DEVELOPMENT AND EVALUATION OF POTATO DIGGER SUITABLE FOR SMALLHOLDINGS

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ABSTRACT

A potato digger (single – row) was developed by adding digging blade to a rotary machine. The blade was designed, fabricated and tested. The developed digger was evaluated at three levels of forward speed (1.2, 2.3 and 4.9 km/h) and three levels of digging depth (12, 17 and 22 cm). Evaluation was based on the following parameters: field capacity, harvesting efficiency, missing tubers, damaged tubers, consumed energy and cost. The results of the study recommended operate the digger at 2.3 km/h and 22 cm depth where the evaluation parameter were field capacity of 0.33 fed/h, harvesting efficiency of 97.13 %, missing tubers of 7.6 %, damaged tubers of 4.3%, consumed energy of 18 kW.h/fed and cost of 90.6 L.E/fed. Using the developed machine, the harvesting time decreased by about 30% compared with the other harvesting methods (manual and local plough), also the harvesting cost was decreased by 13 % and 30.4 % compared with manual harvest and local plough respectively.

Keywords*: potato, digger,* design, *tubers damage, smallholding*

INTRODUCTION

Potato occupies an important place among food crops in many countries of the world, as it is in terms of nutritional value, is the first alternative to cereal crops in solving the food problem (***Horton and Sawyer, 1985***). In Egypt, the potato crop is one the major vegetable crop, as it is grown each year, cultivated area is about 137.52 $\times 10^3$ Ha and quantity production is 3567.05 $\times 10^3$ ton (***Arab Agricultural Statistics Yearbook, 2009***).

The quality of potato tubers, as in all horticultural products, is closely connected to the chemical and structural characteristics of plant tissues and varies widely in relation to different factors such as climate, growing conditions, cultivar and maturity at harvest and harvesting method (***Bentini et al., 2006***).

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Harvesting the potato crop is a critical part of the entire potato production and marketing operation. Most of the actual damage occurs during digging, loading, and transporting operations. Tubers are susceptible to various forms of damage during commercial production including external and internal defects. Internal damage resulting from the effects of impact on tubers during harvesting operations alone, may cause losses in excess of 20% (***Storey and Davies, 1992***). During harvest and transport, potato tubers are exposed to impact damage which ranges from internal black spot bruising through shatter bruising and finally tissue cracking (***Mathew and Hyde, 1997***).

According to an American study (***Peters, 1996***), 70% of total damage is caused by harvesting, 30% during transport and storage; up to 30% of the entire product may be damaged during harvesting.

Tuber damage is generally divided into two categories (***Baritelle et al., 2000***): external (shatter, cutting, skinning, cracking) and internal damage (principally blackspot bruise). ***Michael and William (1998)*** mentioned that there are four major types of potato bruise damage: skinning, blackspot bruise, shatter bruise, and pressure bruise.

Many researches worked to develop the potato digger (***Younis et. al., 2006; Ibrahim et. al. 2008 and Saqib and Wright, 1984*)**

Ibrahim et. al. (1989) developed and tested a sugar beet digger to be used under the Egyptian conditions. They studied the effects of tilt angle, blade width and forward speed on the damage occurred due to the developed harvester. The studied parameters levels were as (15, 20, 25°), (17, 20, 23 cm), and (2, 3.5, 5 km/h) for tilt angle, blade width and forward speed, respectively. Minimum tuber damage and highest lifting efficiency were realized at 20 cm blade width, 20° tilt angle and 3.5 km/h forward speed.

Smallholding is defined as a piece of land under 50 acres that is sold or let to someone for cultivation (***websters dictionary 2011***).

The structure of farming in Egypt has totally changed over the past 50 years. It has gone from a small number of very large holdings, managed by land owners, with little government control; through break-up of holdings and total government control; to very large number of small holdings.

Egyptian agriculture is characterized by a large base of very small holders of less than 0.8 hectare, referred to by the World Bank as poor holders, whose holdings represent about 66.35 % of the total number of holdings (***FAO, 2010***).

The objective of this study was to develop and evaluate a rotary cultivator to dig potato (single-row) that can be suitable for smallholding.

MATERIAL AND METHODS

The development had been introduced to overcome the problems noticed under the harvesting of potato in smallholding by replacing the rotary toolbar by a (single-row) digging blade. The machine was designed and evaluated in farm at Al-Ayat – Giza governorate (العياط - جيزة). The potato (Diamont) was harvested during April 2011. Costs of mechanical harvesting was compared with the manual and local plough harvest.

2.1. Soil properties

The mechanical analysis was carried out at lab of soil science department faculty of Agricultural Cairo University. The soil at the experimental site is considered as clayey loam according to the soil mechanical analysis as presented in table (1) (***Gardner ,1956***).

Table (1): Some properties of soil profile representing the experimental site.

Soil Depth (cm)	Clay (%)	Silt (%)	Sand (%)	Texture class
0 – 50	33.5	35.5	31.0	Clay loam

2.2. Soil penetration resistance

Penetration resistance was measured by three insertions in each plot before digging operation. It was conducted using a handheld cone penetrometer (Eijkelkamp – Agrisearch Equipment, Netherlands). A penetrologger was used with 11.28 mm cone diameter, 30 degree angle and vertical speeds that did not exceed 5 mm s^{-1} based on ASAE standard (***ASAE, 1995***). Penetrometer measurements were taken in increments of 0 to 50 cm depth. Fig.(1) shows the soil penetration resistance. Its value ranged from 0.5 to 3.0 MPa. These values show soil compaction or the required force to penetrate the soil.

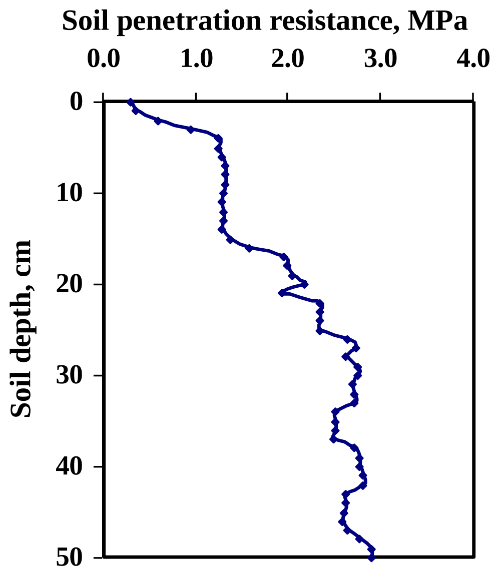


Fig.(1): Soil penetration resistance.

