COMPARATIVE STUDY BETWEEN SOME DIFFERENT POTATO HARVESTING MACHINE IN SMALL HOLDINGS

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ABSTRACT

Field experiments were carried out to compare between some different potato harvesting machines (agitator potato digger, elevator potato digger and chisel plow) and evaluate their performance under field conditions. Potato harvesting machines performance was conducted under four different soil moisture contents (9, 11, 13 and 16%) and thee different digging depths (22, 27 and 32 cm). Digging operation was carried out at four different forward speeds (1.3, 1.8, 2.5and 3.0 km/h.). Harvesting performance was evaluated in terms of potato losses, productivity, harvesting efficiency, energy requirements and harvesting cost. The experimental results reveal that the use of both agitator digger and elevator potato digger maximize harvesting efficiency and minimize losses and cost comparing with chisel plow under the following conditions: The suitable digging depth to dig all potato tubers is 32 cm., the optimum soil moisture content suitable for digging potato is 13%, the proper forward speed for operating potato diggers is 2.5 km/h.

Keywords: *Agitator, digger, elevator digger, energy requirements ,harvesting efficiency*

INTRODUCTION

Potato (*Solanum tuberosum* L.) popularly known as 'The king of vegetables, has emerged as fourth most important food crop in Egypt after rice, wheat and maize. Egyptian vegetables basket is incomplete without Potato because the dry matter, edible energy and edible protein content of potato makes it nutritionally superior vegetable as well as staple food not only in Egypt but also all over the world.

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The cultivated area in Egypt was about 330.000 fed to produce about 3.66 million ton/year distributed on the summer, Nile and winter seasons. The production year 2013 reached to 4.76 million tons (**Ministry of Agric. Static., 2009, 2013**).Harvesting is one of the most critical operations for potato production. Potato tubers are grown below the surface of the ground. Therefore, it requires specially designed machines to dig and separate them from the soil. Recently, some progress towards fully mechanized of potato harvesting have been occurred.The mechanical potato harvester performs the following operations, in sequence: a) Digging (b) Separation of loose soil, small clods and stones (c) Removing of the vines and weeds (d) Partial separation of the tubers from similar sized stones and clods. Potato is easily cut and cracked or skinned during the separation process; therefore the separation of potato from soil, similar size stones and clods is a major problem. **Younis (1987)** tested one row potato digger mounted on 51.5 kW (70 hp) tractor in sandy soil at different digging depths and forward speeds. He found that the total losses such as skinned potato and damage by the lifting operation were about 3% of the total yield compared with 8-14% for conventional harvesting (Baladi plow). **Amin (1990)** developed potato harvester having field capacity of 0.31 fed/h and field efficiency of 91.32% at forward speed of 2.1 km/h. Harvesting potato tubers using the developed harvester costed 16.47 L.E/fed, while the traditional methods costed 80 L.E/fed. **Mady (1999)** indicated that the increasing of digging depth and the decreasing of forward speed reduced the percentage of un-lifted roots, bruised roots and cut roots and increased the percentage of lifted roots and undamaged roots. The lowest values of unlifted roots were 3.0%, bruised roots of 5.1%, cut roots of 4.0% lifted roots of 97%, undamaged roots of 90.9% and digging cost of 44.65 (LE/ton) were obtained at the digging depth of 40 cm and forward speed of 1.5 km/h. He also found that the lowest and highest energy requirements of 66.43 and 187.9 kW.h./fed and the highest and lowest values of cost of 245.28 and 44.65 L.E/ton were obtained at digging depths of 25 and 40 cm and forward speeds of 3.6 and 1.5 km/h., respectively. **Afify and Mechail (2000)** developed and constructed a simple potato harvester. They found that the optimum forward speed for digging was 4.49 km/hto increase the percentage of raised potato to 96.86%, reduce the skin, and cut damage to 1.11% and

missing tubers to 3.14%. They reported that using a box-picker reducing the digging cost to 20%. **Abdel-Aal *et al.* (2002)** modified a potato harvester to be suited for Egyptian farms. The optimum engineering parameters for the modified harvester were forward speed of 2.3km/h., digger tilt angle of 14º, distance between the blade and elevator chain of 5 cm, chain speed of 2.41 m/s riddle speed of 11.16 m/s and riddle inclination of 7º. They achieved the highest undamaged, lowest damaged and losses tubers 87.4%, 1.98 and 10.62%, respectively under the optimum engineering parameters for the modified harvester. **Abdel Maksoud *et al.* (2004)** developed a potato digger for harvesting and gathering potato. They recommended that the forward speed was about 2.4 km/h., penetration angle of 14º, sieve slope of 8º and operating speed of 1.2 m/sec., to achieve the highest undamaged with the lowest damage and buried potato. **Younis *et al.* (2006)** developed and tested a potato digger at four levels of forward speed (0.9, 1.5, 1.9 and 3.2 km/h.), four levels of vibrating amplitude (3, 5, 6 and 10 mm) and five levels of vibrating frequency (400, 600, 800, 1000 and 1200 rpm). They found that the developed digger succeed to operate with lower power tractors thus the harvesting cost was reduced by 28.5%. **Ibrahim *et al.* (2008)** developed a multi-purpose digger for harvesting root crops (potato and peanut). The developed digger was tested at thee levels of forward speed and thee different tilt angles. From the obtained results, the proper conditions to operate the developed digger were 22 cm harvesting depth, 2.6 km/h., forward speed and 18º tilt angle for potato crop. The cost of harvesting using the digger was 91.55 L.E/fed. **Tawfik and Abdallah (2012)** fabricated a prototype of potato digger to suit small holdings, they revealed that the proper operation for the prototype potato digger are forward speed of 2.3 km/h., rake angle of 14º and digging depth of 30 cm **Ali (2013)** manufactured a simplified potato digger and evaluated its performance under laboratory and field conditions. The suitable digging depth to dig all potato tubers is 27, cm the optimum soil moisture content suitable for digging potato is 11% (dry base), the proper forward speed for operating the manufactured potato digger is 2.2 km/h. Although several methods of separation have been proposed, none have been wholly successful without excessive operational cost and potato tubers damage.

Therefore, the objectives of the present study are:

1. Compare the performance of three different potato harvesting machines.
2. Optimize some different operating parameters affecting the performance of potato harvesting machines.
3. Evaluate the performance of potato harvesting machines from the economic point of view.

MATERIALS AND METHODS

The experiments were carried out during 2013 at Shabab project farm, Al-Ismailia Governorate. The mechanical analysis of the experimental soil was classified as a sandy soil as shown in Table (1).The experimental area was planted mechanically *via* belt potato planter (Stractural) using Diamant potato variety, that belongs to the medium late maturing varieties that take about (115-120) days to mature. Field experiments were planted with tuber rate of 1300 kg/fed., 70 cm row spacing, 20cm planting depth and about 30 cm between hills in the same row.

Table (1): Mechanical analysis of the experimental soil

Soil components			Soil type
Clay (%)	Silt (%)	Sand (%)	
5.80	4.38	89.82	Sandy soil

A-Materials
1-Potato specifications
Average dimensions of potato tubers used in the experiments are as follows:
Length (L) = 93 mm, Width (W) = 59 mm and thickness (T) = 53 mm
2-Equipment specifications
Specifications of equipment which used in the present study are as follow:
-Tractor
A 4-wheel drive tractor (FIAT model 115-90DT) of the standard type 115hp (84.6 kW) was used as a power source for operating the different potato harvesting machines.
-Elevator digger
Fig.(1) depicts the elevator digger that used for harvesting potato in the present study. Specifications of the elevator digger are shown in Table(2).

