A STUDY ON SOME MECHANIZED SYSTEMS TO PRODUCE JERUSALEM ARTICHOKE CROP

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ABSTRACT: The present study is aimed to mechanize planting and harvesting operations for Jerusalem artichoke (Helianthus tuberosus L...) crop to reduce energy requirements and machinery cost. The field experiments were carried out through two agricultural seasons of 2005/2006 and 2006/2007. The planting operation was carried out under two mechanical feeding systems (automatic and semi-automatic),the automatic system was operated at forward speeds of 2.05, 2.89, 3.21 and 3.88km/h.While the semi-automatic system was operated at forward speeds of 1.21, 1.48, 1.85 and 2.27 km/h, and the harvesting operation was carried out under two mechanical methods (potato digger and ridger). Both of potato digger and ridger were operated at different forward speeds of 1.5, 2.04, 2.52 and 3.06km/h, by taking into consideration, the field capacity, required energy, tubers losses, total yield and cost analyses. The experimental results revealed the following points: The planting results showed that the tubers yield increased by 12.32% and 9.48% with automatic at forward speed of 2.05 km/h and semi-automatic at forward speed of 1.21km/h system respectively as compared with manual planting, the automatic system recorded the highest tubers yield of 18.020 Mg/fed at forward speed of 2.05 km/h, energy requirement of 57.23 kW.h/fed and operational cost of 70 L.E/fed. While the semi-automatic system recorded the highest tubers yield of 17.580Mg/fed at forward speed of 1.21km/h, energy requirement of 80 kW.h/fed and the operational cost of 125.26L.E/fed. The harvesting results showed that, the potato digger recorded the highest tubers yield of 18.020 Mg/fed, and lowest value of criterion cost of 2618.97 L.E/fed at forward speed of 2.52km/h. While the ridger recorded the highest tubers yield of 16.320 Mg/fed and lowest value of criterion cost of 4582.89 L.E/fed at forward speed of 2.52km/h.

Key words: Jerusalem artichoke, planting, harvesting, forward speed.

INTRODUCTION

Jerusalem artichoke (*Helianthus tuberosus L...*) is classified in family Asteraceae, tubers are good source of inulin, protein, mineral content and vitamins. Tops and leaves may be used for obtaining ethanol, biogas, gasoline additives and pulp for paper. In Egypt Jerusalem artichoke is planted and harvested manually, mechanization of planting and harvesting had not been studied till now. The cultivated area in Egypt is limited due to some problems facing planting and harvesting operations. Bernacki *et al.* (1972) reported that operational speed of potato planter at manual filling of buckets is very low. It is not above 1.5-1.6 km /h. But in automatic potato planter the operational speed ranges from (3 to 8 km /h. He added that in case the number of planting voids is not excess of 2 percent. Kosaric *et al.* (1984) mentioned that, seed tubers are planted in rows, on the level, in individual small hills or in ridges. The distance of 50 to 60 cm between seed tubers (plants) within rows and 70 to 130 cm between rows, is usually recommended, giving a planting density for maximum yield per area that dose not depress average tuber size through crowding. Misener *et al.* (1984) reported some results concerning that the harvester operation of potato at different forward speeds such as: 1.6, 2.4, and 3.2 km/h. The higher speed being equivalent to the upper limit of most commercial harvesters caused more bruise losses. Maughan and Allam (1986) compared mechanical harvesting of potato with manual methods. They found that the mechanical harvesting reduced the requirements of man h / Mg by 72.7 % Klug-Andersen (1992) found that the weight of seed tubers planted (25 to 200 gm) had only a small effect on plant characteristics and no effect on tuber yield. Ismail and Abou El-Maged (1994) found that the operation cost of potato planting with the automatic planter (Cramer) was 20.7 L.E /fed. Compared with 12.4 L.E / fed for the semi-automatic planter (local). Arsenault *et al.* (1996) showed that labor requirements for planting with the planter were 40 – 60 % less than for hand planting. Vairamov *et al.* (1999) stated that the use of potato harvesting machinery to harvest Jerusalem artichoke is discussed, with special reference to experience in using the Russian Kku-2A and Kpk-2 potato combines, and the Kp-2 digger-loader Details are given of the design and basic specifications of a balloon-type cold-crusher developed in Russia to improve the work when harvesting Jerusalem artichoke.

