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FARM MACHINERY AND

DEVELOPING A MULTI PURPOSE DIGGER FOR HARVESTING ROOT CROPS

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ABSTACRT

This study aimed to develop a multi purpose digger for harvesting root crops (potato and peanut), separating and transporting them over soil surface with minimum losses, mechanical damage and cost. Root crops digger was developed by adding a successful vibrating separating mechanism that should based on separating root crops with minimum losses and damage. The developed digger was tested at three levels of forward speeds (1.8, 2 and 2.6 km/h), for potato, (1.4, 1.8 and 2.3 km/h), for peanut and three different tilt angles (12˚ ١٨ْ, and 24˚). The experiments were carried out during two successful agricultural seasons of 2007 for peanuts at El Assasin country, El Sharkia Governorate and 2008 for potato at Manzala city, El Dekahlia governorate. From the obtained results, it was cleared the proper conditions to operate the developed digger were 22 cm harvesting depth, 2.6 km/h forward speed and 0.31 rad (18˚) tilt angle for potato crop and 15 cm harvesting depth, 2.3 km/h forward speed and 0.21 rad (12˚) tilt angle. The cost of harvesting using the digger was 91.55 L.E / fed for potato, 101.24 L.E / fed for peanut.

INTRODUCTION

Several field and vegetables crops, from tubers and roots below the surface of the soil. Those crops could be termed root crops and they may be classified according to the strategic important into major and minor root crops. The major root crops are potatoes, beets for sugar, sweet potatoes, onions and peanuts. **Abou Elmaged (2002).** Potato and peanut consider two of the major root crops, potato is occupied in

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Egypt the first position according to exportation vegetables crops, yearly producing about 2.5 million ton, it is exported from about 200.000 to 250.000 ton, it is raised to 430.000 ton in (2004 / 2005) as a fresh and frozen potatoes to Arabian and European countries, according to **Agricultural Researches Station-bull 813 (2005),** Peanut is considered from the main summery crops, Egypt is occupied the second position at peanut production in (2003/2004) the quantitative production was about 156.000 ton, Egypt is exported from about 30-35 % to Arabian and European countries, according to **Agricultural Researches Station-bull 879 (2003).** Developing, testing and evaluation of agricultural machines are become a big problem should be studied and that is because expanding at agricultural areas, the agricultural machines are become the main factor to increase agricultural production, mostly the agricultural machines which tested in some country is not give the same results which it obtained in another country and that is maybe because local conditions (soil, fuel, oil, workers and climate conditions), and these conditions could be influence the properties of those machines, so developing, testing and evaluation those machines again is very important under local conditions, Harvesting is one of the most critical operation for potato and peanut production. Root crops are grown below the surface of the ground, therefore it requires specially designed machines to dig and separate them from the soil. The subject of vibrating diggers has drawn the attention of many researches. **Kang and Halderson (1991)** designed a two-row, three-point-hitch vibrating digger. Each row compared a pair of four-bar linkages to which two side plates are attached. A bottom plate for each row composed of a soil-digging blade, followed by soil –sieving bars. These bars were rigidly attached to bottom of each pair of side plates to cut and lift the soil and also to allow for soil separation. The motion of the bottom plate was also designed to assist with soil flow. The oscillating assemblies were P T O driven by a cam through by roller chain driven such that one moved forward. While the other moved backward. **Japanese Trade Policy Inst. (1986)** designed a vibrating potato digger, which named NIP/O. P.S. The machine of one row had a little draft resistance. The operation width was 50 cm, the digging depth ranged from 20 to 25 cm, the mass of machine was 38 kg, and power needed was 6 KW. In addition, this type of machine can work only in light soil conditions. **Amin (1990)** developed a vibrating potato digger, having field capacity of 0.31 fed / h, while field efficiency was 91.32 % at forward speed of 2.1 km/h and harvesting a feddan of 250 m. length. Harvesting one feddan by the developed harvester costs was 16.47 L.E, while it was 80 L.E / fed by using the traditional manual method**. Magdy (1991)** stated that vibrating shares and separating table leads directly to reduce the required draft and increases the performance efficiency. **Mizrach et al (1983)** carried out a design of machine for digging, picking up, and separating peanut. The technique of machine used depended upon cutting the soil with peanut, plant and elevates all on screen with space equal 10.5 mm between the rods to loosen the soil. **Srivastava et al. (1995)** mentioned that using the reciprocated blades with plows increases the soil penetration and decreases the drawbar pull of the tractor. So using a web potato digger equipped with reciprocated blades may help to solve many technical and economical problems.