- Agitator digger

Fig.(2) depicts the agitator digger that used for harvesting potato in the present study Specifications of the agitator digger are shown in Table (2).

- Chisel plow

A local mounted chisel plow was used for harvesting potato with 7 shares corresponding to 175 cm working width, plow mass is 250kg.

B- Methods

The field experiments were carried out to evaluate the performance of thee different potato harvesting machines. The experimental area was about 12 feddans divided into four equal plots (3 feddans each) with dimensions of (50×252) m with average four different soil moisture contents of 9, 11, 13 and 16% (db). Each plot was divided into thee equal sub- plots (one feddan each) with dimensions of (50×84) m. In each sub-plot, one of the following potato harvesting machines was used:

  - Potato elevator digger
  - Potato agitator digger
  - Chisel plow

Each sub-plot was divided into thee areas (50×28m) for thee different harvesting depths of 22, 27 and 32cm. Each area was divided into four equal areas slices of (50×7m) to operate potato harvesting machines under four average different forward speeds of 1.3, 1.8, 2.5 and 3.0 km/h.

All experiments were carried out under recommended share angle of 14° and chain speed of 10.4 rpm (1.25 m/s). The vines of the potato were removed (killed) ten days before harvesting with chemical spraying.

Soil moisture content was determined on dry basis with the oven method at 105ºC for 24 hours. Mechanical analysis and soil moisture contents were done in laboratory of Agriculture College, Zagazig University.

-Measurements

Evaluation of potato harvesting machines was carried out taking into consideration the following indicators:

-Field capacity and field efficiency:

 Field efficiency (F.E) is the ratio of actual field capacity to theoretical field capacity expressed as follows:

$$\text{Field efficiency (F.E)} = \frac{\text{A. F.C}}{\text{T.F.C}} \times 100$$

Where:

A.F.C: Actual field capacity, fed/h.

T.F.C: Theoretical field capacity, fed/h.

The theoretical field capacity was calculated by using the following relationship:

$$\text{Theoretical field capacity(T.F.C)} = \frac{W \times S}{4.2} \quad , \text{fed./h.}$$

Where:

W: Working width of potato harvesting machine, m.

S: Average working forward speed, km/h.

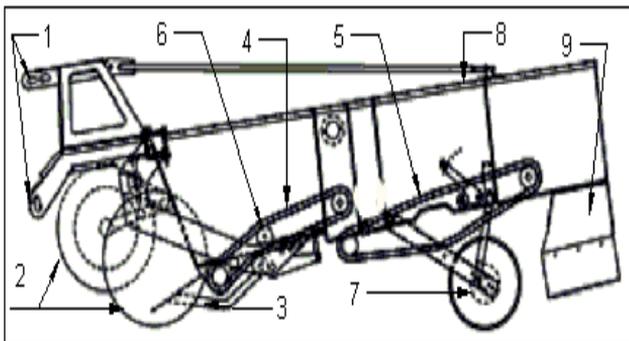$$\text{Actual field capacity(A.F.C)} = \frac{1}{T_a} \quad , \text{fed./h.}$$

Where:

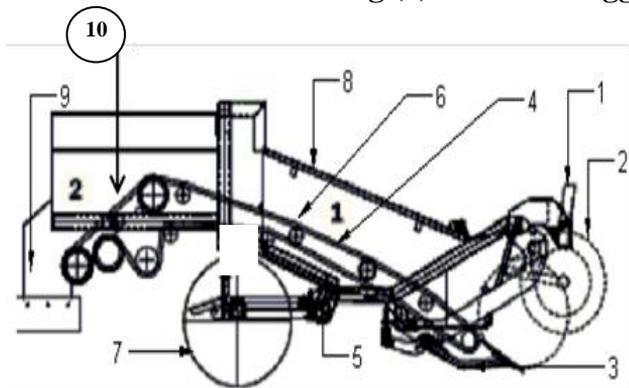Ta: Total actual time consumed to dig one feddan, Ta=T1+T2+T3,

T1: Digging time,h

T2: Turning tim,h.

T3: Adjustment time,h.

Part No.	Name
1	Linkage attachment point
2	Disc coulters
3	Share blade with 3 legs
4	Front web
5	Rear web
6	Rollers
7	wheel
8	Frame
9	Gather

Fig.(1): Elevator digger

Part No.	Name
1	Linkage attachment point
2	Disc coulters
3	Share blade with 3 legs
4	web
5	Driven rotary agitator in
6	Rollers
7	wheel
8	Frame
	Gather
10	Italic end of web

Fig.(2): Agitator digger

Table(2) :The technical specifications of the potato diggers.

Item	Elevator digger	Agitator digger
Source/Model	Germany / Grimme GVR 1700	Germany /Grimme RL 1700
Type	semi-mounted	semi-mounted
Dimensions:		
Length, m	3.80	4.6
Width, m	2.05	2.28
Height, m	1.20	1.65
Mass, kg	1500	With haulm web: 2350
Tires	5.00-8	10.0/75-15
Row width	75-90cm	75-90cm
Number of rows	Two	Two
Intake	4 disc coulters (spring loaded and pulled)	4 disc coulters (spring loaded and pulled)
Share type	Share blade with 3 legs	Share blade with 3 legs
Share depth control	With Diablo rollers	With diablo rollers
Main webs	1st main web (front) 1.64 m wide, 1.40 m long,40mm pitch 2nd web (rear) 1.64 m wide, 1.10 m long,40mm pitch	main web 1.64 m wide, 3.40 m long,40mm pitch
Agitator	Driven rotary agitator in 2nd main web	Driven rotary agitator in 1st main web Option: electrically adjustable agitator Option: two rotary agitators in 1st main web
Power requirement	55 hp (40) kW	47.6 hp(35)kW
Potato discharge	Centre discharge at the rear of the machine Option: hydraulically driven cross conveyor to one side	Centre discharge at the rear of the machine Option: hydraulically driven cross conveyor to one side

-Raised tubers

The raised tubers (R_t) in Mg/feddan was determined by massing the tuber (Mr) kg raised by the digger over the soil surface collected from a length to (10) m by using the following equation **(Arfa, 2007):**

$$R_t = \frac{4200 \times Mr}{(1.8 \times 10) \times 1000} \ , \ Mg/fed.$$

Where:

R_t: Raised tubers, Mg/fed.

Mr: Mass of the raised tubers, kg

(1.8 ×10): Area of unit it's length (10) m and the width equal 1.8 m.

-Buried tubers

The buried tubers determined by massing the buried tuber by manual digging form the experimental area of (1.8×100) m^2 using the following equation:

$$Bt = \frac{4200 \times Mb}{(1.8 \times 10) \times 1000} \ , \ Mg/fed.$$

Where:

Bt: buried tubers, Mg/fed.

Mb: Mass of buried tubers, kg

- Damaged and undamaged tubers

Random samples of tubers were collected and weighted for each treatment, each sample was divided into two portions, the damaged (D_t) and un-damaged tubers ($U.D_t$) ,the mass of damaged tubers is (m_1) and the mass of un-damaged tubers is (m_2).

