Termezy et al. (2022) created a portable harvesting device. Results were contrasted with those of the conventional manual method under identical operating conditions. According to the findings, using the modified fruit harvesting device for picking navel orange and pomegranate fruits at a disc speed of 3.66 m/s with all cutting heights resulted in improved performance rates and fruit damage ratios as well as lower specific energy and operational costs. For navel orange and pomegranate fruits, the obtained results under ideal conditions were machine performance rates of 24.33 and 20 fruit/min, fruits damage ratios of 9.66 and 9.25%, specific energies of 6.45 and 7.58 kW h/Mg, and operational costs of 85.74 and 100.71 L.E./Mg, respectively.

Referring to the above mentioned literature review; the author attempts to solve the problem of citrus tree harvesting so as to carry out the operation easily and quickly with high fruits qualities.

Therefore, the following are the goals of the current work:

- Develop a simple tool provided with a micro switch sensor for harvesting citrus fruits.
- Identify the optimal parameters (Harvesting disc speed, teeth number of harvesting disc and fruit type) affecting the performance of the developed harvesting tool.
- Estimate the harvesting cost required for operating the developed harvesting tool.

MATERIALS AND METHOD

To create and assess the effectiveness of a tool to be used for harvesting citrus fruits, the major experiments were conducted at Horticulture Farm Research Station, El Kasaseen Sharkia Governorate, Egypt.

1. The developed citrus trees harvesting tool

A developed harvesting prototype, suitable for harvesting citrus fruits, was made specifically in a small workshop located at Sharkia Governorate. To enable a telescope to reach the high places of the citrus fruits on the tree, the tool was manufactured from lightweight materials. The developed tool was based on validating the correct stem cutting position, safeguarding the fruits from harm, and preventing the fruits from falling via the fruit tube. The following are the primary components of the developed harvesting tool (Figs. 1 and 2):

- Telescopic tubes

Six telescopic tubes made of plastic with thickness of 1 mm were used to carry the harvesting device on its top. Each tube has length of 500 mm and edges diameters of 36 and 32 mm.

- The harvesting device

The harvesting-device base was fastened with the top of the telescopic tube by two iron-brackets with a thickness of 1.5 mm, length of 100 mm and width of 25 mm. The two brackets were bolted with the end of telescopic tube by two bolts with a diameter of 5 mm.

The harvesting device consists of the following parts:

- Cutting disc

Three cutting discs with varying numbers of teeth were put to the test. The alloy steel teethed cutting disc has a 125 mm diameter and a 1 mm thickness.

- Power source

The cutting tool was driven by a 12 volt DC motor. These were the motor's specifications: Germany's Buhler Motor GmbH, write in brush 12 volts. The power is 60 W (0.082 HP), the rotational speed is 3,300 rpm, and the shaft diameter is 5 mm. The torque is 0.18 N.m. By adjusting the voltage control switch, an adjustable voltage regulator was employed to enable the operator to regulate and control the electric motor's rotational speed.

- Sensor

A micro switch sensor was bolted at one side of Y-shaped guide by a screw bolt with a diameter of 2 mm. The harvesting device motor was operated when the fruit neck touches the sensor vane

- Formed base

A threaded plate with a diameter of 18 mm and a thickness of 6.5 mm obstructs the motor shaft. A nut with an inside diameter of 18 mm held the threaded plate and the harvesting disc together. Underneath the threaded plate is a formed base. Three bolts with a 3 mm diameter were used to fasten this base to the motor. The base features a Y-shaped guide, and on the opposite side is a bent bracket that is attached to the telescopic tube by a bolt.

Cutting - disc housing

- Two plastic covers with dimensions of 156 mm in diameter, 17 mm in height, and 1.5 mm in thickness make up the housing for the cutting disc. Each cover was fastened to the formed base using 3 mm-diameter bolts.

- Dry battery

Electric wire with a thickness of 2 mm connects the 12 Volt rechargeable dry battery. Electric cables are inserted into each telescopic tube. The operator wears a belt that holds the battery bag.