MATERIAL AND METHODS

Such development had been introduced to overcome the problems noticed under the harvesting operation using the ordinary digger, the digger unsuitable for harvesting root crops successfully, high percentage of losses as well as damage are resulted during the harvesting operation. The development was done at the local workshop at Agricultural Engineering Department, Mansoura University to help the original digger to reduce losses, damage and reach root crops bruising to minimal.

1. Materials

Table (1): Showed some of physical properties of (Nikola) variety for potato:-

Property		Value
Average diameter	cm	3.6
Average length	cm	7.5
Average mass	gm	64.9

Table (2): Showed the physical properties of (Giza 5) variety for peanut-:

Average pod weight g	Average pod length cm	Average pod diameter cm
2.72	3.51	1.62

Physical properties for both of potato crop and peanut crop to determine the dimensions of separating unit.

1-2 Tractor:

The agricultural tractor was used in experiments for (potato and peanut), its model (Kubota), it has an engine power 28 hp (20.91 kw).

1-3 Soil moisture content:

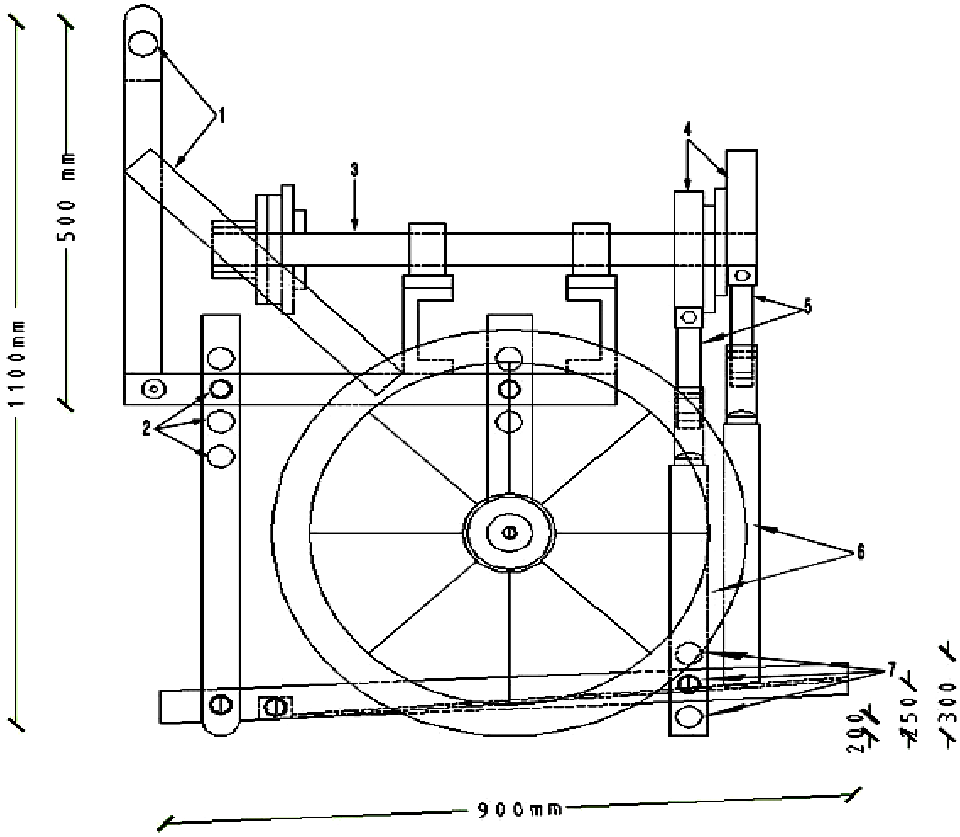
A random samples were taken from soil at 25 cm depth for potato and 15 cm depth for peanut to determine moisture content, it was 19.907 for potato and 15.815 for peanut, Soil moisture content for (potato and peanut) was determined on dry basis with the oven method at 378 k (105 C°) for 24 hours in the land and soil research institute at Mansoura.