- Total crop losses

Total crop losses can be determined using the following equation:

Total crop losses (Mg/fed)= Buried tubers + Damaged tubers

- Harvesting efficiency

Harvesting efficiency is calculated by using the following equation:

$$\eta_H = \frac{R_t - D_t}{M_t} \times 100 \ , \ \%$$

Where:

R_t: Mass of tubers lifted on surface, kg

D_t: Mass of damaged tubers, kg

M_t: Mass of total tubers in experimental area, kg

- Fuel consumption

During the harvesting operation, fuel consumption was determined by measuring the required fuel to refill the fuel tank after the working periods by means of graduated glass cylinder it was calculated by using the following equation:

$$Fc = \frac{Vf}{T} \times 3.6 \quad , L/h.$$

Where:

Fc: Fuel consumption

Vf: Volume of consumed fuel, cm^3

T: Time of digging, s

- Required power

Required power was estimated from the fuel consumed during the harvesting operation using the following formula (**Barger *et al.,* 1963**)

$$p = F_C \times \frac{1}{60 \times 60} \times \rho_f \times L.C.V \times 427 \times \eta_{th} \times \eta_m \times \frac{1}{75} \times \frac{1}{1.36}, \quad kW$$

Where:

Fc: Fuel consumption, L/h.

ρ_f: Density of fuel, kg/1 (for diesel fuel 0.85 kg/L

η_{th}: Thermal efficiency ≈ 40% for diesel engine

η_m: Mechanical efficiency of the engine (80-85%)

L.C.V: Lower Calorific value of fuel (10000-11000) kcal/kg

427 : Thermo mechanical equivalent J/kcal

- Energy Requirements

Estimation of the energy required for operating the harvesting machines was carried out using the following formula:

$$Energy\ requirements = \frac{Required\ power\,(}{Actual\ field\ capacity\,(fad/h.)}\,, kW.h./fed.$$

- Machine hourly cost

Machine and tractor hourly cost was determined by using the following equation **(Awady, 1978):**

$$C = \frac{p}{h}\left[\frac{1}{e} + \frac{i}{2} + t + r\right] + (1.2W \times f \times s) + \frac{M}{144}$$

Where:

C: Hourly cost, LE/h.

P: price of machine, LE

h: Yearly working hour, h./year

e: Life expectancy of equipment in year .

i: Interest rate ,%

t: Taxes and over heads ,%

r: Repairs ratio of total investment %

1.2: A factor including reasonable estimation of the oil consumption in addition to fuel.

W: Power of engine, kW

F: Specific fuel consumption, L/hp.h.

S: Price of fuel per liter, LE/L

M: Labor wage rate per month, LE/month

144: Monthly average of working hour's

-Operating cost

The operating cost was determined from the following formula:

$$\text{Operating cost} = \frac{\text{Machine cost , L.E/h.}}{\text{Actual field capacity, fed./h.}} \text{, LE/fed.}$$

Product losses cost

Product losses cost was determined from the following formula:

Product losses cost = $L_1 (P_0 - P_1) + L_2 P_0$ LE/fed.

Where:

L_1: Damage tubers, kg/fed

L_2: Buried tuber, kg/fed.

P_0: The price of one kg of intact potato tuber. L.E/kg,

P_1: The price of one kg of damaged potato tuber, L.E/kg.

-Criterion Cost

Criterion cost (C) can be calculated using the following equation (**Awady et al., 1982**).

C = operating cost + product losses cost, L.E/fed.

RESULTS AND DISCUSSION

1- Effect of Harvesting Machine Operating Parameters on Field Capacity and Field Efficiency:

Concerning the effect of machine forward speed on field capacity and field efficiency, the obtained results in Fig.(3) showed a remarkable drop in the field efficiency with a consequent sharp rise in actual field capacity due to increasing the forward speed. Results show that, increasing forward speed from 1.3 to 3.0 km/h, leads to increase the actual field capacity values from 0.49 to 1.00, from 0.48 to 0.95 and from 0.50 to 1.04 fed/h, for agitator digger, elevator digger and chisel plow, respectively at soil moisture content of 13% and harvesting depth of 32 cm. On the other hand, increasing forward speed from 1.3 to 3.0 km/h, leads to decrease field efficiency values from 89.06 to 77.92%, from 87.1 to 74.53% and from 90.81 to 81.08%, for agitator digger, elevator digger and chisel plow, respectively under the same previous conditions. The major reason for the reduction in field efficiency by increasing forward speed is due to the low value of the theoretical time. Regarding to the effect of soil moisture content on field capacity and field efficiency, the obtained results in Fig.(3) showed that, increasing soil moisture content from 9 to 16% leads to decrease the actual field capacity values from 0.81 to 0.77, from 0.78 to 0.74 and from 0.84 to 0.807 fed./h, for agitator digger, elevator digger and chisel plow, respectively at harvesting machine forward speed of 2.5 km/h., and harvesting depth of 32 cm.
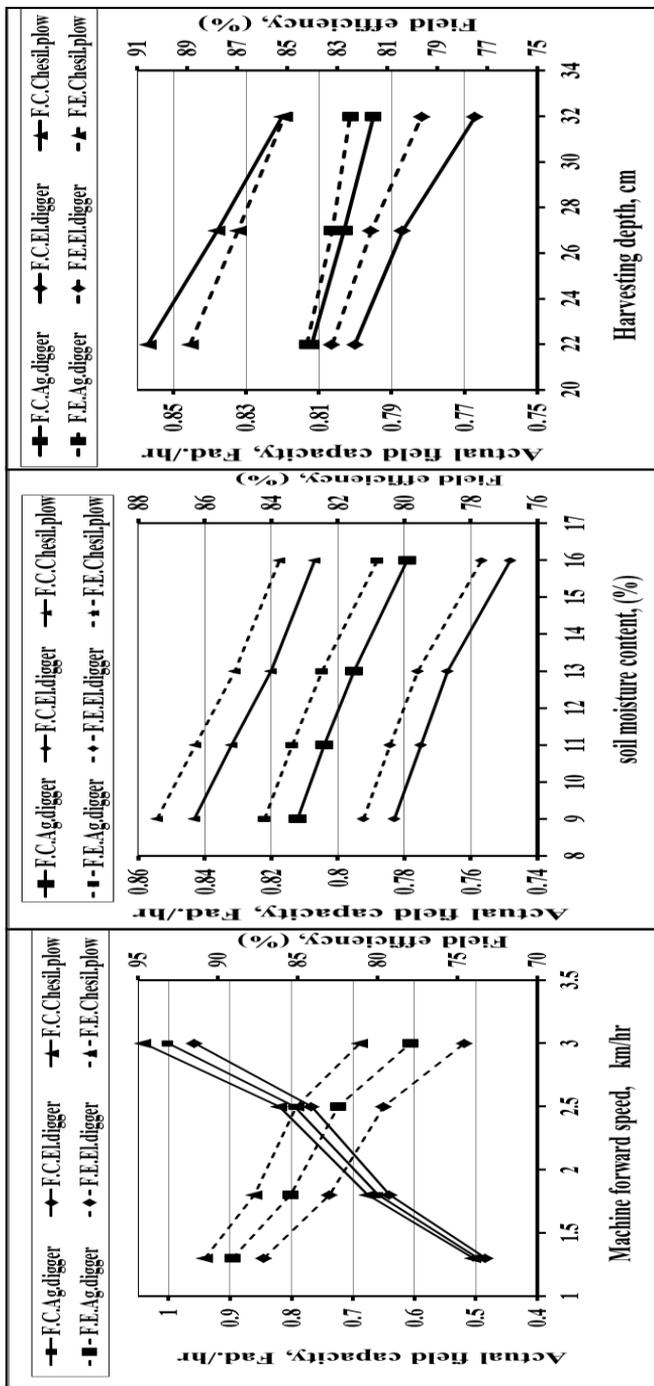
Fig.(3): Effect of harvesting machine operating parameters on field capacity and field efficiency.