The present study is aimed to determine energy requirements and machinery cost, that accomplished mechanizing some planting and harvesting operations for Jerusalem artichoke crop.

MATERIALS AND METHODES

Materials

Jerusalem Artichoke Specifications

Jerusalem artichoke (Fuseau variety) having the average dimension; tuber diameter of 5cm; Tuber length of 9cm; Tuber mass of 80g; Stem height of 300cm; Stem number /plant of 3; Stem diameter of 2.2cm; and Rhizomes length of 30 cm.

The Equipment Specifications

The tractors

Two types of tractors were used for planting and harvesting operations. (Massey – Fergson) England with engine of 38 hp (28.348 kW) and PTO 540 r.p.m which was used in the planting operation, while the second was (Roman tractor) with engine of 75 hp (55.147 kW) and PTO speed of 540 r.p.m which was used in the harvesting operation.

The potato planter

A locally one row machine, with a mass: of 300 kg, working width: 80 cm, it can be used as semi-automatic feeding and automatic feeding planter Fig.1

The potato digger

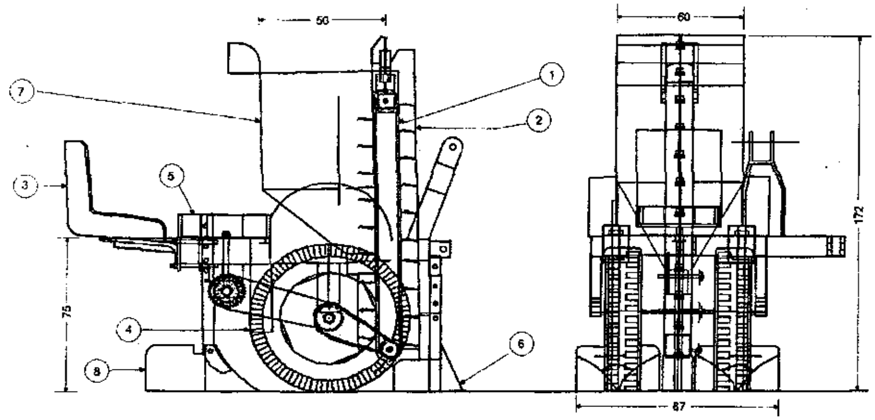
The potato digger consists of the parts given in Fig.2, it has a share width: of 70 cm, one row, number of chains: of 2 and mass: of 400 kg.

The ridger

Locally made, mass: of 150 kg, number of tines: 1 and working width: of 100cm.