1-4 Root crops digger before development:

The root crops digger before development consists of a frame, digging blade, a stationary separating unit and an unit to adjust tilt angles.

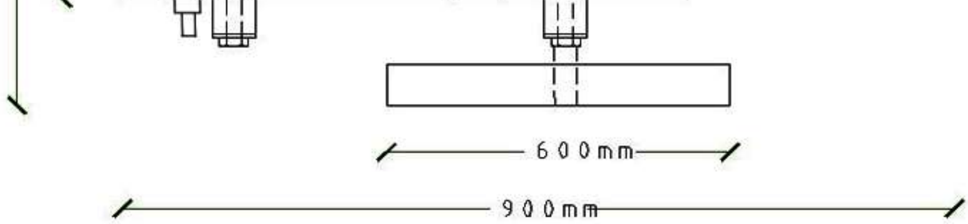
1-5 Root crops digger after development:

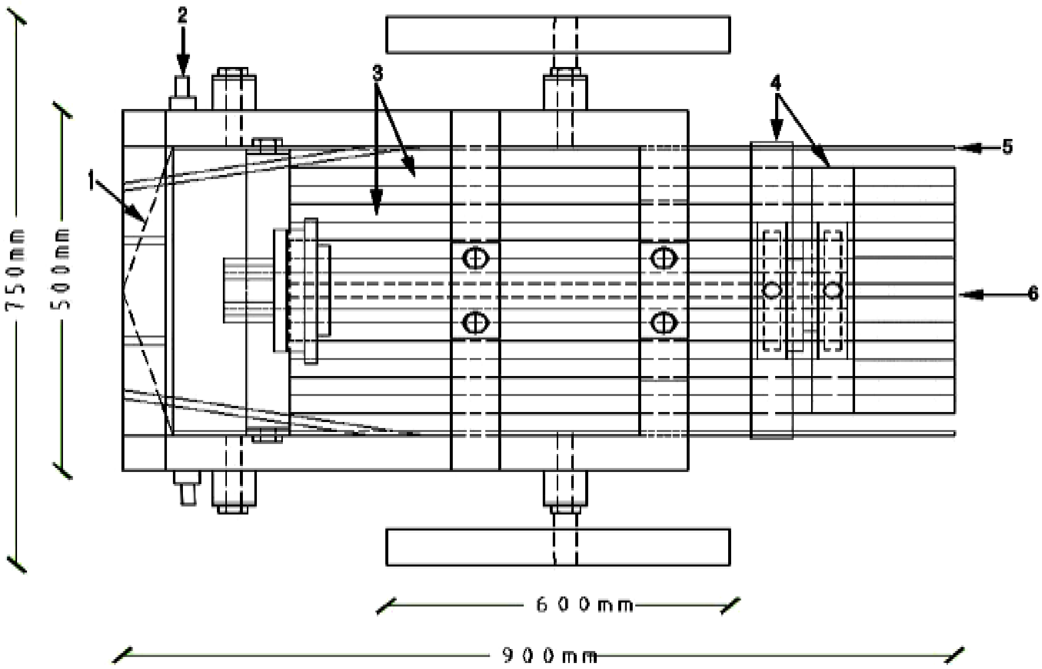
The development was done at the local workshop at Agricultural Engineering Department, Mansoura University, it consists of a frame, vibrating digging blade, vibrating separating units, transmission system and cardan column. Fig (1) and fig (2) show the elevation and the plan view for developed digger.