Also increasing soil moisture content from 9 to 16% leads to decrease field efficiency values from 84.21 to 80.8, from 81.21 to 77.66 and from 87.43 to 83.76% for agitator digger, elevator digger and chisel plow respectively under the same previous conditions.

Regarding to the effect of harvesting depth on field capacity and field efficiency, Fig.(3) shows that, increasing harvesting depth from 22 to 32 cm leads to decrease the actual field capacity values from 0.81 to 0.79, from 0.80to 0.76 and from 0.85 to 0.82 fed./h., for agitator digger, elevator digger and chisel plow, respectively at harvesting machine forward speed of 2.5 km/h., and soil moisture content of 13%. Also, increasing harvesting depth from 22 to 32 cm leads to decrease field efficiency values from 84.21 to 82.47%, from 83.21 to 79.60% and from 88.88 to 85.10% for agitator digger, elevator digger and chisel plow, respectively under the same previous conditions. From this point of view, it was noticed that the highest field capacity was obtained by using chisel plow for harvesting potato at forward speed 3.0 km/h., and harvesting depth of 22 cm in soil moisture content of 9% meanwhile, the lowest value was obtained by using elevator digger at forward speed 1.3 km/h., and harvesting depth of 32 cm in soil moisture content of 16%. At the same time the highest value of field efficiency was noticed with the use of chisel plow for harvesting potato at forward speed 1.3 km/h, harvesting depth of 22 cm and soil moisture content of 9% while, the lowest value was obtained by using elevator digger at forward speed 3.0 km/h, harvesting depth of 32 cm and soil moisture content of 16%.

2- Effect of Harvesting Machine Operating Parameters on Potato Tuber Losses:

-Buried tubers

The obtained results in Fig.(4) shows that, the buried tubers were more pronounced as the forward speed increased at any harvesting depth up to 2.5 km/h. The obtained data showed that increasing forward speed from 1.3 to 2.5 km/h, decreased the buried tubers from 2.38 to 1.87, from 1.38 to 1.03 and from 0.38 to 0.19 Mg/fed at harvesting depth of 22 ,27 and 32 cm respectively, using agitator digger ,while it decreased from 2.8 to 2.20, from1.62 to 1.21 and from 0.45 to 0.23 Mg/fed at the mentioned depths using elevator digger and from 4.19 to 4.08, from 3.68 to 3.47 and from 2.48 to 1.79 Mg/fed using chisel plow at soil moisture content of 13%. Any further increase in forward speed more than 2.5 up to 3.0 km/h, the contrarily

trend was noticed under the same previous conditions. The increase in buried tubers at high forward speeds may be due to the floating action of the digger blades that increased the circulating motion of soil on the blades consequently more potato tubers were left in the soil.The obtained results in Fig.(5) show that, increasing soil moisture content from 9 to 13%, and harvesting depth from 22 to 32 cm, decreased buried tubers from 2.0 to 0.19, from 2.43 to 0.23 and from 4.16 to 1.79 for agitator digger, elevator digger and chisel plow, respectively at forward speed of 2.5 km/h. Any further increase in soil moisture content more than 13 up to 16%, the contrarily was occurred under the mentioned previous conditions. The increase of buried tubers at high soil moisture content may be attributed to the cohesive nature of the soil slice which interfaced the digger blade, where cohesive soil slice keep potato tubers in the soil consequently increased buried tubers.

-Damaged tubers

The obtained results in Fig.(4) show that, the damaged tubers were more pronounced as the forward speed increased at any harvesting depth up to 3.0 km/h. The obtained data showed that, increasing forward speed from 1.3 to 3.0 km/h, increased the damaged tubers from 2.780 to 3.069, from 1.567 to 1.743 and from 0.267 to 0.406 Mg/fed at harvesting depth of 22 ,27 and 32 cm respectively, using agitator digger ,while it increased from 3.068 to 3.302, from 1.685 to 1.890 and from 0.303 to 0.467 Mg/fed, at the mentioned depths using elevator digger and from 3.460 to 3.721, from 1.898 to 2.128 and from 0.339 to 0.522 Mg/fed, using chisel plow under soil moisture content of 13%. The increase of damaged tubers by increasing forward speed is due to the floating action of the blade and increasing the circulation motion of the soil on the blade which subjected potato tubers to more friction resulting in high damaged tubers. The highest damaged tubers at a low depth is due to breaking tubers by the share at potato tuber level, also the damaged tubers are greatly affected by soil moisture content as shown in Fig.(5). The obtained data indicated that, increasing soil moisture content from 9 to 13% and harvesting depths of 22 to 32 cm, decreased damaged tubers from 3.05 to 0.32, from 3.30 to 0.38 and from 3.71 to 0.43 Mg/fed for agitator digger, elevator digger and chisel plow, respectively at constant forward speed of 2.5 km/h. Any further increase in soil moisture content more than 13 up to 16%, the damaged tubers increased under the same mentioned conditions.
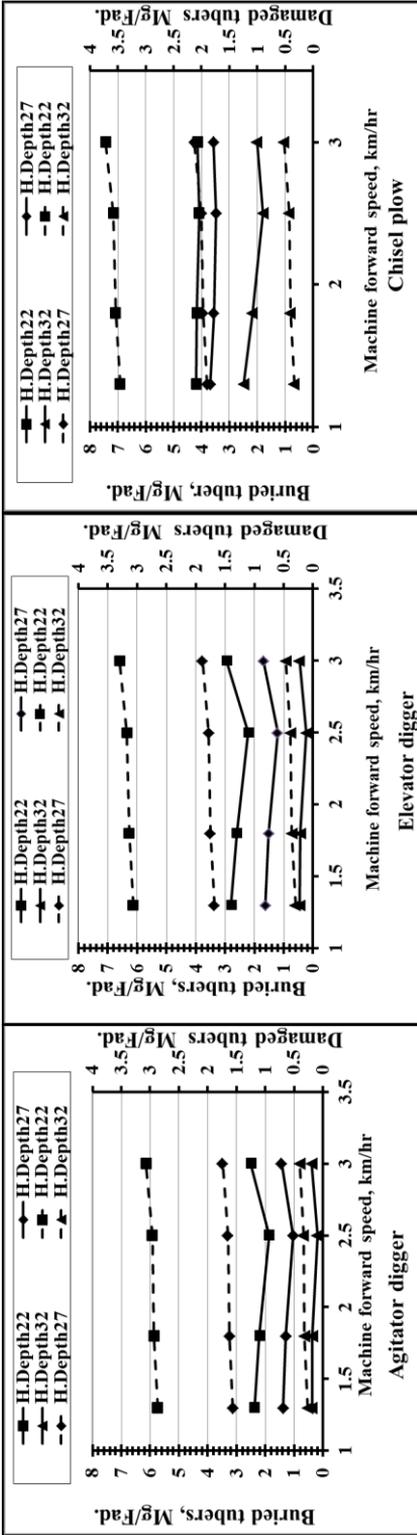
Fig.(4):Effect of harvesting machine forward speed on buried and damaged tubers under different harvesting depths
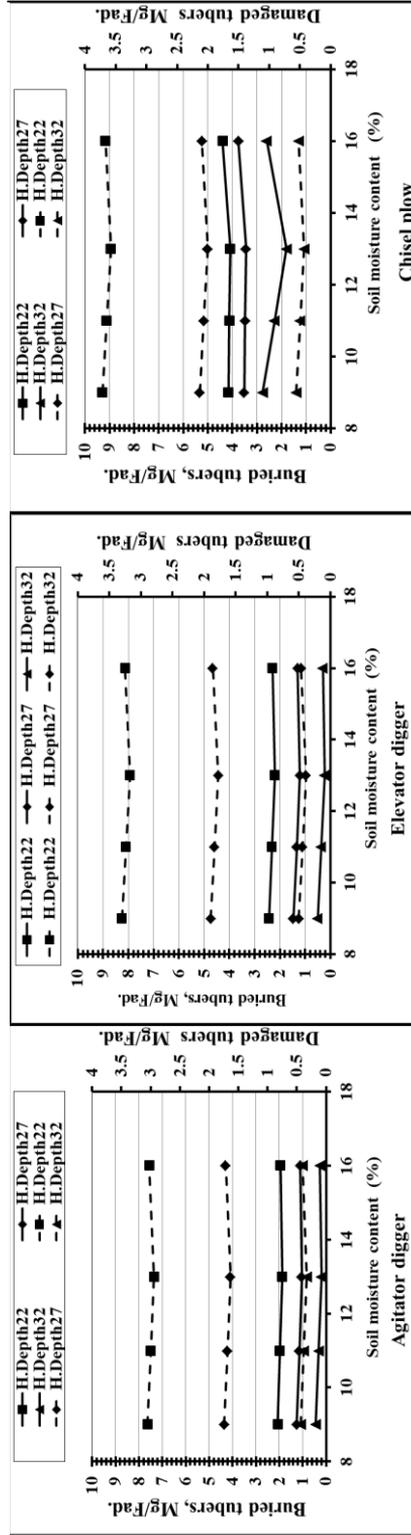