2. 3. Potato tubers distribution

To determine the digging depth and the blade width, potato tubers distribution has been studied in row at random on 10 different plants in the experimental field. Distribution was measured longitudinally of the tops of the tubers along the row and traverselly of the tubers on the row width. Spacing was measured between the top of the row and the lowest tubers. Figure (2) shows the distribution of tubers. The average distance between the top of the row and tuber mother is 12 cm, and the average distance between the top of the line and the lowest point of the tubers is 16 cm, (ranging between 12 to 20 cm). So the depths of digging of the developed machine where taken at 12, 17, 22 cm from the top of the row.

2.4. Description of the machine

A machine was developed by disassembling a rotavator blades and adding a singe digging blade to the machine.

2.4.1 Rotary machine

The original rotary machine model was Howred jem. It has 12 hp (8.8 kW) engine power (diesel engine). The dimensions were as follows: Length: 208 cm - Height to top of handlebar: 104 cm. Width: 70 cm.

Land speeds (At 2800 rpm) are 1st gear of 1.4 km/h, 2nd gear of 2.3 km/h , 3rd gear of 4.9 km/h and reverse of 2.9 k/h). Wheels: 20" (50.8 cm) overall diameter. Fig. (3) shows the dimensions of the rotary machine.

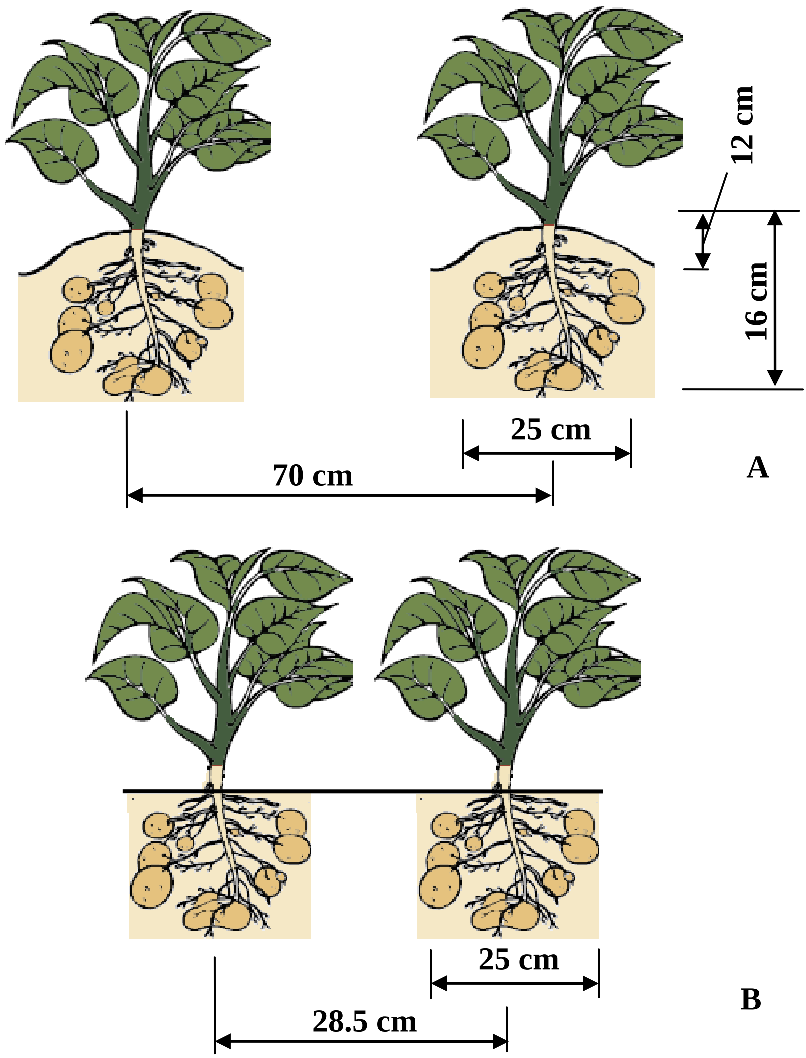
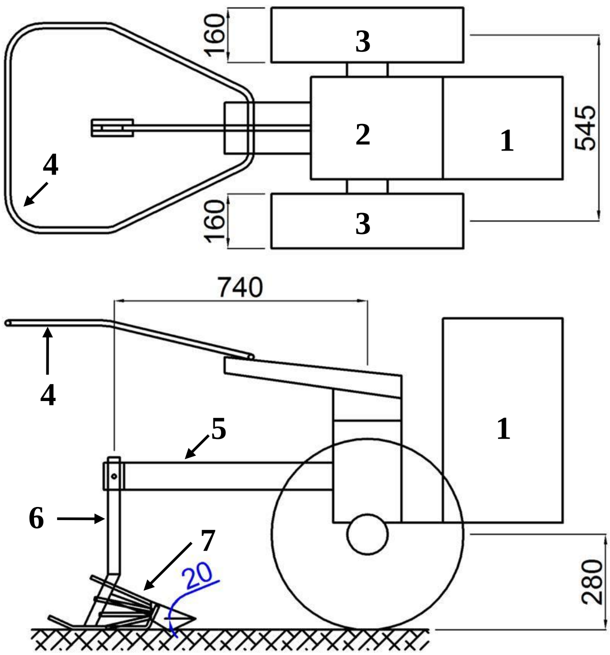


Fig. (2): Potato tuber distribution – (A) longitudinal distribution – (B) traverse distribution



Dims. in mm

1-Engine **2**- Gear box **3**- Driven wheel
4- Handle steering **5**- Machine beam holder **6**- Blade beam holder
7- Developed blade

Figure (3): The developed machine.