1	Hitching points.
2	Four points to adjust harvesting depths.
3	Spindle.
4	Two cams.
5	Two connecting rods.
6	Two longitudinal frames.
7	Three different tilt angles.

Fig. (1): Elevation view for developed digger.





1	Vibrating digging blade.
2	Hitching points.
3	Rods.
4	Two longitudinal frames.
5	Blade frame.
6	Separating unit.

Fig. (2): Plan view for developed digger.

The frame:

The frame is made of a square sheet steel with dimension of 50x50x7 mm, the frame takes a rectangular shape with dimension of 650x550 mm, include elements to fix (a spindle transports the vibrating movement to a cam at the end of it and hitching system) the digger frame is carried by two tire wheels of 600 mm. diameter and 10 cm thickness.

The digging blade:

The blade is made of steel iron (12.3mm) thickness, 140 mm length, 500 mm width, and 150 sweep angle. Fig (3).

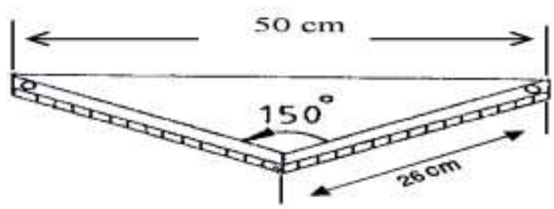


Fig. (3): Blade with (150° sweep angle).

The separating unit:

The separating unit is consists of to a frame with 900 mm long, 460 mm width, 10 mm thickness, has 6 rods, 30 mm the distance between rods, 10 mm thickness, this frame is connected to vibrating blade by bolts, it is used a net for peanut has square holes with dimensions of 1x1 cm, the same dimensions of separating unit for the net fig (4), also at the end of that frame longitudinal frame 500 mm height, 450 mm width, 10 mm thickness.

Fig. (4): A net for peanut.

The transmission system:

The transmission system consists of a spindle transports the vibrating movement from (P.T.O) to a cam at the end of it, to another two longitudinal rods is connected to the longitudinal frames.

The cardan column:

The cardan column was connected to the spindle to give the vibrating movement from

(P.T.O) at 700 r.p.m to both of vibrating blade and separating unit by a cam.

2 - Methods:

The experimental area was about (2 feddans), one feddan for potato and one feddan for peanut. The harvesting investigations were conducted using three different tilt angles of 0.21,0.31 and 0.42rad (12,18 and 24 deg.) for potato and peanut, three different forward speeds of 1.6, 2 and 2.6 km / h. for potato and three different forward speeds of 1.4, 1.8 and 2.3 km / h for peanut, once using the vibrating movement and once without using it.

Measurements :-

2-1 Lifted root crops percentage *(lift %)*

After the harvesting operation was done for the experimental groups, root crops over the soil surface collected, also the unlifted root crops were manually harvested by hand. The lifted root crops percentage (lift %) were determine from the following:

$$lif_t = \frac{m_1}{m_1 + m_2} \times 100$$

Where-:

m1= The mass of lifted root crops (potato or peanut) of over soil surface (kg).

m2= The mass of unlifted root crops (potato or peanut) (kg).