Fig.(5): Effect of soil moisture content on buried and damaged potato tubers under different harvesting depths

-Total crop losses

The obtained results in Fig.(6) showed that increasing forward speed from 1.3 to 2.5 km/h, decreased total losses from 5.25 to 4.83, from 2.950 to 2.67 and from 0.65 to 0.56 Mg/fed at harvesting depths from 22 to32 cm respectively using agitator digger, while it decreased from 5.86 to 5.37, from 3.31 to 2.99 and from 0.75 to 0.61 Mg/fed at the mentioned depths using elevator digger and from 7.70 to 6.65, from 5.56 to 5.44 and from 2.582 to 2.22 Mg/fed using chisel plow, under soil moisture content of 13%. Any further increase in forward speed more than 2.5 up to 3.0 km/h, the total losses increased under the same previous conditions. The increase in total losses tubers at high forward speeds is due to the increase in both buried and damaged tubers. The obtained results in Fig.(7) showed that increasing soil moisture content from 9 to 13%, the total losses decreased from 5.13 to 4.83, from 2.99 to 2.67 and from 0.87 to 0.53 Mg/fed at harvesting depths of 22, 27 and 32 cm respectively, using agitator digger; while the total losses decrease from 5.74 to 5.37, from 3.36 to 2.99 and from 1.01 to 0.61 Mg/fed at the depths of 22,27 and 32 cm respectively using elevator digger, but for the chisel plow the losses decreased from 8.05 to 6.65, from 5.85 to 5.44 and from 3.32 to 2.22 at the mentioned depths under forward speed of 2.5 km/h. Any further increase in soil moisture content more than 13 up to 16%, total losses increased under the mentioned previous conditions. The obtained data showed that the highest total losses of 8.25, 6.78 and 6.02 Mg/fed were recorded at forward speed of 3.0 km/h, soil moisture content of 9% and harvesting depth of 22 cm for chisel plow, elevator digger and agitator digger, respectively. While the lowest total losses tubers of 2.22, 0.61 and 0.53 Mg/fed were recorded at forward speed of 2.5 km/h, soil moisture content of 13% and harvesting depth of 32 cm under the same mentioned machines respectively. The increase in total crop losses at high forward speed, low harvesting depth and high soil moisture content is due to the increase in both buried and damaged tubers.

3- Effect of Harvesting Machine Operating Parameters on Raised Tubers and Harvesting Efficiency

- Raised tubers

Fig.(8) showed that, increasing forward speed from 1.3 to 2.5 km/h., and

the harvesting depths from 22 to 32 cm, increased the raised tubers from 14.87 to19.25 ,from 13.65 to 17.66 , and from 10.77 to 14.49 Mg/fed, for agitator digger; elevator digger and chisel plow, respectively at soil moisture content of 13%. Any further increase in forward speed more than 2.5 up to 3.0 km/h, raised tubers decreased under the same operating conditions. Fig.(9) showed that ,increase soil moisture content from 9 to 13%, and harvesting depths from 22 to 32 cm, increased raised tubers from 16.16 to 19.15, from 14.82 to 17.66 and from 11.54 to 14.49 Mg/fed for agitator digger ,elevator digger and chisel plow respectively. Any further increase in soil moisture content more than 13 up to 16 %, the raised tubers decreased under the same conditions. The decrease in raised tubers at soil moisture content less or more than 13% is attributed to the high catching force at lower soil moisture content and high elastic soil conditions at higher moisture content**.**

- Harvesting efficiency

Fig.(8) shows that, increasing forward speed from 1.3 to 2.5 km/h., and harvesting depths from 22 to 32 cm, increased the harvesting efficiency from 69.57 to 97.24%,from 64.32 to 96.54% and from 48.88 to 86.35% for agitator digger elevator digger and chisel plow, respectively at soil moisture content of 13%. Any further increase in forward speed more than 2.5 up to 3.0 km/h., harvesting efficiency decreased under the same conditions. The increase in harvesting efficiency by increasing forward speed up to 2.5 km/h was attributed to the increase in raised potato at that range of speeds. While the decrease in harvesting efficiency at speeds higher than 2.5 up to 3 km/h was attributed to the decrease of the raised potatoes compared with the increase in buried potatoes. The obtained results in Fig.(9) show that, increasing soil moisture content from 9 to 13%, and harvesting depths from 22 to 32 cm, increased the harvesting efficiency from 71.79 to 97.243%; from 66.75 to 96.54% and from 49.81 to 86.35% for the agitator digger, elevator digger and chisel plow respectively, but any further increase in soil moisture content more than 13 up to 16%, harvesting efficiency decreased slightly under the same conditions. The obtained data showed that the highest values of harvesting efficiency of 97.24, 96.54 and 86.35% were recorded at forward speed of 2.5 km/h., soil moisture content of 13% and harvesting
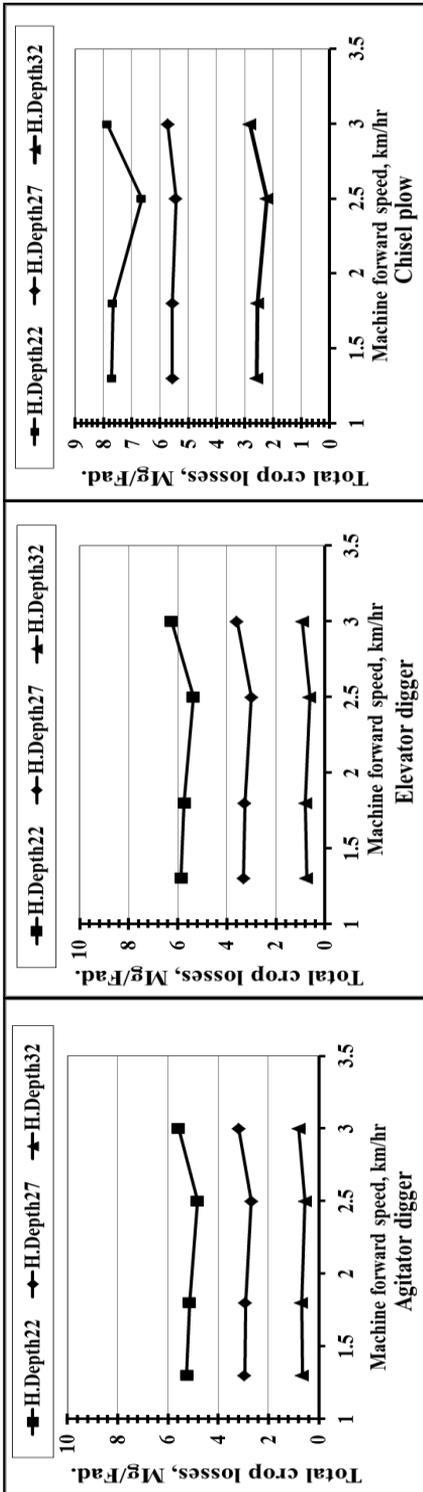
Fig.(6): Effect of harvesting machine forward speed on total crop losses under different harvesting depths.
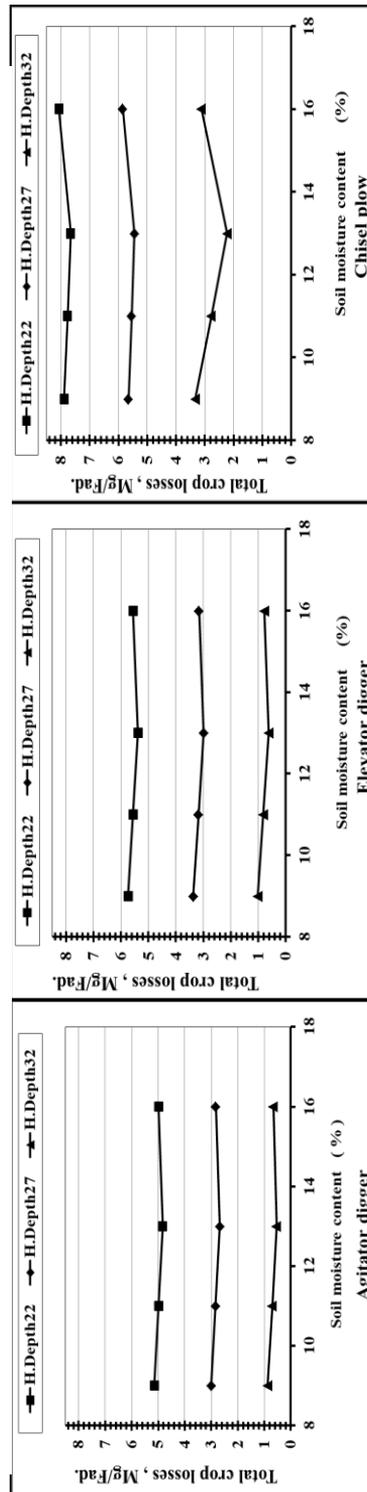