2.4.2. Theoretical approach for blade design:

Soehne (1956) analyzed the forces acting on the tillage tool and the soil to develop an expression for the total draft force needed to overcome the various soil reactions. ***Srivastava et al. (2006)*** have presented the work by Soehne. ***Soehne (1956)*** concluded that soil-metal friction, shear failure, acceleration force for each block of soil, and cutting resistance act on the tillage tool as it moves through the soil. Figure (4) shows a free body diagram of a segment of soil as it reacts to the advancing tool. The specific draft force (D*) is defined as: $D^* = D - kb$

$$D^* = \frac{W}{z} + \frac{C\,A_1 + B}{z\,(\sin\beta + \mu\cos\beta)} \qquad \textbf{(1)}$$

Where

D : Tool support horizontal force.
K : Cutting resistance.

W : Soil weight, N. $W = \gamma b d^{*}\left[L_o + \frac{L_1 + L_2}{2}\right]$

z : $z = \left[\frac{\cos\delta - \mu' \sin\delta}{\sin\delta + \mu' \cos\delta} + \frac{\cos\beta - \mu\sin\beta}{\sin\beta + \mu\cos\beta}\right]$

C : Soil cohesion, Pa.

A_1 : Area of forward shear failure surface, m^2. $A_1 = \frac{b\,d}{\sin\beta}$

B : Acceleration force. $B = \frac{\gamma}{g} b\,d\,v_o^2 \frac{\sin\delta}{\sin(\delta+\beta)}$

β : Angle of the forward failure surface, rad = (90° – φ)/2

δ : Tool lift angle.

μ : Coefficient of internal soil friction = tan φ.

μ′ : Coefficient of soil-metal friction.

φ : Angle of internal friction.

b : Tool width, m.

d : Tool depth, m.

d* : d {[sin(δ+β)]/sin β}, m.

γ : Wet bulk density of soil, kg/m^3.

L_o : Blade length,m.

L_1 : d {[cos(δ+β)]/sin β}, m.

L_2 : d*tanδ, m.

V_o : Tool velocity, m/s.

G : Acceleration due to gravity, m/s^2.

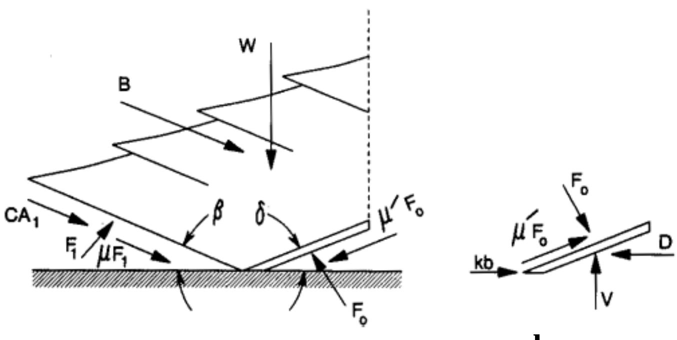


Fig. (4): Soil and tool reaction forces (free body diagram of a segment of soil as it reacts to the advancing tool).

When calculated the required force to dig the soil, it was taken the following parameter:

$\Delta = 45^o$	d = 25 cm	b= 25 cm
$\Phi = 37^o$	L_o = 16 cm	μ'= 0.3
P = 1200 kg/m^3	V_o = 4.9 km/h	C = 30 kPa (clay – plastic)

The draft force (**D***) was found to be **3886 N.**

2.4.3. Drawbar pull

The draft was measured using a drawbar load cell dynamometer (Omegadyne inc. – Model: LC203 – 8 K –Capacity: 0 to 8000 LBC. USA). Dynamometer was attached to the front of rotary machine on which the digging blade mounted. Another auxiliary tractor pulled the digging blade mounted machine through the dynamometer (Fig. 5).

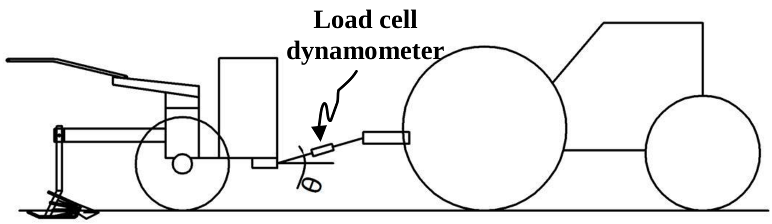


Fig.(5): Measuring of draft for digger.

The line of pull through the dynamometer is not horizontal, it was measured the angle (θ) and calculated the horizontal component from the following equation:

$$D_F = P \cos\theta \quad \textbf{(2)}$$

Where

D_F : Draft.

P : Pull measured by a dynamometer.

θ : Angle between the line of pull and the horizontal.

The auxiliary tractor pulls the digging blade mounted rotary machine with the latter in neutral gear but with the implement in operation position, record the draft in the measured distance (20 m) as well as time taken to traverse it. On the same field, lift the digging blade out of the ground and record the draft. The difference gives the draft of the digging blade (***RNAM Test codes, 1983)***.

The required force for pull digging blade equal **3556 N**.

2.4.4. Design of beam holder

It was necessary to design and manufacture a connection which holds the digging blades fitted to the hitch point in the machine by a bolt in the back of the beam itself as shown in Fig. (5).

Section A – A is subjected to: (Fig. 6)

1- Bending stress due to bending moment of horizontal load value (F_h):