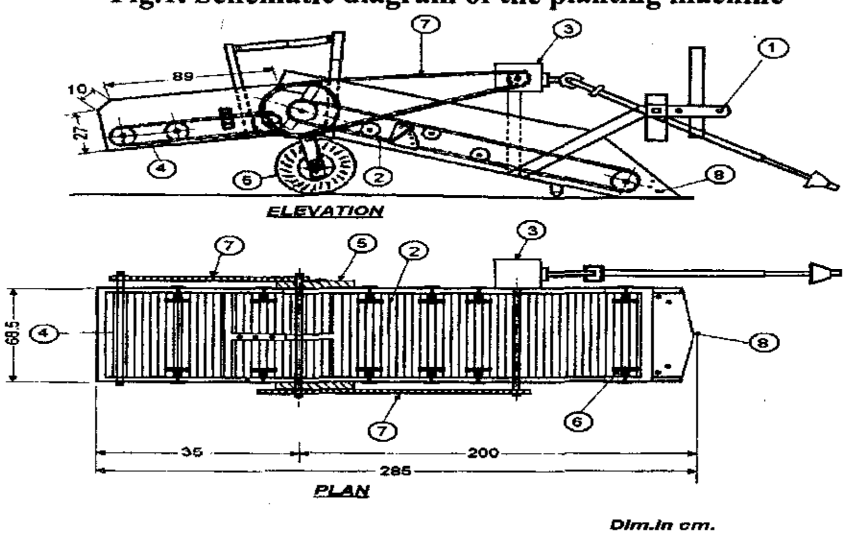
Methods

To mechanize the planting and harvesting operations, the field experiments were carried out through two agricultural seasons of 2005/2006 and 2006/2007 at Abo-Soltan village Abo Hammad Sharkia Governorate, the soil type was sandy loam with moisture content about 16% and 18% for planting and harvesting respectively. The total experimental area was about 1.5 feddan divided into three equal main plots according to the used planting system each main plot was of (72 x 28 m) and it was divided into three subplots, each of (28x24m) according to the used harvesting system.



1-Automatic feeding chain with spoons
2- Planting tube
3-Operator's seat
4- planter wheel
5-Semi automatic feeding tray
6-furrow opener
7-Seed hopper
8-covering ridgers

Fig.1. Schematic diagram of the planting machine



1-Linkage attachment point
3-Gear box
5-Transport wheel
7-Transmission system
2-Front chain
4-Rear chain
6-Roller
8-Digging blade

Fig.2. Elevation and plan of potato digger

The planting systems

The first plot of area (72 x 28 m) was planted by automatic system at four different forward speeds of an average about 2.05, 2.89, 3.21 and 3.88km/h. The second main plot of area (72 x 28 m) was planted by semi-automatic system at four different forward speeds of about 1.21, 1.48, 1.85 and 2.27 km/h. While the third main plot of area (72 x 28 m) was planted manually.

The harvesting systems

The first subplot of area (28 x 24m) was harvested by potato digger. The second subplot of area (28 x 24 m) was harvested by ridger. Both potato digger and ridger were operated at four different forward speeds of about 1.5, 2.04, 2.52 and 3.06km/h. While the third subplot of area (28 x 24 m) was harvested manually.

The Measurements

The Missed hill percentage (M_h)

$$M_h = \frac{N_v}{N_d} X100,\%$$

Where:

N_v= No. of missed hill,

N_d= No. of tubers delivered at adjustment of feeding mechanism

The double tuber percentage (D)

$$D = \frac{M}{N} X100,\%$$

Where:

M= No. of double tubers in 20m length,

N= No. of plant in 20m length.

The theoretical field capacity (Fc_{th})

$$Fc_{th} = \frac{WXV}{4.2}$$

Where:

W= theoretical width, m,

V= travel speed, Km/h.

The actual field capacity (Fc_{act})

$$Fc_{act} = \frac{60}{T_u + T_i}$$

Where:

T_u= utilization time per feddan in minutes,

T_i= summation of lost time per feddan in minutes.

The field efficiency (E_f)

$$E_f = \frac{Fc_{act}}{Fc_{th}} x100,\%$$

The raised tubers (R_t)

$$R_t = \frac{W}{W_T} X100,\%$$

Where:

W= mass of tubers raised on surface, kg,

W_T= mass of total tubers, kg.

Total losses [damaged (D_t) and buried tubers (B_t)]

$$D_t = \frac{M_1}{M_t} X100,\%$$

Where:

M_l= mass of damaged tubers, kg,

W_t= mass of the sample, Kg.

$$B_t = \frac{M}{M_T} X100,\%$$

M= mass of buried tubers, kg,

The harvesting efficiency (η_H)

$$\eta_H = \frac{R_t - D_t}{W_t} X100,\%$$

The power and energy requirements (Embaby, 1985)

$$P = [F.C \frac{1}{3600} X \rho_F X L.C.V X 427 X \eta_{thb} x \eta_m X \frac{1}{75} x \frac{1}{1.36}], kW$$

Where:

F.C= fuel consumption, L/h,

ρ_f = density of fuel (For diesel = 0.85), Kg/L,

L.C.V= calorific value of fuel (10000), Kcal / Kg,

427=thermo-mechanical equivalent, Kg.m/Kcal,

η_{thb} = thermal efficiency of engine ($\approx$ 35%for diesel),

η_m = mechanical efficiency of engine (80% For diesel).