- Fruit tube

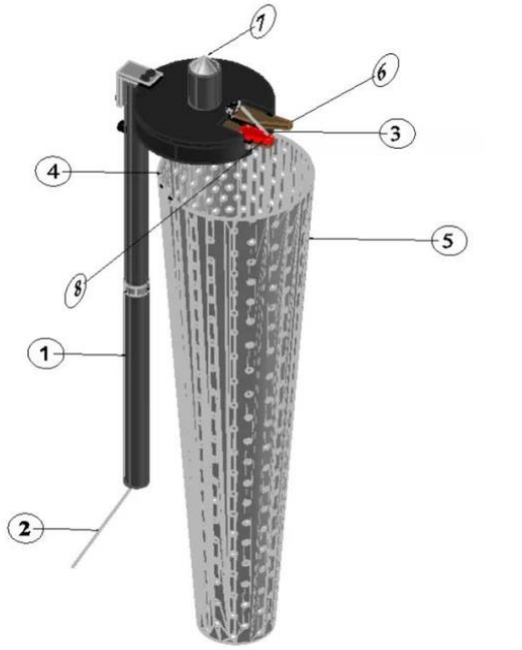
The fruit tube consists of a top iron ring with 220 mm diameter and 8 mm thickness and a cloth tube with length of 3 m. The fruit ring has an outside plate bolted with the telescopic tube by bolting. The distance between the cutting device and the fruit tube ring is 200 mm.

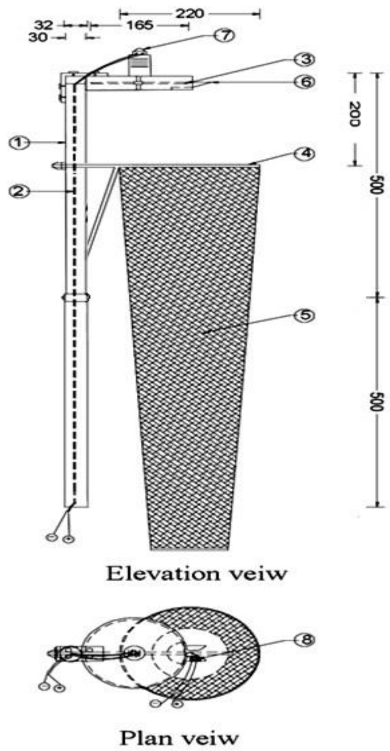
- Collection basket

The collection fruit-basket was made of plastic with volume of 120 liters. The fruit basket has two rubber wheels.

- Charger

A Charger A hardwood cuboid box measuring 125 mm by 125 mm by 200 mm and 10 mm thick is used to make battery charger. It has a transformer with an input voltage of 220 volts and an output voltage of 12 volts, and it is wired to an indicator to show how much battery charge is required. When the battery is empty, it takes 8 hours to fully charge it.





No.	Part name	No.	Part name
1	Telescopic tube	5	Cloth tube
2	Electrical cable	6	Fruit guide
3	cutting disc	7	Dc-motor
4	Fruit tube	8	Sensor

Fig. 1. The developed citrus fruits harvesting tool

Fig. 2. Images of the developed citrus fruit harvesting tool

2. The used fruits

A sour orange and a Washington navel orange were the two varieties of citrus fruits used. In Table 1, Some of sour orange and Washington navel orange physical and mechanical characteristics are displayed. According to the standards established in, these values were measured for 20 fruit samples (Sharifi et al., 2007).

Table 1. The some of Sour orange and Washington navel oranges' physical and mechanical Characteristics

Characteristics Physical properties	Sour orange	Washington navel oranges
Fruit ripening dates	January - March	November - March
Tree yield (fruit)	200-300	250-300
Fruit mass (g)	160-220	180-250
The crust	Spherical	Quite thick
Number of lobes (lobe)	8-9	9-10
Fruit diameter (mm)	50-80	70-100
Number of seeds in the fruit	35-40	-

2. Methods

Studies and evaluations of the created citrus fruit harvesting tool's performance under various operating circumstances were done through experiments.