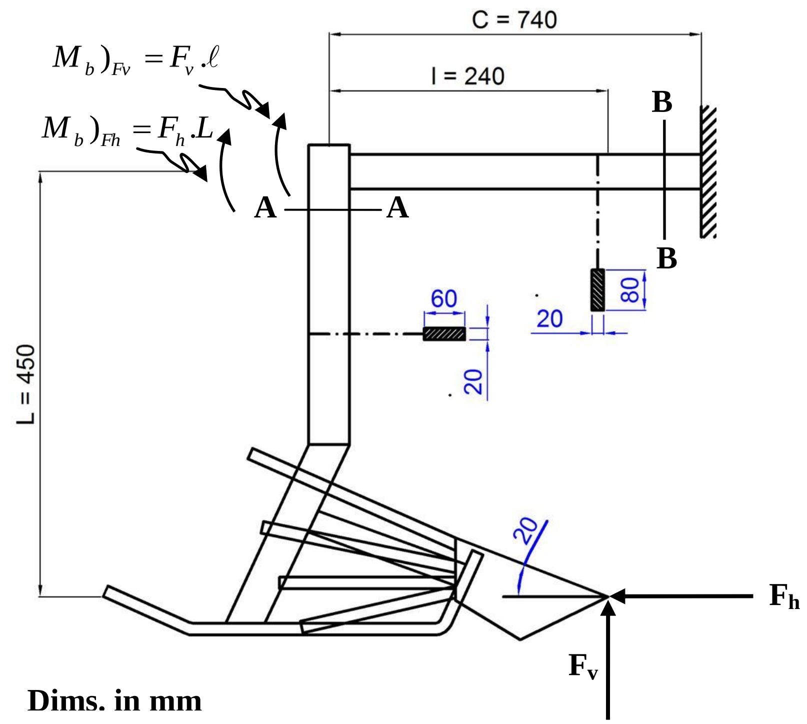
$$M_b)_h = F_h L \quad \textbf{(3)}$$

Where

M_b : Bending moment applied on the blade, $N.mm$.

F_h : horizontal load = D* = 3886 N (theoretical calculation).

L : Blade length from the blade edge to the supporting point = 450 mm.



Dims. in mm

Fig. (6): Forces act on beam holder of blade.

$$Bending\ \ stress\ (\sigma_b) = \frac{M_b y}{I} \quad \textbf{(4)}$$

Where

I : Bending Moment of inertia $= \frac{1}{12}(b).(t)^3$

t : Blade width, mm; $=60\,mm$.
b : Beam thickness, $mm = 20\ mm$.
y : $\frac{t}{2}, mm$.

$$Bending\ \ stress\ \ (\sigma_b)_h = \frac{F_h L * \frac{60}{2}}{\frac{1}{12}(20)(40)^3} = 145.7\ \mathrm{N/mm^2}\ (\mathrm{MPa})$$

2- Bending stress due to vertical load (F_v):

$$M_b)_v = F_v * l \qquad \textbf{(5)}$$

$$F_v = F_h \tan 20^o = 3886 \times \tan 20^o = 1414.4\ \mathrm{N}$$

$$\sigma_b)_v = \frac{M_b y}{I} = \frac{1414.4 \times 240 \times 30}{\frac{1}{12}(20)(60)^3} = 28.3\ N\ /mm^2\ (\mathrm{MPa}) \qquad \textbf{(6)}$$

$$\sigma_b)_{total} = \sigma_b)_h + \sigma_b)_v = 145.7 + 28.3 = 174\ \mathrm{N/mm^2}$$

3- Compression stress due to the vertical load (F_v):

$$\sigma_c = \frac{F_v}{A} = \frac{1414.4}{20 \times 60} \cong 2\ N\ /mm^2 \qquad \textbf{(7)}$$

Can be neglected compared to the bending stress applied on the bean section. Max stress applied on bean section is normal stress with value of 175 N/mm^2 (app)

Bean Material for safety factor more than 2, where $S_y \geq 350\ N\ /mm^2$

$\therefore$ Material with ultimate strength $\frac{350}{0.7}$ = 500 N/mm^2 is reasonable.

$\therefore$ Beam material was taken safely with ultimate strength equal 500 N/mm^2 consequently the beam material was steel 60 without any heat treatment or steel 50 with heat treatment.

<u>Section B –B is subjected to: (Fig. 6)</u>

1- Bending moment:

$$M_b = M_t + F_v C = (F_h L + F_v \ell) + F_v C \qquad \textbf{(8)}$$

M_b = 3886 × 450 + 1414.4 × 240 + 1414.4 × 740 = 3134814 N.mm

$$\sigma_b = \frac{M_b y}{I} = \frac{3134814 \times 40}{\frac{1}{12} \times (20) \times (80)^3} = 146.9\ \mathrm{N/mm^2}$$

2- Tensile load:

$$\sigma_t = \frac{F_h}{A} = \frac{3886}{20 \times 60} = 3.4 \text{ N/mm}^2 \qquad \textbf{(9)}$$

$$\sigma_{total} = \sigma_b + \sigma_t = 147 + 4 = 151 \text{ N/mm}^2 \leq S_{allow} \qquad \textbf{(10)}$$

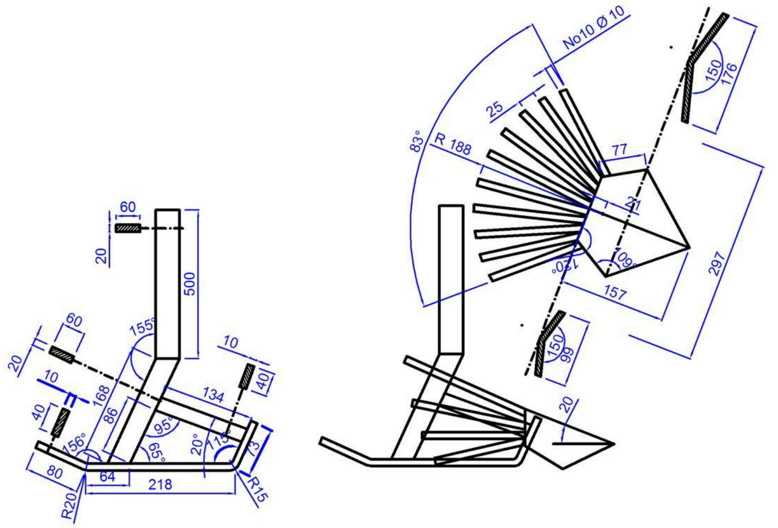
$$S_{allow} = \frac{0.7 \times S_{ultimate}}{F.S = 2}$$

$$\text{S}_{\text{ultimate}} = \frac{151 \times 2}{0.7} = 431.4 \text{ N/mm}^2$$

The same material is as used before.