Energy

$$\frac{\text{Power}}{\text{Actual field capacity}}, kW.h/fed$$

The cost of operations (Awady, 1978).

Hourly cost = P/H (1/A + I/2 + T + R) + (0.9W.S.F.) + M /144, L.E /h

Where:

P= price of machine, L.E,

H= yearly working hours, h/year,

A= life expected of machine, year,

I= interest rate /year,

T= taxes, over heads ratio,

R= repairs and maintenance ration,

0.9= factor accounting for lubrication,

W= power, hp,

S=specific fuel consumption ,L/hp.h,

F= fuel price, L.E./L,

M/144= monthly wage ratio, L.E,

The operating cost was determined using the following equation (Awady *et al.,* 1982)

Operating cost/fed =

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

The criterion cost (C)

C = operation cost /fed + product losses cost/fed.

RESULTS AND DISCUSSION

The obtained results will be discussed under the following points:

The Planting Operation

Missed hill percentage

Results in Fig. 3 showed that increasing of forward speed of mechanical planting unit lead to increase the missed hill percentage under two feeding mechanisms. It may be due to increasing of forward speed is followed with an increase in the miss percentage of feeding device. The values of missed hill percentage with automatic feeding were 1.06, 2.23, 3.85and 5.8% at forward speed of 2.05, 2.89, 3.21 and 3.88 km/h respectively. Meanwhile the values of missed hill percentage with semi- automatic feeding were 2.2, 3.1, 5.4 and 8.28 % at forward speed of 1.21, 1.48, 1.85 and 2.27 km/h respectively.

Double tuber percentage

Results in Fig. 4 indicated that, increasing of forward speed of mechanical unit lead to decrease the double tubers percentage under automatic feeding, but in semi-automatic feeding the increasing of forward speed of mechanical unit lead to increase the double tubers percentage this is may be attributed to the increase of forward speed causes an increase in tray speed which leads to the labor cannot adjust only one tuber in each gate of tray.

The values of double tubers percent with automatic feeding were 4.81, 4.50, 3.83and 2.67% at forward speed of 2.05, 2.89, 3.21 and 3.88 km/h respectively. Meanwhile the values of double tubers percentage with semi-automatic feeding were 0.52, 0.91, 1.56 and 2.00 % at forward speed of 1.21, 1.48, 1.85 and 2.27 km/h respectively.

Field capacity and field efficiency

Results in Fig. 5 indicated that, in automatic feeding, the actual field capacity increased from 0.30 to 0.50 fed/h when the forward speed increased from 2.05 to 3.88 km/h. Meanwhile the actual field capacity of semi- automatic feeding increased from 0.18 to 0.285 fed/h when the forward speed increased from 1.21 to 2.27 km/h. The field efficiency of mechanical planting system decreased with increasing the forward speed. This is due to the increasing lost time required for refilling the planter hopper. The maximum value of the field efficiency was 90% was recorded at forward speed of 1.21 km/h for semi- automatic planting system, while the minimum value of the field efficiency was 74% at forward speed of 3.88km/h for automatic planting system. While the field efficiency of the manual planting was 87%.

Power and energy requirements

Results in Fig. 6 revealed that, the power requirement for mechanical planting increased with increasing of forward speed. The values of power requirement with automatic feeding were 17.17, 18.97, 20.55 and 22.49kW at forward speed of 2.05, 2.89, 3.21 and 3.88 km/h respectively. Meanwhile the values of power requirement with semi-automatic feeding were 14.4, 15.24, 16.07 and 17.51 kW at forward speed of 1.21, 1.48, 1.85 and 2.27 km/h respectively.