Experimental circumstances

The following variables were used to experimentally examine the fruit-harvesting tool's performance:

- Two types of fruit trees (Sour orange –Washington navel oranges .
- Four different harvesting disc speeds (9.81,13.74,17.66 and 21.59 m/sec).
- Three different numbers of cutting disc teeth (60 ,80 and 100 teeth) as shown in Fig. 3.

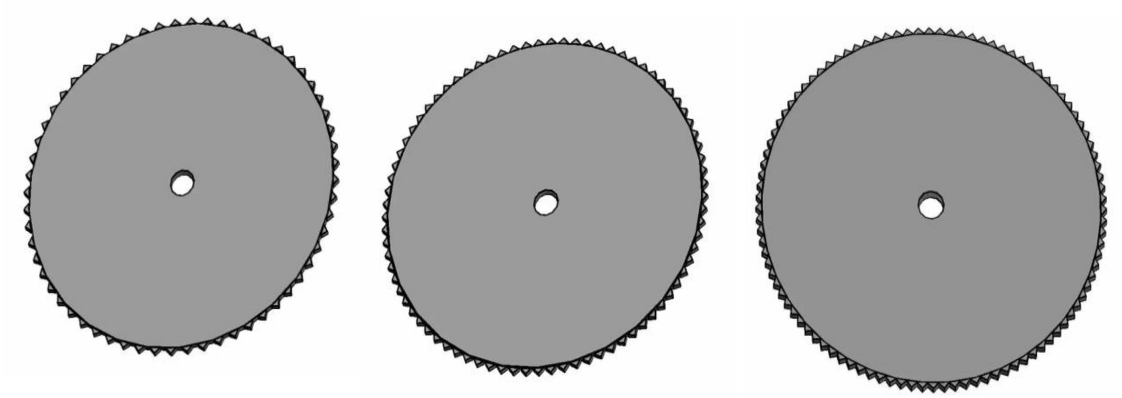


Fig. 3. The three different number of harvesting disc teeth

Measurements and calculations

Following indicators were taken into account when evaluating the effectiveness of the designed fruit-harvesting tool:

- Harvesting tool productivity

The following equation was used to calculate the productivity of the harvesting tool:

$$HTP = \frac{Q}{t}$$

Where:

HTP - The harvesting tool productivity, kg/h,
Q - The harvested quantity of fruits, kg,
t - The time required to harvest the fruit quantity, h.

- Harvesting fruit losses

The following equation was used to calculate the harvesting fruit losses of the harvesting tool:

$$HFL = \frac{M_{ma}}{M_{mb}} \times 100$$

Where:

HFL - The harvesting fruit losses, %,
M_{ma} - Mass of mature fruit still on the tree after harvesting, kg,
M_{mb} - Mass of mature fruit still on the tree before harvesting, kg.

- Harvesting fruit damage

The following equation was used to calculate the harvesting fruit damage of the harvesting tool:

$$HFD = \frac{M_{da}}{M_{mb}} \times 100$$

Where:

HFD - The harvesting fruit damage, %,
M_{da} - Mass of damaged fruit after harvesting, kg,
M_{mb} - Total mass of mature fruit after harvesting, kg

- Total harvesting fruit losses

The total harvesting fruit losses (THFL) was determined using the following equation:

$$THFL = HFL + HFD$$

- Harvesting tool efficiency, %

The following equation was used to calculate the harvesting efficiency

$$HE = \frac{N}{M_{mb}} \times 100$$

Where:

HE - The harvesting efficiency, %
N - The number of harvested fruits after harvesting, fruit
M_{mb} - The number of mature fruits on the tree before harvesting , fruit.