Fig. (7:) Effect of soil moisture content on total crop losses under different harvesting depths.
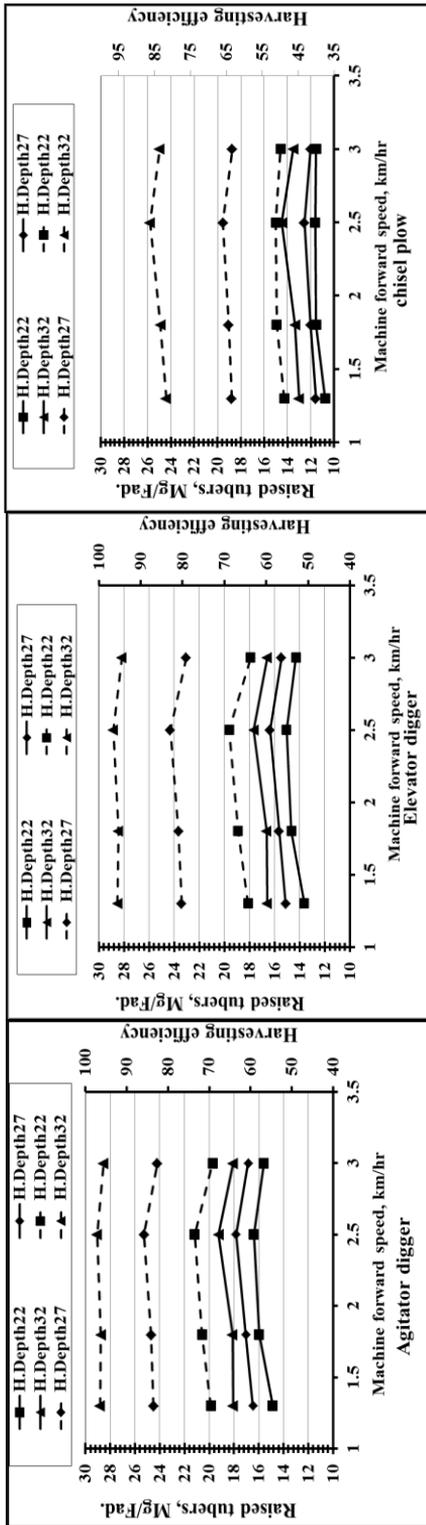
Fig.(8): Effect of machine forward speed on raised tubers and harvesting efficiency under different harvesting depths
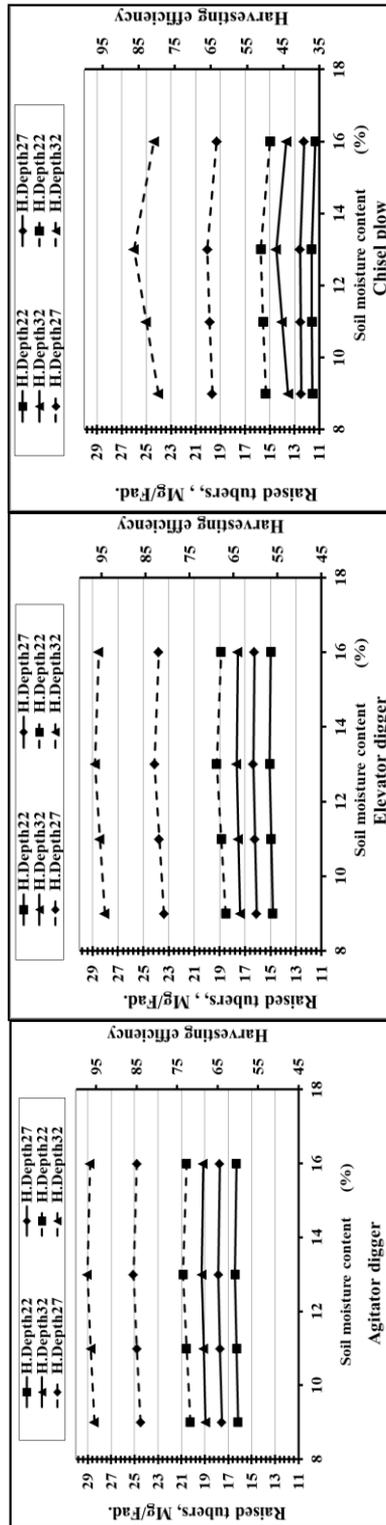

Fig.(9): Effect of soil moisture content on raised tubers and harvesting efficiency under different harvesting depths

depth of 32 cm for agitator digger, elevator digger and chisel plow respectively. On the other hand, the lowest values of harvesting efficiency of 66.55, 60.71 and 46.18 were obtained at forward speed of 3.0 km/h., soil moisture content 9% and harvesting depth of 22 cm for agitator digger, elevator digger and chisel plow respectively.