2.4.5. Fabricated digging blade

The digger blade assembly consisted of one steel plate and associated framework and drive mechanism (Fig. 7). The front plate or blade was rigid and did the actual soil cutting. It was welded to a bottom or horizontal plate at an angle of 20^o degrees. The bottom plate provided rigidity and a means of fastening the digger assembly to the main frame.



Dims. in mm

Beam holder **Blade fitted on beam**

Fig. (7): Digger blade with beam.

2.5. Evaluation of the developed machine

The measurements were followed as reported in ***RNAM Test codes (1983)***. The harvesting investigations were conducted using three different forward speeds of (1.4, 2.3 and 4.9 km/h) and three different levels of digging depth of (12, 17 and 22 cm).

2.5.1. Digger field capacity

The potato digger field capacity was calculated from the following equation:

$$FC = A /(t_p+t_l) \quad \textbf{(11)}$$

Where

- FC : Effective field capacity; fed./h;
- A : Performed area by the digger, fed.
- t_p : Productive time, h.
- t_l : Non-productive time, h. (Time lost for turning, loading and adjustment).

2.5.2. Wheel slip

Slip was calculated from the following equation:

$$\text{Wheel slip (\%)} = \frac{B-C}{C}\times 100 \quad \textbf{(12)}$$

Where

B : the distance tractor moves forward as measured (say 10 revolutions) under no load, m.

C : the distance tractor moves forward as measured (same as revolutions with load), m.

2.5.3. Fuel consumption

The tank is filled to full capacity before and after each test trial. Amount of refueling after the test is the fuel consumption for the test. When filling up the tank, careful attention should be paid to keep the tank horizontal and not to leave empty space in the tank.

$$F_C = \frac{V}{t} \quad \textbf{(13)}$$

Where

- F_C : Fuel consumption, L/h.
- V : Volume of fuel consumed, L.
- t : Total operating time, h.

2.5.4. The required power:

Power was estimated by the following equation:

$$\text{Power (kW)} = F_C \times \frac{1}{3600} \times P_F \times L.C.V \times \eta_{th} \times \eta_m \times 427 \times \frac{1}{75} \times \frac{1}{1.36} \quad \textbf{(14)}$$

Where

F_C	:	Fuel consumption, L/h.
P_F	:	Fuel density, kg / L.
L.C.V	:	Lower calorific value of fuel, kcal / kg.
427	:	Thermo – mechanical equivalent, kg. m/kcal.
η_{th}	:	Thermal efficiency of the engine.
η_m	:	Mechanical efficiency of the engine.

2.5.5. Energy consumption

$$\text{Energy} = \frac{\text{Required power (kW)}}{\text{Eff. field capacity (fed / h)}} \quad \text{(kW. h / fed)} \qquad \textbf{(15)}$$

2.5.6. Lifted root crops percentage (raised tuber)

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

$$lift_t = \frac{m_1}{m_1 + m_2} \times 100 \qquad \textbf{(16)}$$

Where

m_1 : The mass of lifted potato over soil surface (kg).

m_2 : The mass of unlifted potato (kg).

2.5.7. Root crop damage percent

The mass of root crops (m_3) is for tubers which have no bruise or cutting for each of the mentioned samples, and the mass of damaged root crops (m_4) had only serious damage or neglected slight damage. The damaged tubers percent (D_t) are could be determined using the following formula:

$$D_t = \frac{m_4}{m_3 + m_4} \times 100 \qquad \textbf{(17)}$$

2.5.8. Harvesting efficiency

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

$$\eta_H = \frac{m_1 - m_4}{m_1} \times 100 \qquad \textbf{(18)}$$

2.5.9. Operation costs

The digger operating costs were calculated 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 equation (***Awady, 1978***).

$$C = \frac{p}{H}\left(\frac{1}{y} + \frac{i}{2} + t + m\right) + \left(A \times K \times f \times u\right) + \frac{S}{144} \qquad \textbf{(19)}$$

Where:

C	:	Total hourly cost.
P	:	Initial price or capital of tractor or machinery.
H	:	Estimated yearly – operating hours.
y	:	Estimated life-expectancy of machines in years.
i	:	Investment or interest rate.
t	:	Taxes and overhead rates.
m	:	Maintenance and repairs ratio to capital head.
K	:	Nominal power in kW or hp.
A	:	Ratio of rated power and lubrication related to fuel cost (0.75-0.9)
f	:	Specific fuel-consumption in L/kW.h or L/hp.h.
u	:	Price of fuel per litre (diesel = 1.1 LE/L).
S	:	Monthly wages or salaries (1500 LE/month).
144	:	Estimated working hours per month.

Operation cost of the developed machine was compared with other methods for potato harvesting by manual and local animal plough.

RESULTS AND DISCUSSION

3. The performance of the digger

Table (2) shows the results of potato harvester performance, for the digger speed at three levels (1.4, 2.3, 4.9 km/h) and three depths (12, 17, 22 cm).

3.1. Digger field capacity and slip

The field capacity was affected directly by operating conditions speed and digging depth. From obtained data in table (2) and Fig. (8), It is clear that the digger felid capacity increased by increasing the forward speed from 1.4 to 2.3 km/h and decreased by increasing the forward speed from 2.3 to 4.9 km/h. This was due to slip in the machine at the high speed. On the other hand, felid capacity decreased by increasing the digging depth due to increased force with increasing the depth, thus machine will slip. The maximum value of the digger field capacity was 0.39 fed./h at forward speed of 2.3 km/h and digging depth of 12 cm, while the minimum value was 0.2 fed./h at forward speed of 1.4 km/h and digging depth of 22 cm. The maximum value of slip was 27.4 % at forward speed of 4.9 km/h and digging depth of 22 cm, while the minimum value was 9.5 % at forward speed of 1.4 km/h and digging depth of 12 cm.

Table (2): Effect of working speed and digging depth on the different performance parameters of the developed digger.