2-2 Root crops damage percent *(Dt%)*

Taking in consideration the mass of root crops (m3) which have no bruise or cutting for each of the mentioned samples and the mass of damaged root crops (m4) (only serious damaged and neglected slight damage). The percent could be determined using the following formula:

$$D_t \% = \frac{m_4}{m_3 + m_4} \times 100$$

<u>2-3 Harvester efficiency *(ηH):*</u>

Harvesting efficiency is the mass ratio of undamaged root crops raised over the soil surface by the digger and calculated by using the following equation:

$$\eta_H = \frac{R_t - D_t}{W_t} \times 100$$

Where-:

Rt = Raised potato tubers (kg). Dr = Damaged potato tubers (kg).
Wt = Total mass of the sample (kg).
Or-:
The machine efficiency ***(ηH)*** was considered under the different treatment according to formula. Ahmed and Shamsudeen (1987).

$$E_\eta = \frac{W_i - W_s - W_r}{W_i} \times 100$$

Wi =Total weight of harvested peanut pods (kg).
Ws =Total weight of not lifted peanut pods (kg).
Wr =Total weight of broken peanut pods (kg).

<u>2-4 Yield per feddans *(Ry):*</u>

The yield of harvested root crop ***(Ry)*** was determined by weighting the root crop lifted over surface after the harvesting operation per (ton/feddan).

<u>2-5 The operation cost:</u>

The cost of mechanical operation was based on the initial cost of machine, interest on capital, cost of fuel and oil consumed, cost maintenance and wage of operator according to following (Awady, 1978).

$$C = \frac{p}{h}\left(\frac{1}{e}+\frac{i}{2}+t+r\right)+\left(0.9hp\times f\times s\right)+\frac{W}{144}$$

c = the hourly. p = the capital investment.

h = the yearly operation hours. e = the lift expectancy of equipment in years.

i = the interest rate. t = the taxes rate and over heads .

r = the repairs ratio of total investment. hp= the engine horsepower .

f = the specific fuel consumption in lit/ hp .hr.

s = the price of fuel per liter. w = the labor wage rate per month .

١٤٤ = a reasonable estimation of monthly working hours.

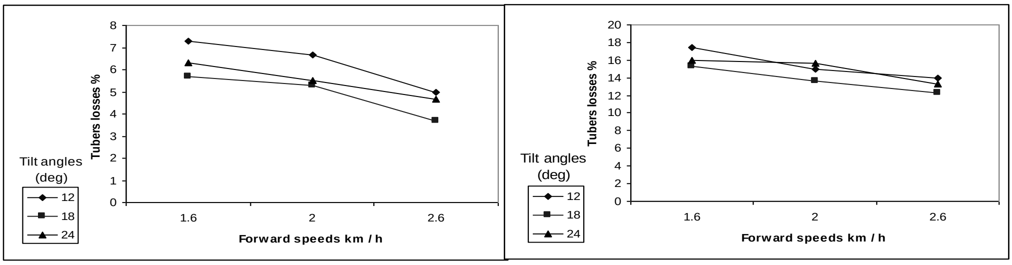
٠,٩ = a factor including reasonable estimation of oil consumption in addition to fuel .

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following headings-:

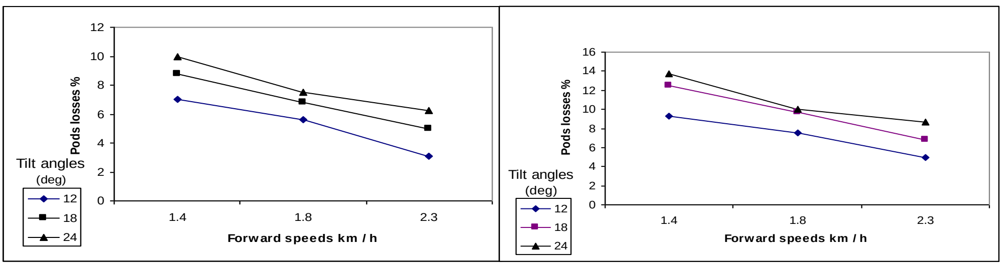
1- Effect of harvesting digger on root crops losses:

Fig (5) and fig (6) showed that the obtained data for potato showed that the highest percentage of losses of 17.43 % was recorded at forward speed of 1.6 km / h and tilt angle 0.21 rad(12 deg.), without using the vibrating movement. While the lowest percentage of losses of 3.67 % was recorded at forward speed of 2.6 km / h and tilt angle 0.31 rad(18 deg.), with using the vibrating movement. For peanut the highest percentage of losses of 13.7 % was recorded at forward speed of 1.4 km / h and tilt angle 0.42 rad(24 deg.), without using the vibrating movement. While the lowest percentage of losses of 3.1 % was recorded at forward speed of 2.3 km / h and tilt angle 0.21 rad (12 deg.), with using the vibrating movement.



With vibrating movement Without vibrating movement

Fig. (5): Effect of harvesting digger on potato tubers losses.

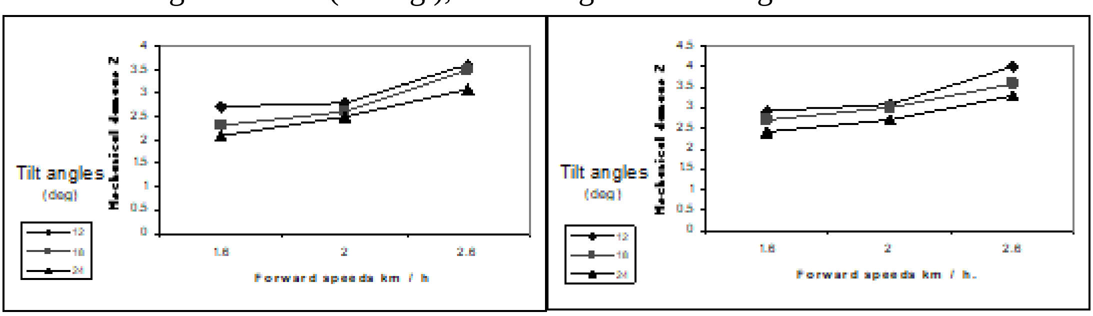


With vibrating movement Without vibrating movement

Fig. (6): Effect of harvesting digger on peanut pods losses.

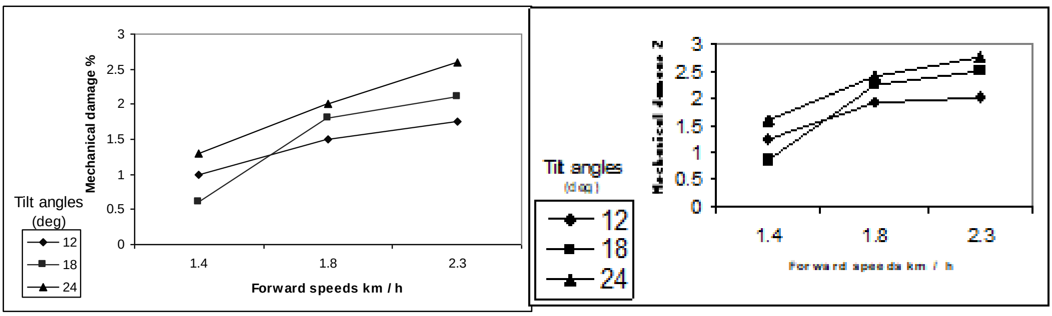
2- Effect of harvesting digger on mechanical damage:

Fig(7) and fig (8) showed that the obtained data for potato showed that the highest percentage of mechanical damage of 4 % was recorded at forward speed of 2.6 km / h and tilt angle 0.21 rad(12 deg.), without using the vibrating movement, While the lowest percentage of mechanical damage of 2.1 % was recorded at forward speed 1.6 km / h and tilt angle 0.42 rad (24 deg.), with using the vibrating movement. For



With vibrating movement Without vibrating movement

Fig. (7): Effect of harvesting digger on potato tubers mechanical damage peanut the highest percentage of mechanical damage of 2.75 % was recorded at forward speed of 2.3 km / h and tilt angle 0.42 rad (24 deg.), without using the vibrating movement. While the lowest percentage of mechanical damage of 0.6 % was recorded at forward speed of 1.4 km / h and tilt angle 0.31 rad(18 deg.), with using the vibrating movement.