4- Effect of Harvesting Machine Operating Parameters on Power and Energy Requirements

-Required power

The obtained results in Fig.(10) showed that, the increasing forward speed from 1.3 to 3.0 km/h and the harvesting depth from 22 to 32 cm, increased the required power from 22.99 to 31.05 kW, from 27.71 to 36.39 kW and from 21.74 to 30.05 kW for the agitator digger, elevator digger and chisel plow respectively under soil moisture content of 13%. Fig.(11) showed that increasing soil moisture content from 9 to 16% and the harvesting depths from 22 to 32 cm, the required power increased from 25.13 to 32.20 kW, from 29.99 to 37.918 kW and from 24.06 to 31.048 kW for agitator digger elevator digger and chisel plow respectively at forward speed of 2.5 km/h.

-Energy requirements

Fig.(10) shows that, increasing forward speed from 1.3 to3.0 km/h., measured, decreased energy requirements from 45.2 to 25.5, from 49.4 to 28.04 and from 54.24 to 30.99 kW.h./fed, at harvesting depths of 22, 27 and 32 cm using agitator digger respectively ,while the consumed energy decreased from 55.15 to 31.19,from 60.57 to 34.35 and from 66.45 to 37.97 kW.h./fed using elevator digger under mentioned depths and from 41.87 to 23.67, from 45.99 to 26.08 and from 50.45 to 28.82 kW.h./fed using chisel plow under constant soil moisture content of 13%. The decrease in energy requirements by increasing forward speed could be due to the high increase in field capacity compared with the increased in the required power. The decrease in energy requirements by increasing forward speed could be due to the high increase in field capacity compared with the increased in the required power. Fig.(11) shows that, increasing soil moisture content from 9 to 16% and harvesting depth from 22 to 32 cm, increased energy requirements from 29.52 to 41.32 kW.h./fed, from 36.13 to 50.62 kW.h/fed and from 27.45 to 38.436

kW.h/fed, for the agitator digger elevator digger and chisel plow respectively at forward speed of 2.5 km/h.

5- Effect of the Harvesting Machine Operating Parameters on Criterion Cost

Fig.(12) shows that increasing forward speed from 1.3 to 2.5 km/h , decreased criterion cost from 13082.6 to 11673.4, from 7489.8 to 6523.4 and from 1907.1 to 1405.7 L.E/fed at harvesting depths of 22, 27 and 32 cm respectively using agitator digger, also the costs decreased from 14765.4 to 13106.0, from 8484.3 to 7346.4 and from 2214.6 to 1626.5 L.E/fed using elevator digger at the mentioned depths, meanwhile the costs decreased from 19348.3 to 19142.2, from 11919.6 to 11416.4 and from 7424.58 to 6297.64 L.E/fed using chisel plow for the three depths under soil moisture content of 13%. Any further increase in forward speed more than 2.5 up to 3.0 km/h., criterion cost increased under the same previous conditions. The decrease in criterion cost in the speed range from 1.3 to 2.5 km/h was attributed to the increased in field capacity, while the increase in criterion cost by increasing forward speed up to 3.0 km/h is due to the increase in total losses cost. The obtained results in Fig.(13) showed that increasing soil moisture content from 9 to 13%, decreased criterion cost from 12482.6 to 11673.4, from 7372.6 to 6523.3 and from 2314.1 to 1405.7 L.E/fed at harvesting depths of 22, 27 and 32 cm respectively using agitator digger, also the costs decreased from 14058.7 to 13106, from 8345.5 to 7346.4 and from 2695.2 to 1626.5 LE/fed using elevator digger at the mentioned depths, while the costs decreased from2 0291.6 to 19142.2, from 12535.3 to 11416.4 and from 9365.68 to 6297.64 L.E/fed using chisel plow at the three depths of 22,27 and32cm respectively under forward speed of 2.5 km/h. Any further increase in soil moisture content more than 13 up to 16%, criterion cost increased under the mentioned previous conditions.

CONCLUSION

The recommendations of the present work can be summarized as follow:

1. The agitator potato digger followed by elevator potato digger are recommended to be used for harvesting potato because of their higher harvesting efficiency and less of both losses and cost comparing with the chisel plow.
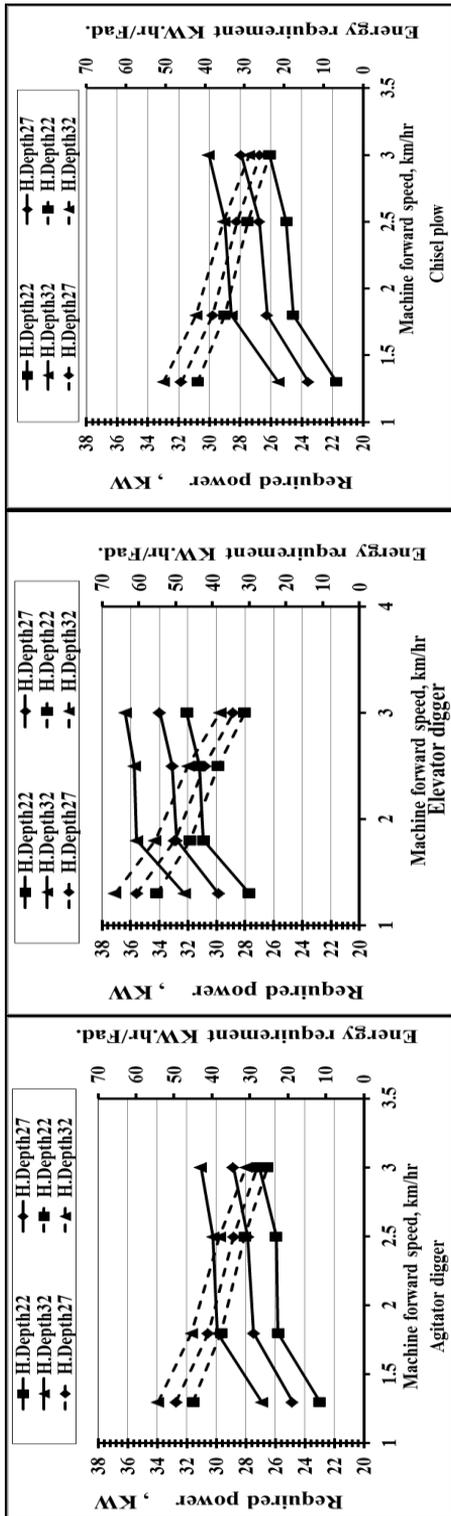
Fig.(10): Effect of harvesting machine forward speed on power and energy requirements under different harvesting depths.
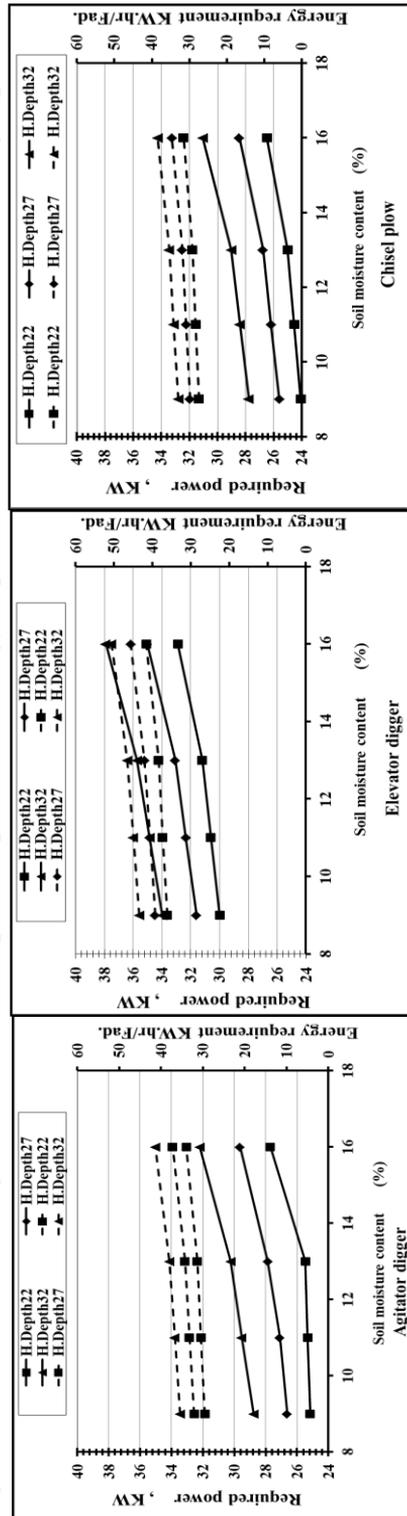