Speed (km/h)	1.4			2.3			4.9		
Depth (cm)	12	17	22	12	17	22	12	17	22
Field capacity (fed./h)	0.23	0.22	0.20	0.39	0.37	0.33	0.36	0.34	0.32
Harvest eff. (%)	82.3	91.43	98.75	72.2	89.58	97.13	65.6	76.6	87.8
Raised tuber (%)	72.5	82.3	85.6	79.2	86.5	92.4	75.4	80.8	82.9
Missing tuber (%)	27.5	17.7	14.4	20.8	13.5	7.6	24.6	19.2	17.1
Damage tuber (%)	5.5	4.33	3.8	7.8	5.6	4.3	8.2	7.44	5.4
Required power (kW)	2.66	3.1	4.3	4.55	5.2	5.95	6.83	7.3	7.88
Consumed energy (kW.h/fed.)	11.4	14.1	21.5	11.7	14.2	18.0	19.0	21.5	24.6
Cost (L.E/fed)	128.2	136.4	150	76.9	81.7	90.6	83.3	88.2	93.8
Slip (%)	9.5	12.8	14.8	12.34	17.77	20.4	15.3	20.5	27.4

3.2. Harvesting efficiency and raised tubers

The harvester efficiency is related with the raised, damaged, undamaged and left tubers. Table (2) and Fig. (9) showed decreasing harvester efficiency by increasing the speed from 1.4 to 4.9 km/h with different digging depths of 12, 17, and 22 cm. The maximum value of harvester efficiency was 98.75 % at forward speed of 1.4 km/h and digging depth of 22 cm, while the minimum value was 65.6 % at forward speed of 4.9 km/h and digging depth of 12 cm.

The percentage of raised potatoes was affected greatly by the speed and digging depth. By increasing the speed from 1.4 to 2.3 km/ h, the percentage of raised potatoes increased, but increasing the speed from 2.3 to 4.9 km/ h decreased the percentage of raised tubers with different digging depths. The maximum value of raised potatoes was 92.4 % at forward speed of 2.3 km/h and digging depth of 22 cm, while the minimum value was 72.5 % at forward speed of 1.4 km/h and digging depth of 12 cm.

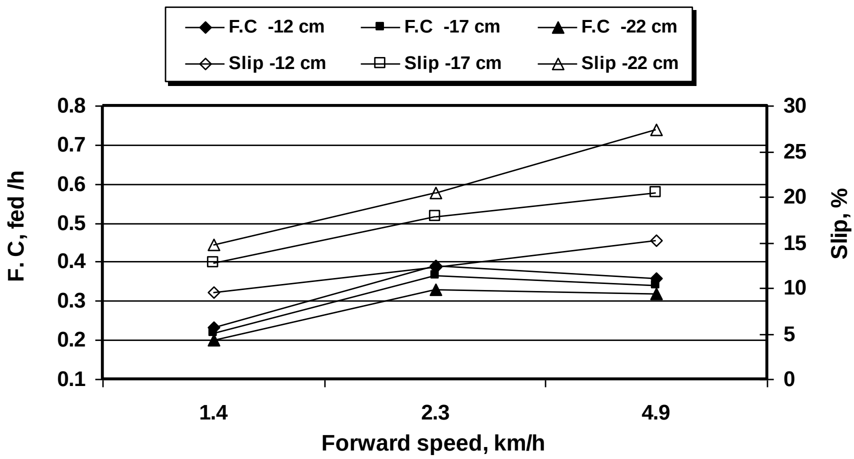


Fig. (8): Variation of field capacity and slip with different speeds and different depths of digger.

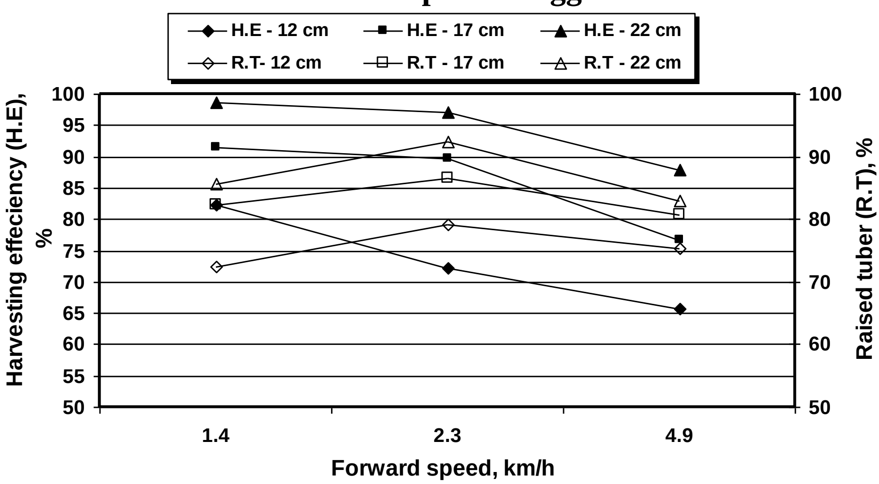


Fig. (9): Variation of harvesting efficiency and raised tubers percentage with different speeds and different depths of digger.

3.3. Missing and damaged tuber

The percentage of missing tubers decreased with increasing the speed from 1.4 km/h to 2.3 km/h. After increasing speed from 2.3 to 4.9 km/h, the missing tubers percent increased due to increasing the slip. It was noticed that with increasing the digging depth, the missing tubers decreased due to the distance between the top of the line and the lowest point of the tubers rang from 13 to 20 cm. The maximum value of missing tubers was 27.5 % at forward speed of 1.4 km/h and digging depth of 12 cm, while the minimum value was 7.6 % at forward speed of 2.3 km/h and digging depth of 22 cm (Fig. 10).

The percentage of damaged tubers was increased by increasing the speed from 1.4 – 4.9 km/h due to the friction between the blade and tuber, but the damage percent decreased with increasing the digging depth. The maximum value of missing tuber was 8.2 % at forward speed of 4.9 km/h and digging depth of 12 cm, while the minimum value was 3.8 % at forward speed of 1.4 km/h and digging depth of 22 cm (Fig. 10).