While energy requirement for mechanical planting system decreased with increasing of the forward speed. The lowest energy value of 45 kW.h/fed was obtained at forward speed of 3.88 km/h by automatic system. This result may be due to increasing the planting speed leads to increasing the fuel consumption rate, L/h and actual field capacity, fed/h. While the energy requirement of the manual planting was 55.22 kW.h/fed.

Tubers yield

The results in Fig. 7 showed that, the tubers yield was highly affected by the forward speed of planting unit under two feeding mechanisms, the increasing of forward speed lead to decrease of tubers yield under the mechanical planting mechanisms, this may be due to increase of missed hill percentage and seed spacing.

The highest values of tubers yield were obtained with automatic feeding mechanism under different levels of forward speed, the values of tubers yield were 18.020, 17.580, 17.250 and 16.800 Mg/fed at forward speeds of 2.05, 2.89, 3.21 and 3.88 km/h respectively, and were 17.564, 17.400, 16.940 and 16.364 Mg/fed with semi-automatic at forward speeds of 1.21, 1.48, 1.85and 2.27 km/h respectively. While the manual planting recorded 16.043 Mg/fed.

Cost of planting operation

Concerning the operational cost, it decreased by increasing forward speed. The maximum value of the operational cost was of 125.26 L.E/fed at forward speed of 1.21 km/h for semi- automatic planting system, while the minimum value of the operational cost was 44.92L.E/fed at forward speed of 3.88km/h for automatic planting system. Fig. 12 represented the operational cost (L.E/fed and L.E/Mg) for planting operation under mechanical planting unit (automatic and semi-automatic feeding). While the operation cost of manual planting recorded 119.9L.E/fed.

Harvesting Operation

Field capacity and field efficiency

Results in Fig. 8 indicated that, depending on the digger the actual field capacity increased from0.26 to 0.40 fed/h when the forward speed increased from 1,5 to 3.06 km/h. Meanwhile the actual field capacity of ridger increased from 0.18 to 0.34 fed/h when the forward speed increased from 1.5 to 3.06 km/h. The highest value of field efficiency was 90% recorded by using digger at forward speed of 1.5 Km/h, meanwhile the lowest value of field efficiency was 75.5% remarked by using ridger at forward speed of 3.06Km / h. This might be revealed to the decrease in required time for harvesting as a result of increasing the speed added to lose turning time per unit area.

Energy requirements

The results in Fig. 9 showed that, the highest power value of 19.11 and 19.25 kW were recorded

at forward speed of 3.06 km/h for potato digger and ridger respectively, while the lowest power values of 14.2 and 14.4kW were recorded at forward speed of 1.5 km/h for digger and ridger respectively. The highest energy value of 77.2 kW.h/fed was recorded at forward speed of 1.5 km/h by ridger, while the lowest energy value of 47.8 kW.h/fed was recorded at forward speed of 3.06 km/h by digger. The increase in required power by increasing forward speed is due to increasing in fuel consumption due to increase in load. While the decrease in energy requirements by increasing forward speed could be due to the high increase in field capacity compared with the increase in the required power.