Fig.(11): Effect of soil moisture content on power and energy requirements under different harvesting depths.
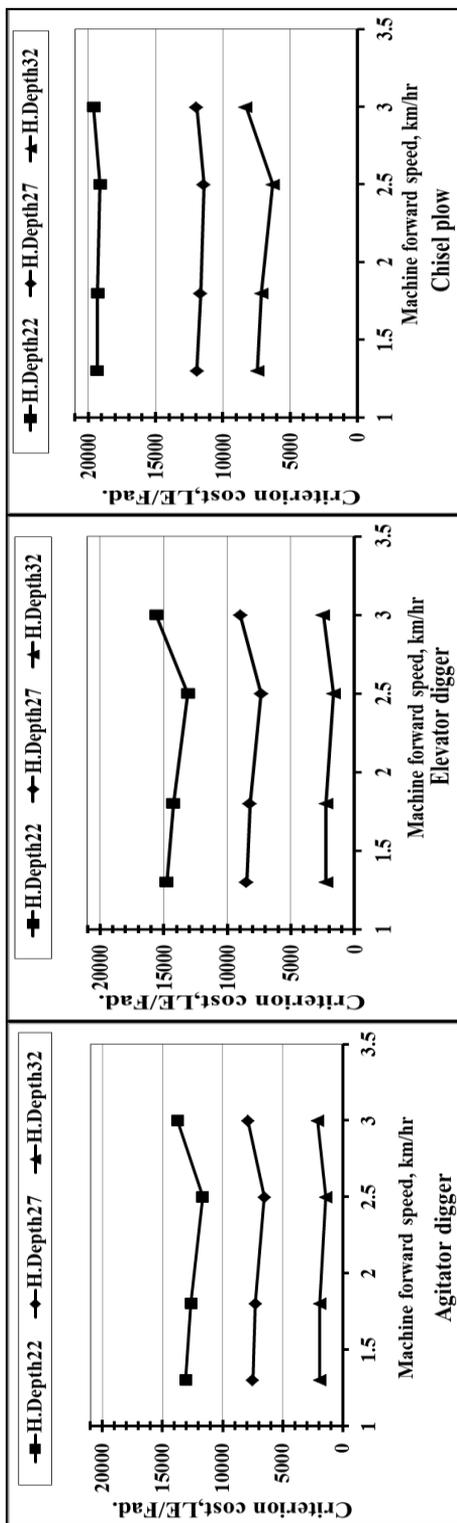
Fig. (12): Effect of harvesting machine forward speed on criterion cost under different harvesting depths
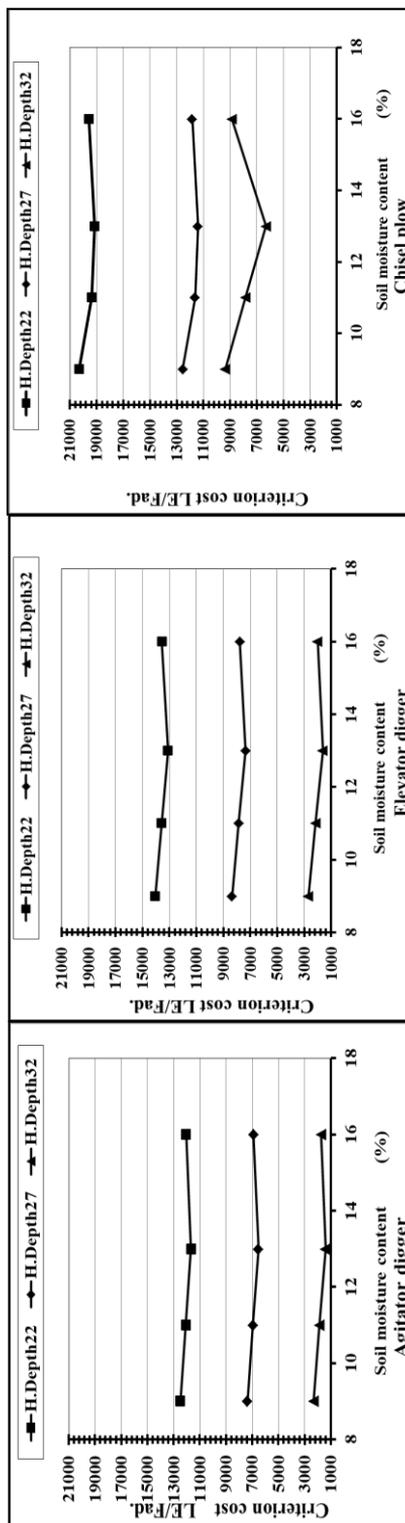
Fig.(13): Effect of soil moisture content on criterion cost under different harvesting depths.

2. The proper operational conditions for operating the potato digger are: forward speed of 2.5 km/h, harvesting depth of 32 cm, and soil moisture content of 13%.

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الملخص العربى

دراسة مقــارنــة بين بعض الآلات المختلفـة لحصــاد البطـــاطس فـى الحيــازات الصغيــرة

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تم إجراء التجربة فى مشروع الشباب بمحافظة الإسماعيلية للمقارنة بين ثلاث أنواع من آلات حصاد البطاطس, الديجر الناقل (آلة حصاد البطاطس ذات الحصيرتين) والديجر الهزاز (آلة حصاد البطاطس ذات الحصيرة الواحدة بثلاث مناسيب ارتفاع) والمحراث الحفار المستخدم فى الحصاد التقليدى للبطاطس, تم إجراء المقارنة تحت ظروف تشغيل مختلفة حيث تم استخدام أربع سرعات أمامية للآلة ١,٣ ، ١,٨ ، ٢,٥ ، ٣ كم/ ساعة وأعماق تقليع مختلفة من الحصاد ٢٢ ،٢٧، ٣٢ سم ونسب رطوبة التربة ٩ ، ١١، ١٣، ١٦% (على أساس جاف)، تم إجراء التجربة على مساحة ١٢ فدان, تم تقييم أداء الآلات المستخدمة آخذاً فى الإعتبار كلا من (السعة الحقلية والكفاءة الحقلية – الفقد والتلف فى الدرنات – كفاءة الحصاد – إستهلاك الوقود والقدرة والطاقة المتطلبة لعملية الحصاد – التكاليف). من النتائج المتحصل عليها يمكن التوصية باستخدام الديجر الهزاز يتبعه الديجر الناقل لإرتفاع كفاءة الحصاد وقلة الفقد والتلف فى الدرنات وكذلك تحقيق تكلفة أقل مقارنة بالمحراث الحفار, ويتم تشغيل الآلة عند سرعة أمامية ٢,٥ كم/الساعة وعمق تقليع ٣٢ سم ونسبة رطوبة التربة ١٣% .

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