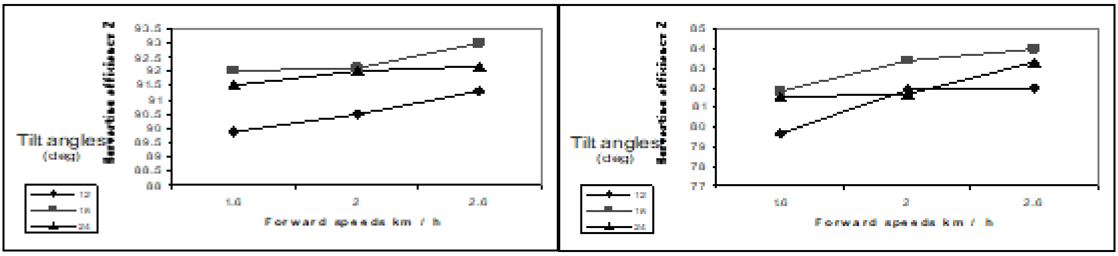


With vibrating movement   Without vibrating movement

Fig. (8): Effect of harvesting digger on peanut pods mechanical damage.

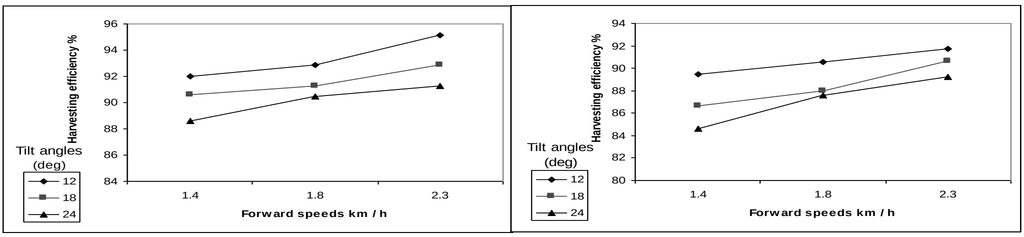
3- Effect harvesting digger on harvesting efficiency:

Fig (9) and fig (10) showed that the obtained data for potato showed that showed that the highest percentage of harvesting efficiency of 93 % was recorded at forward speed of 2.6 km / h and tilt angle 0.31 rad(18 deg.), with using the vibrating movement. While the lowest percentage of harvesting efficiency of 79.7 % was recorded at forward speed of 1.6 km / h and tilt angle 0.21 rad(12 deg.), without using the vibrating movement. For peanut the highest percentage of harvesting efficiency of 95.12 % was recorded at forward speed of 2.3 km / h and tilt angle 0.21 rad(12 deg.), with using the vibrating movement. While the lowest percentage of harvesting efficiency of 84.62 % was recorded at forward speed of 1.4 km / h and tilt angle 0.42 rad(24 deg.), without using the vibrating movement.



With vibrating movement Without vibrating movement

Fig. (9): Effect harvesting digger on potato tubers harvesting efficiency.



With vibrating movement Without vibrating movement

Fig. (10): Effect harvesting digger on peanut pods harvesting efficiency.

Harvesting time:

The developed root crops digger reduced the time from 48 hour under manual method to 3.21 and 3.55 h / fed under mechanical harvesting for potato and peanut respectively, and that is shown in fig (11) .