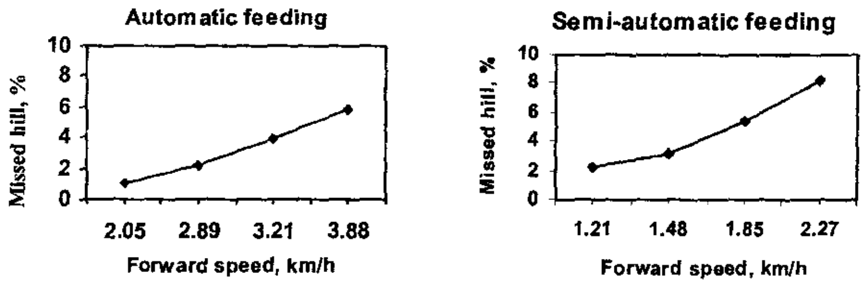


Fig. 3.The effect of forward speed on missed hill percentage

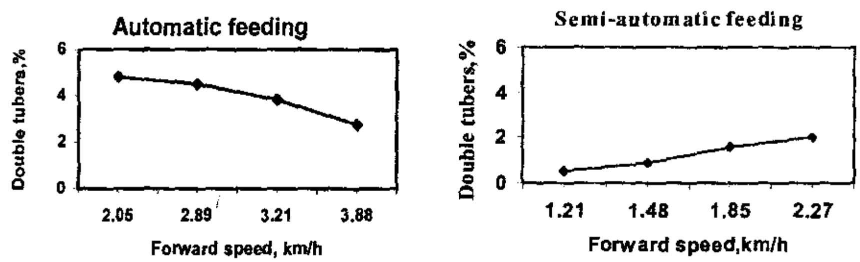


Fig.4.The effect of forward speed on double tuber percentage

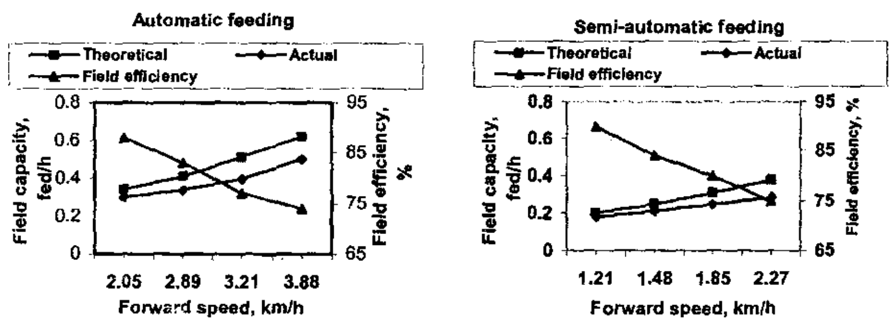


Fig.5.The field capacity and field efficiency of mechanical planting unit

Effect of forward speed on harvesting efficiency under harvesting machines

Results illustrated in Fig. 10 showed that, the increase in harvesting efficiency by increasing forward speed from 1.5 to 2.52 km/h was attributed to the increase in raised Jerusalem artichoke tubers at that range of speeds. While the decrease in harvesting efficiency at speeds from 2.52 to 3.06km/h was attributed to the decrease of the raised Jerusalem artichoke tubers compared with the increase in buried tubers. The highest harvesting efficiency values were 86 and 75.1% at forward speed of 2.52 km/h for potato digger and ridger respectively. The lowest harvesting efficiency values were 83.2 and 72.8% at forward speed of 3.06 km/h under the same previous conditions.

Effect of harvesting methods on Jerusalem artichoke losses and yield

The results illustrated in Fig. 11 showed that, the highest percentage of total losses of 16.8 and 27.2 % were recorded at forward speed of 3.06 km/h under potato digger and ridger respectively, while the lowest percentages of total losses of 14 and 24.9 % were recorded at forward speed of 2.52 km/h for potato digger and ridger respectively. The increase in total losses at high forward speeds is due to the increase in both buried and damaged tubers, while the increasing in damage percent at high forward speed may due to the floating action of the blade and increasing the circulating motion of the soil on the blade as a result and high friction will be expected. The values of damaged tubers with potato digger were 3.1, 3.7, 4.1and4.6% at forward speeds of 1.5, 2.04, 2.52and3.06 km/h respectively, and were5.4, 6.2, 6.5and7.6% with ridger at forward speeds of at the same previous conditions. The values of buried tubers with potato digger were 12.9, 10.8, 9.9and12.2% at forward speeds of 1.5, 2.04, 2.52and3.06 km/h respectively, and were21.4, 19.3, 18.4and19.6% with ridger at forward speeds of at the same previous conditions.While the total losses of manual harvesting was 5.1%, damaged tubers was 2.1% and buried tubers was 3%.