- Required power

The equation below was used to calculate the necessary power. (Chancellor, 1981):

$$Required\ power,\ kW = \frac{I \times V \times \cos\theta}{1000}$$

Required power, W= I × V × cos θ

Where:

I - Current strength, Amperes;
V - Potential difference, Voltage;
cos θ - Power factor = constant= 0.85

- Energy requirements

$$Energy\ requirements,\ Wh/kg = \frac{Required\ power,\ W}{Harvesting\ tool\ productivity,\ kg/h}$$

- Harvesting cost

The following equation was used to calculate the hourly cost of the harvesting tool. (Awady et al., 1978):

$$C = \frac{p}{h}\left(\frac{1}{a} + \frac{i}{2} + t + r\right) + (W.e) + \frac{m}{144}$$

where

C is the pruning device hourly cost [EGP/h,] p is the pruning device price[EGP], h is the pruning device yearly operating hours [h/year], l is the pruning device life expectancy [h] , i is the interest rate per year [%], t is the taxes rate [%], r is the repair and maintenance ratio [%], PR is the power requirements [kW], e is the hourly electricity cost [EGP/kWh], m is the operator's monthly wage [EGP], and 144 is the monthly working hours

The operational cost was calculated using the following formula:

$$Operational\ cost, \text{EGP Mg} = \frac{Harvesting\ tool\ hourly\ cos,EGP}{Harvesting\ tool\ productivity,Mg/h}$$

The required harvesting cost was estimated according to the following equation:

Harvesting cost (,EGP Mg) = Operational cost (,EGP Mg) + THFL (,EGP Mg)

RESULTS AND DISCUSSION

The results were obtained and discussed.

1. The developed harvesting tool productivity via operating parameters.

Representative values of the developed harvesting tool productivity versus cutting disc speed for different numbers of cutting disc teeth were illustrated in Fig.(4).

Concerning the influence of cutting disc speed on the developed tool productivity, increasing disc speed from 9.81 to 21.59 m/s at the cutting disc teeth of 100 teeth, tool productivities were increased from 210 to 290 and from 235 to 315kg/h, for Sour orange and Washington navel oranges, respectively.

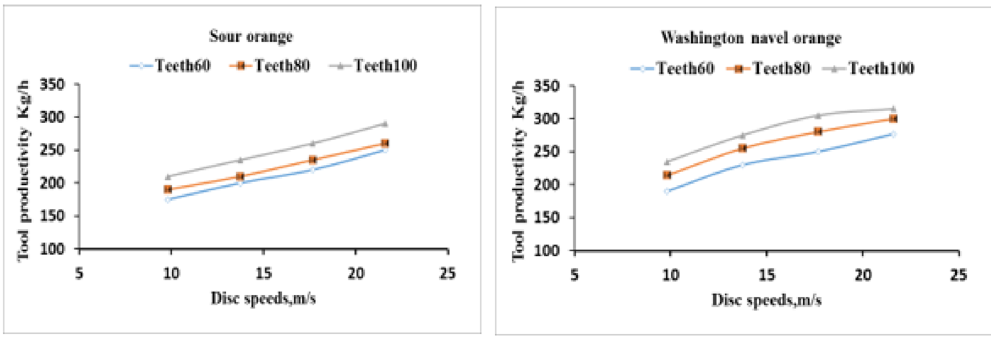


Fig. 4. The developed harvesting tool productivity via operating parameters.

Regarding the influence of number of cutting disc teeth on the developed tool productivity, increasing the number of cutting disc teeth from 60 to 100 teeth at A number cutting disc speed of 21.59 m/s, tool productivities was increased from 250 to 290 and from 277 to 315 kg/h, for Sour orange and Washington navel oranges, respectively. Increasing the speed works to increase the successive blows of the cutting disc teeth on the neck of the fruit, so it works to increase the cutting of the fruits and thus increase the productivity.

Influence of some operating parameters on harvesting efficiency

The influence of cutting disc speed and number of harvesting disc teeth on harvesting efficiency for the two types of orange were presented in Fig.(5).