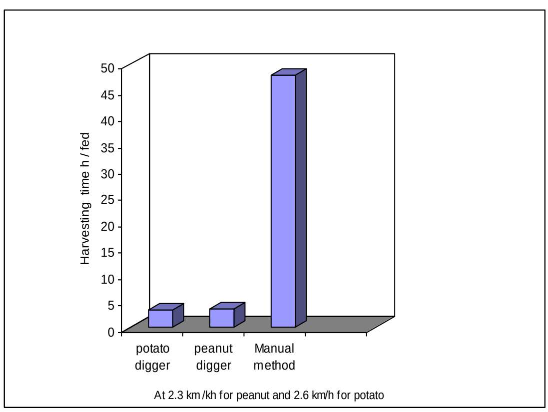


Fig. (11): Harvesting time requirement for different systems at optimum speeds (٢,٣)and 2.6 km/h.

CONCLUSION

From the obvious results, it can be concluded that the developed digger can be operated efficiently under the following conditions:

١ - For potato (22 cm) harvesting depth, (2.6 km / h) forward speed and 0.31 rad (18 deg) tilt angle with using vibrating movement.

٢ - For peanut (15 cm) harvesting depth, (2.3 km / h) forward speed and 0.21 rad (12 deg) tilt angle with using vibrating movement.

the cost of harvesting per feddan was 91.55 L.E for potato, 101.24 L.E for peanut, by using the digger.

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الملخص العربي

تطوير حفار متعدد الأغراض لحصاد المحاصيل الجذرية

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أجريت هذه الدراسة خلال موسمين زراعيين ٢٠٠٧-٢٠٠٨ م موسم ٢٠٠٧ لمحصول الفول السوداني في قرية القصاصين بمحافظه الشرقية وموسم ٢٠٠٨ لمحصول البطاطس في مدينة المنزلة بمحافظه الدقهلية حيث تم إجراء تعديل على حفار لكي يستخدم في حصاد المحاصيل الجذرية وتم إستخدام مساحة ٢ فدان لكلا من المحصولين . تم إختبار الاله عند ثلاث سرعات أمامية وثلاث زوايا إختراق وتم إستخدام الماكينة مره باستخدام الحركة الترددية ومره أخري بدون إستخدامها.

وكانت أهداف الدراسة كالأتي :

١. تطوير حفار متعدد الأغراض لحصاد المحاصيل الجذرية وفصلها عن التربة بواسطة الهزار ورفعها من التربة مع محاولة تقليل كلا من التلف الميكانيكي والفقد والتكاليف.

٢. محاولة الوصول إلى القيم المثلي لبعض عوامل التشغيل (السرعة الأمامية – زوايا الاختراق – الحركة الترددية) للاله المطورة.

٣. مقارنة نتائج الاله المطورة مرة باستخدام الحركة الترددية لكلا من السلاح والحصيرة ومره أخرى بدون استخدامها .

وتم استخدام ثلاث سرعات أمامية مختلفة لكلاً من محصول البطاطس ومحصول الفول السوداني حيث تم استخدام السرعات ١,٦ و ٢ و ٢,٦ كم / ساعة لمحصول البطاطس وسرعات ١،٤ , ١,٨ و ٢,٣ كم / ساعة لمحصول الفول السوداني وتم إستخدام ثلاث زوايا اختراق وهم ١٢ ، ١٤ و ٢٤ درجة.

وخرجت النتائج بالتوصيات الآتية :

- إستخدام الحفار المتعدد الأغراض المطور حيث أدى إستخدامه إلى رفع كفاءتي الحصاد والتنظيف وخفض فاقد المحصول وتكاليفه.
- تشغيل الحفار المطور عند سرعة أمامية ٢,٦ كم / ساعة تقريبا وزاوية اختراق ١٨ درجة لمحصول البطاطس وعند سرعة أمامية ٢,٣ كم / ساعة تقريبا وزاوية اختراق ١٢ درجة لمحصول الفول السوداني.
- يوصى باستخدام الحركة الترددية لكلا من السلاح والحصيرة.

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٣.طالب دراسات عليا – قسم الهندسة الزراعية – جامعة المنصورة.