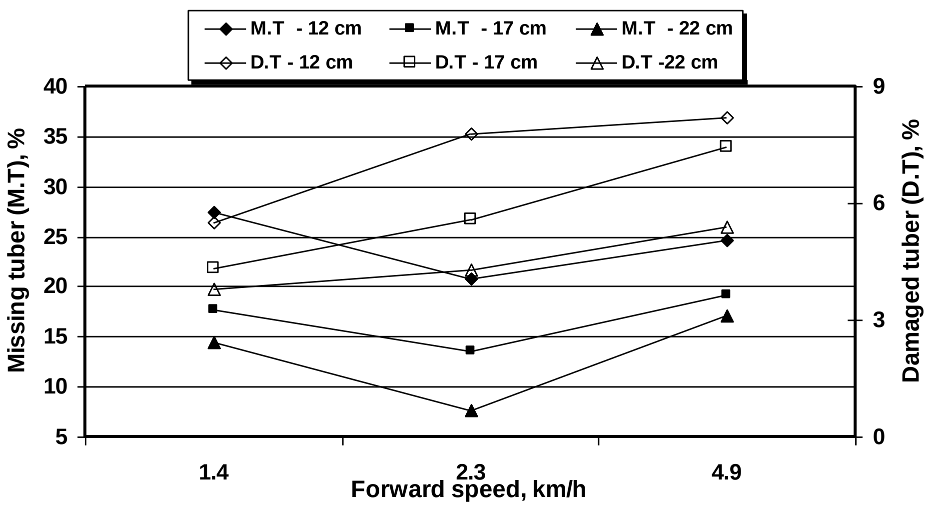


Fig. (10): Variation of missing and damaged tubers with different speeds and different depths of digger.

3.4. Consumed energy and costs

The energy is affected directly by the forward speed and field capacity. Referring to Fig. (11), the consumed energy was reduced in the speed range 1.4 to 2.3 km/h due to the corresponding of increase the field capacity. After that, energy increased with speed change from 2.3 to 4.9 km/h due to decreased field capacity. On the other hand energy increased with increasing digging depth due to increasing the required power to overcome the higher resistance of the soil at deeper depths.

The maximum value of consumed energy was 24.6 kW.h/fed at forward speed of 4.9 km/h and digging depth of 22 cm, while the minimum value was 11.4 % at forward speed of 1.4 km/h and digging depth of 12 cm.

The unit specific cost is affected directly by field capacity. Fig. (11) demonstrates reduction in cost as the increased the field capacity. After that, cost increased when speed increased from 2.3 to 4.9 km/h due to decreased field capacity. It can be observed that the cost increases with increased digging depth due to increasing the required power to overcome provide the sufficient draft force.

The maximum value of cost was 150 L.E/fed at forward speed of 1.4 km/h and digging depth of 22 cm, while the minimum value was 76.9 L.E/fed at forward speed of 2.3 km/h and digging depth of 12 cm.

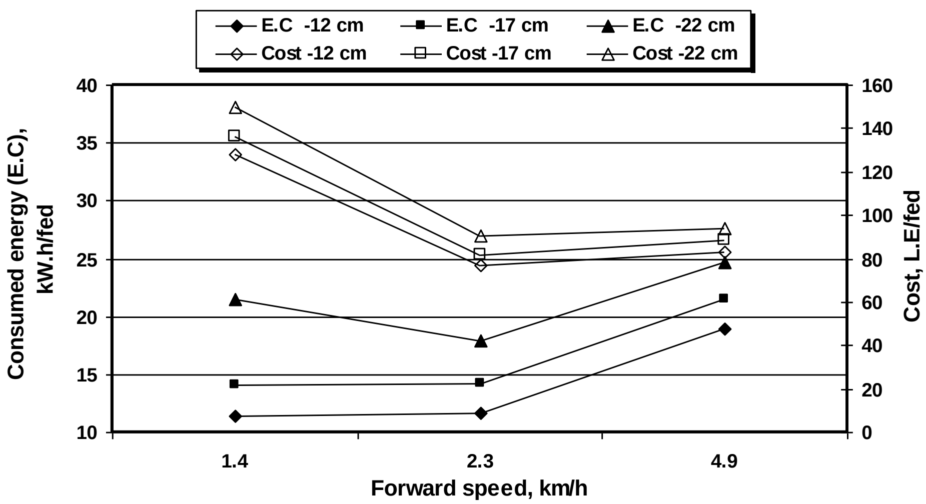


Fig. (11): Variation of consumed energy and cost with different speeds and different depths of digger.

As a result of this study, it is recommended to use the following operating variables: speed is 2.3 km/h and 22 cm depth, therefore the evaluation parameters were field capacity of 0.33 fed/h, harvesting efficiency of 97.13 %, missing tubers of 7.6 %, damaged tubers of 4.3 %, consumed energy of 18 kW.h/fed and cost 90.6 of L.E/fed.

Comparing the man power, time and costs required developed machine with the commonly practiced methods of potato harvesting positive results were obtained in favour of the developed machine.

From Fig. (12), that in potato harvesting times for one faddan by the manual, local plough and developed machine are 9, 8 and 3 hours respectively, and Fig. (13) shows that the harvesting costs for one faddan with different methods are 700, 300 and 90.6 L.E (according to 2011 local conditions). Using the developed machine the harvesting time reduces to about 30% compared with the other methods (men – local plough). Also the harvesting cost reduces to 30.4 % and 13 % compared with harvesting by local plough and men.

On the other hand, using this machine or the developed blade with rotary machine will result in good benefit, because of increasing the operation hours of the machine.

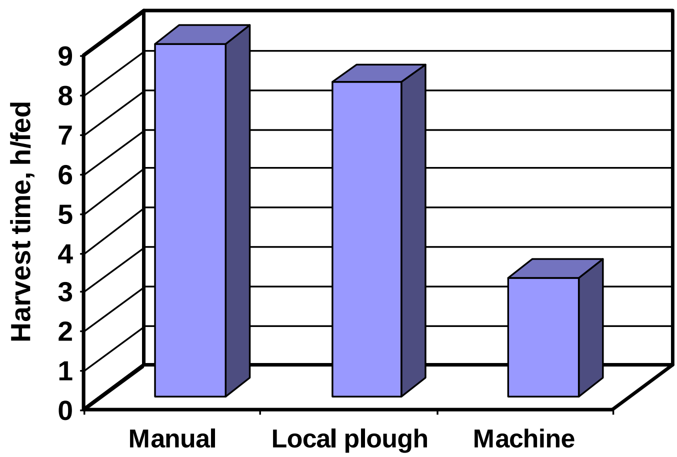


Fig. (12): Harvesting time with different potato harvesting methods.