Relating to the influence of cutting disc speed on harvesting efficiency, increasing cutting disc speed from 9.81 to 17.66 m/s at the constant number of cutting disc teeth of 80 teeth, cutting efficiencies were increased from 93 to 96 and from 94 to 97.5 %, for Sour orange and Washington navel oranges, respectively. Any further increase in cutting disc speed more than 17.66 up to 21.59 m/s, harvesting efficiency decreased from 96 to 93.5 and from 97.5 to 94%, under the same previous conditions. The increase in harvesting efficiencies by increasing cutting disc speed from 9.81 to 17.66 m/s, is attributed to the increase of the impacting forces applied to the neck of the fruit, that tend to improve harvesting operation.

As to the effect of number of cutting disc teeth on harvesting efficiency, increasing number of cutting disc teeth from 60 to 80 teeth at constant cutting disc speed of 17.66 m/s, harvesting efficiencies were increased from 94 to 96 and from 93 to 97.5 % for Sour orange and Washington navel oranges, respectively. Any further increase in number of cutting disc teeth more than 80 up to 100 teeth, decreased harvesting efficiency from 96 to 93.5 and from 97.5 to 95 %. While the vice versa is noticed in the range from 80 to 100 teeth due to the increase in fruit damage.

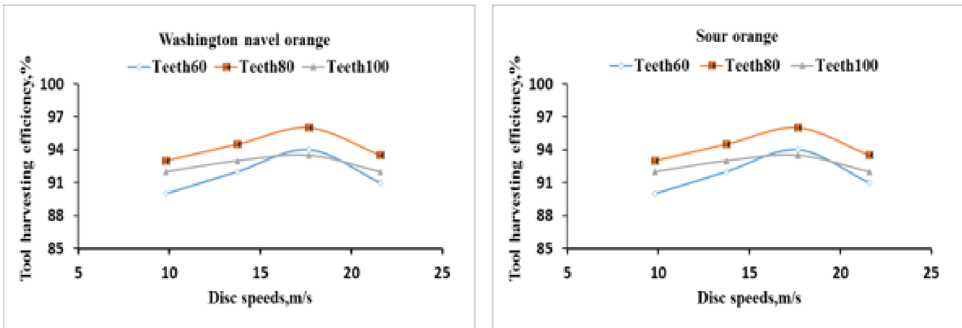


Fig. 5. Influence of some operating parameters on harvesting efficiency

The high speed of the cutting disc leads to an increase in the number of harvested fruits, but at the same time the control over the accuracy of harvesting the fruits decreases, which results in an increase in the length of the cut part of the fruit neck, or the occurrence of scratches or cutting the outer shell of the fruit, which results in a decrease in the harvesting efficiency.

Influence of some operating parameters on the total harvesting fruit losses

The total harvesting fruit losses (harvesting fruit losses and harvesting fruit damage) are greatly affected by cutting disc speed and the number of cutting disc teeth for the two types of orange as shown in Fig. (6).

Regarding the influence of cutting disc speed on the total harvesting fruit losses, increasing cutting disc speed from 9.81 to 17.66 m/s at the constant number of cutting disc teeth of 80 teeth, the total harvesting fruit losses were decreased from 7 to 4 and from 6 to 2.5% for Sour orange and Washington navel oranges, respectively. Under the same prior circumstances, every further increase in the cutting disc speed over 17.66 up to 21.59 m/s were resulted in an increase in the total harvesting fruit losses of 4 to 6.5 and 2.5 to 6%. Increasing cutting disc speed by more than 17.66 up to 21.59 m/s led to increasing fruit damage, as well as increasing the length of the neck of the fruit more than 5 mm, which is the appropriate length for harvesting. So, in order to create the best working conditions, the total fruit harvesting losses and fruit harvesting damage are crucial.

As to the influence of the number of cutting disc teeth on the total harvesting fruit losses, results show that increasing the number of cutting disc teeth from 60 to 80 teeth at constant the cutting disc speed of 17.66 m/s, the total harvesting fruit losses were decreased from 6 to 4 and from 7 to 2.5% for Sour orange and Washington navel oranges, respectively. Any further increased in the number of cutting disc teeth more than 80 up to 100 teeth were increased total harvesting fruit losses from 4.0 to 6.5 and from 2.5 to 5%, under the same conditions.

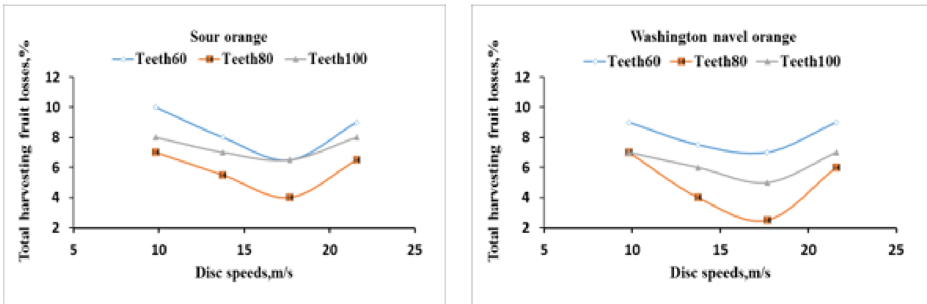


Fig. 6. The total fruit losses of the harvesting tool developed by operating parameters

Due to the strong impacting force that the cutting disc teeth apply to the fruit's neck, the damage to harvesting fruit increases as the number of disc teeth increases. Even though increasing the cutting disc speed results in higher impacting forces being applied to the fruit, this actually tends to improve harvesting operations and reduce harvesting fruit losses.

Influence of some operating parameters on the required power and energy

Values of both required power and energy versus cutting disc speed and the number of cutting disc teeth are represented for the two types of orange in Figs. (7 and 8).

Regarding the relationship between required power and energy and cutting disc speed, for Sour oranges and Washington navel oranges, respectively, increasing the cutting disc speed from 9.81 to 17.66 m/s at a constant number of cutting disc teeth of 80 teeth were resulted in increase in required power of 31.35 to 036.10 and were decrease in required energy from 0.165 to 0.153 and 0.140 to 0.125 W h/Mg.