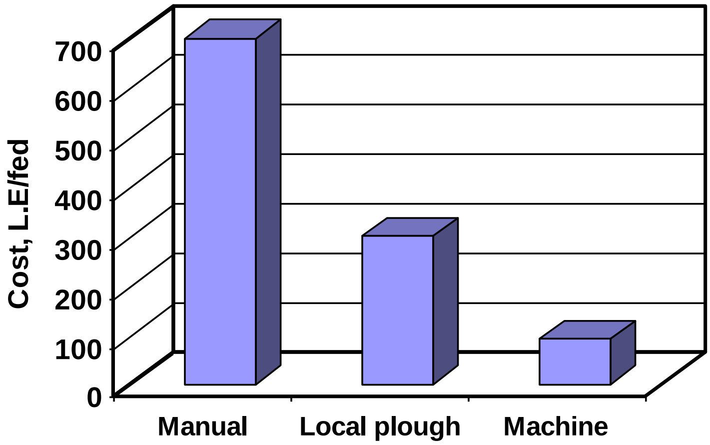


Fig. (13): Harvesting costs with different potato harvesting methods.

CONCLUSION

The obtained results can be summarized as follows:

1. The digger felid capacity increased by increasing the forward speed from 1.4 to 2.3 km/h and decreased by increasing the forward speed from 2.3 to 4.9 km/h. On the other hand, felid capacity decreased by increasing the digging depth.
2. The harvester efficiency decreased by increasing the speed from 1.4 to 4.9 km/h with different digging depths of 12, 17, and 22 cm.
3. Increasing the speed from 1.4 to 2.3 km/h, increased the percentage of raised potatoes, but increasing the speed from 2.3 to 4.9 km/ h decreased the percentage of raised potatoes with different digging depths.
4. The percentage of missing tubers decreased by increasing the speed from 1.4 km/h to 2.3 km/h. Increasing speed from 2.3 to 4.9 the increasing missing tubers. By increasing the digging depth the missing tuber decreased.
5. The percentage of damaged tubers increased by increasing the speed from 1.4 – 4.9 km/h, but the damaged percent decreased with increasing the digging depth.

6. The consumed energy decreased in the speed range 1.4 to 2.3 km/h, after that energy increased with speed from 2.3 to 4.9 km/h. Also energy increased with increasing digging depth.
7. The cost decreased with the speed 1.4 to 2.3 km/h due to increased field capacity. after that, cost increased when speed increased from 2.3 to 4.9 km/h due to decreased field capacity.
8. It is recommended to use the following operating variables: speed is 2.3 km/h and 22 cm depth.
9. Using the machine developed, the harvesting time will decrease to about 30% compared with the other methods (manual and local plough harvest). Also the harvesting cost will decrease to 30.4 % and 13 % compare with harvest by local plough and manual.

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الملخص العربي

تطوير وتقييم آلة لتقليع البطاطس تناسب الحيازات الصغيرة

محمد محمود إبراهيم (1) **ماهر فتحي عطية** (2)

يهدف هذا البحث إلي تطوير أحد الآلات المحلية التي تقوم بتقليع محصول البطاطس تناسب الحيازات الصغيرة، حيث أجريت هذه الدراسة خلال الموسم الربيعي لعام 2011 على محصول البطاطس في قرية العياط بمحافظة الجيزة، حيث تم إجراء تعديل على عزاقة دورانية ذات قدرة 12 حصان بمحرك خاص، تم استبدال سلاح فجاج بسلاح المحراث الدوراني لكي يستخدم في حصاد البطاطس، وقد تم تصميم السلاح وتصنيع واختبار السلاح وتم استخدامه مع تربة طينية طميية مزروعة بطاطس. تم اختبار الآلة عند ثلاث سرعات أمامية (1.4 ، 2.3 ، 4.9 كم/ساعة) وثلاث أعماق مختلفة (12 ، 17 ، 22 سم).

وقد بينت الدراسة ما يلي:

١. بزيادة السرعة من 1.4 إلى 2.3 كم/ساعة تزداد السعة الحقلية، أما عند زيادة السرعة إلى 4.9 كم/ساعة تقل السعة الحقلية ، أما مع زيادة العمق فان السعة الحقلية تقل.
٢. بزيادة السرعة من 1.4 إلى 2.3 كم/ساعة تقل النسبة المئوية للدرنات المتروكة في التربة وبعد ذلك تزداد هذه النسبة عند زيادة السرعة إلى 4.9 كم/ساعة، وتقل هذه النسبة مع زيادة عمق الحصاد ، و تزداد النسبة المئوية للدرنات المتضررة مع زيادة السرعة، وتقل كلما ازداد عمق الحصاد.
٣. تزداد الطاقة المستهلكة في عملية التقليع مع زيادة السرعة من 1.4 إلى 2.3 كم/ساعة نتيجة لزيادة السعة الحقلية ثم تقل الطاقة مع زيادة السرعة إلى 4.9 كم/ساعة، أما عند زيادة عمق الحصاد فتزداد الطاقة اللازمة.
٤. ينصح بتشغيل الآلة على سرعة 2.3 كم/ساعة على عمق 22 سم، مما ينتج عنه سعة حقلية 0.33 فدان/ساعة، وكفاءة حصاد 97.14 %، ونسبة الدرنات المتروكة 7.6 %، ونسبة الدرنات المتضررة 4.3 %، والطاقة المستهلكة 18 كيلووات. ساعة/فدان بتكلفة 90.6 جنية/فدان.
٥. باستخدام الآلة سوف يقل الزمن اللازم لحصاد الفدان بنسبة 30 % مقارنة بالحصاد بكل من الحصاد اليدوي وبالمحراث البلدي الذي يجره الحيوانات، وأيضا تقل تكاليف الحصاد باستخدام الآلة المطورة إلى حوالي 30.4 %، 13 % مقارنة بالحصاد بالمحراث البلدي و الحصاد اليدوي على التوالي.

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