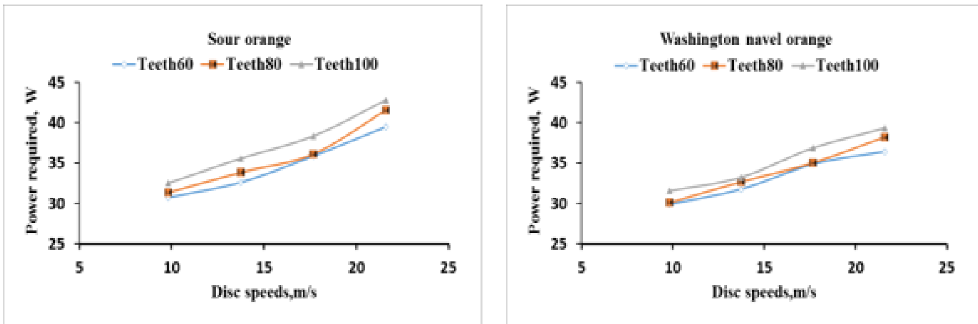


Fig. 7. Influence of some operating parameters on the required power

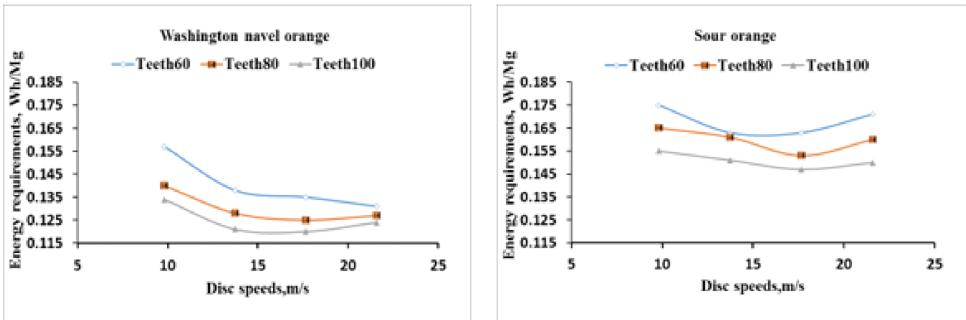


Fig. 8. Influence of some operating parameters on energy requirements

As to the influence of the number of cutting disc teeth on required power and energy requirements, increasing number of cutting disc teeth on a sensor from 60 to 80 teeth at constant cutting disc speed of 17.66 m/s, the required powers were increased from 35.85 to 36.10 and from 34.85 to 35.02 W, while the energies were decreased from 0.163 to 0.153 and from 0.139 to 0.125 W.h/Mg,for Sour orange and Washington navel oranges, respectively.

Because an increase in speed is frequently accompanied by an increase in required power, power increased by increasing cutting disc speed.

Influence of some operating parameters on operational and harvesting costs

A thorough cost analysis that took into account the productivity of the harvesting tool was conducted under various operating situations. Cutting disc speed was found to have an impact on the ensuing operating cost, the number of cutting disc teeth and power.

Figures (9) and (10) show the two types of orange, representative values of operational cost and harvesting cost via harvesting disc speed and the number of teeth. The cost of operation and all fruit losses during harvest were added to determine the harvesting cost.

Considering the influence of the cutting disc speed on the harvesting cost, increasing cutting disc speed from 9.81 to 17.66 m/s at constant number of cutting disc teeth of 80 teeth, the harvesting costs were decreased from 77.50 to 61.30 and from 70.24 to 50.56 EGP/Mg, for Sour orange and Washington navel oranges respectively.

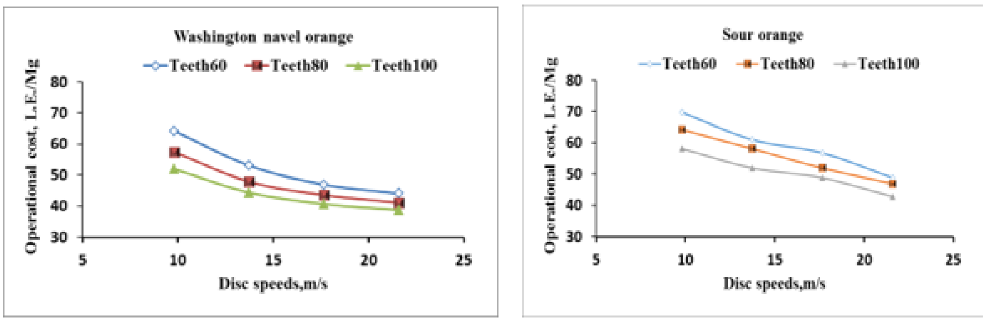


Fig. 9. Influence of some operating parameters on operational cost.

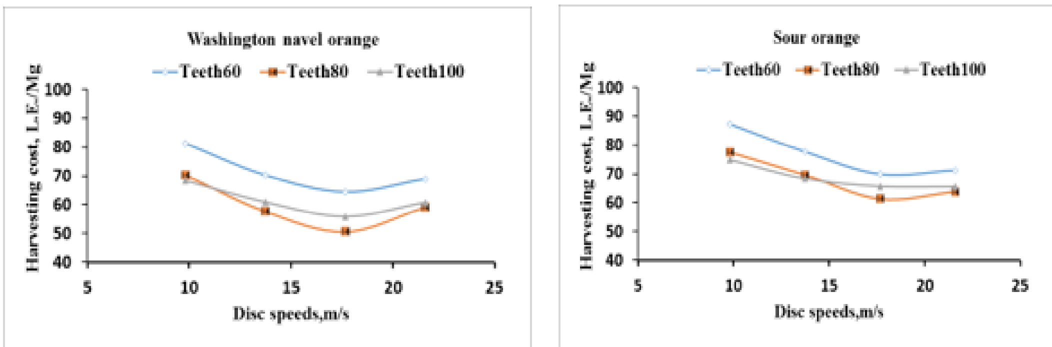


Fig. 10. Influence of some operating parameters on harvesting cost.

Any further increase in cutting disc speed of more than 17.66 up to 21.59 m/s, were increased harvesting cost from 61.30 to 63.82 and from 50.56 to 59.08 EGP /Mg, under the same mentioned conditions.

Due to the rise in overall fruit harvesting losses, harvesting costs tend to increase for both higher and lower values of cutting disc speed and the number of teeth compared to the optimal value.

CONCLUSION

Findings of the current paper confirmed the effectiveness of using the developed harvesting tool for harvesting citrus fruits. So, it can be recommended to use the developed harvesting tool for harvesting citrus fruits under conditions of 17.66 m/s cutting disc speed with cutting disc of 80 teeth. Under these conditions the following data were achieved:

- The highest values for each harvesting tool productivity and machine efficiency were 315 - 285 Kg/h and 97.5 - 96.0% for harvesting Sour orange and Washington navel oranges, respectively.
- The lowest values of total harvesting fruit losses were 8.05 and 7.6 %, energy requirements were 0. 153 and 0. 125 W h/Mg and harvesting costs were 61.30 and 50.56 L.E./Mg for harvesting Sour orange and Washington navel oranges, respectively.

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تطوير أداة بسيطة مزودة بمستشعر لحصاد ثمار الموالح

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الملخص

تهدف الورقة البحثية إلى تطوير أداة بسيطة مزودة بجهاز استشعار لاستخدامها في حصاد ثمار الموالح. تم تصنيع الأداة من مواد خفيفة للسماح للمنظار بالوصول إلى المواقع العالية لثمار الموالح . اعتمدت الأداة المطورة على التحقق من الوضع الصحيح لقطع الساق ، وحماية الثمار من الضرر ، ومنع الثمار من السقوط. تتكون أداة الحصاد المطورة من أنابيب تلسكوبيه وجهاز حصاد مزود بجهاز استشعار وبطارية جافة وأنبوب فاكهة وسلة تجميع. تم استخدام نوعين من أشجار الفاكهة (النارنج والبرتقال ابو سرة) لاختبار أداة الحصاد المطورة. أجريت تجارب لدراسة تأثير بعض متغيرات التشغيل على أداء أداة الحصاد المطورة. هذه المعاملات : اربع سرعات لقرص الحصاد 9.81 و 13.74 و 17.66 و 21.95م/ ث وثلاثة اقراص حصاد ذات 60 و 80 و 100 سن. تم تقييم أداة الحصاد المطورة من حيث إنتاجية ، وكفاءة الحصاد ، وإجمالي فواقد الفاكهة ، متطلبات القدرة والطاقة وتكلفة الحصاد. أظهرت النتائج أن أعلى قيم إنتاجية وكفاءة الحصاد كانت 285 و 315 كجم / ساعة و 96.0 و 97.5٪ للنارنج وبرتقال أبو سرة على التوالي.و أن الحد الأدنى من متطلبات القدرة والطاقة النوعية كانت 36. 10 واط و 35. 02 و 0. 125 واط · ساعة / ميجا جرام للنوعين السابقين من البرتقالي. - أدنى قيم لتكلفة الحصاد 42.80 و 38.72 ج / ميجا جرام لنفس النوعين المذكورين من الثمار. تم الحصول على البيانات المذكورة أعلاه باستخدام أداة الحصاد المطورة لحصاد ثمار الموالح تحت ظروف تشغيل لسرعة قرص الحصاد 17.66 م / ثانية وقرص حصاد ذو 80 سن. ا