Cost of harvesting operation

Results in Fig. 13 showed that the criterion cost and operation cost decreased by increasing forward speed only to certain extent. The lowest criterion cost values of 2618.97 and 4582.89 L.E/fed were achieved at forward speed of 2.52 km/h for potato digger and ridger respectively. The highest criterion cost values of 3153.04 and 5115.61 L.E/fed were achieved at forward speed of 1.5 km/h for potato digger and ridger respectively. The decrease in criterion cost in the speed range from 1.5 to 2.52 km/h was attributed to the increase in field capacity, while the increase in criterion cost by increasing forward speed up to 3.06 km/h was due to the increase in total losses cost. While the criterion cost of manual harvesting recorded 2990 L.E/fed

Conclusion

The experimental results of mechanized the operations of planting and harvesting recommended the following:

- Operate the automatic system at forward speed of about 2.05 km/h for planting Jerusalem artichoke due the maximum tubers yield comparing with semi- automatic planting and manual planting respectively.
- Operate the potato digger at forward speed of about 2.52 km/h for harvesting Jerusalem artichoke due the maximum tubers yield comparing with ridger and manual harvesting respective.

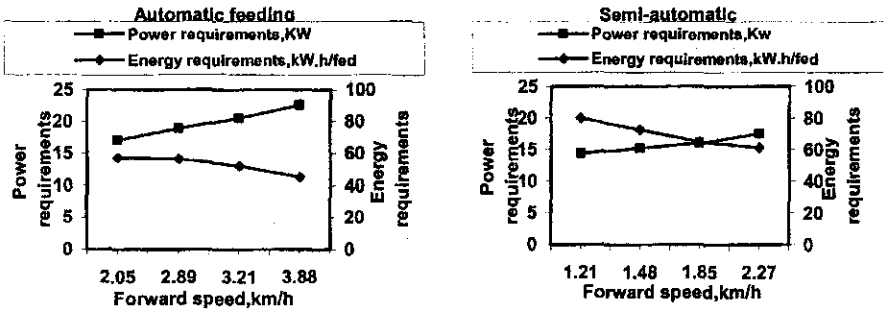


Fig.6. Power and energy requirements of mechanical planting unit

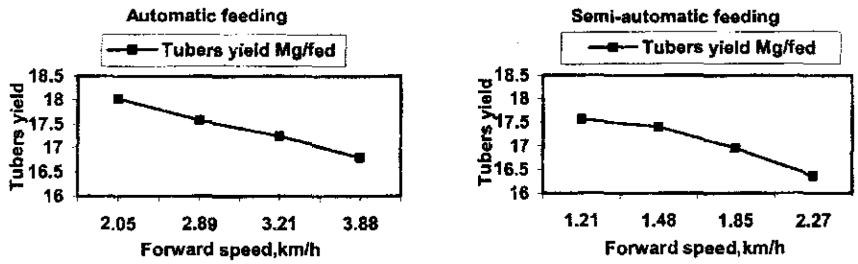


Fig.7.Effect of forward speed on tubers yield of mechanical planting unit

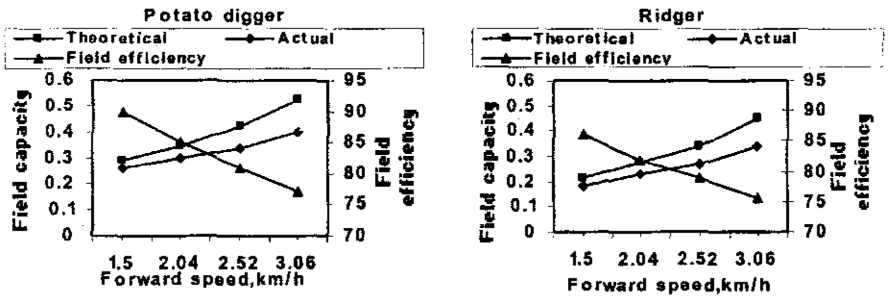


Fig.8. Field capacity and field efficiency of harvesting machines

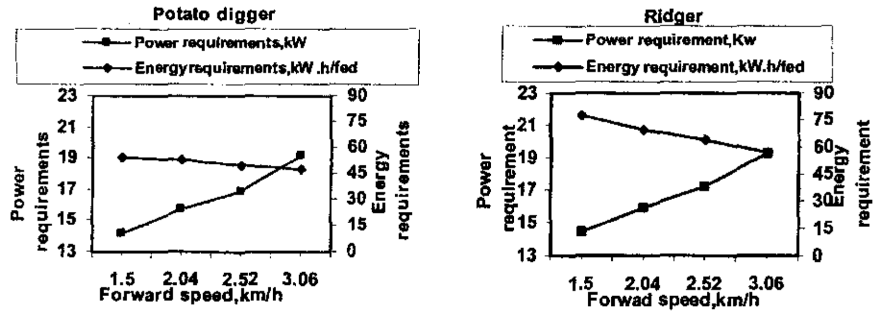


Fig.9. Effect of harvesting machines on power and energy

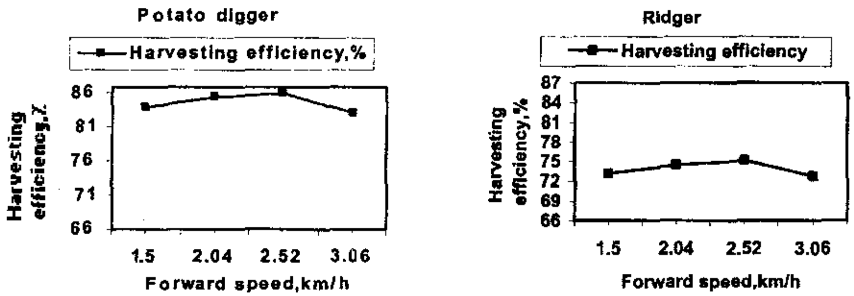


Fig.10. Effect of harvesting machines on harvesting efficiency

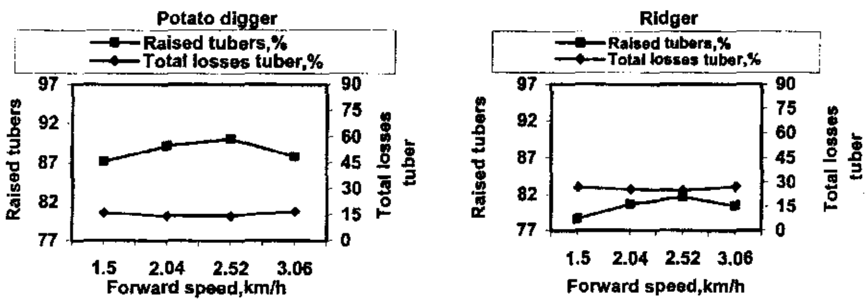


Fig.11. Effect of harvesting machines on raised tubers and total losses percentage

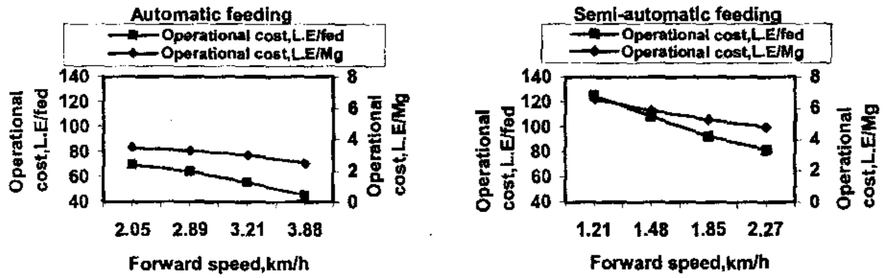


Fig.12. Effect of forward speed on operational cost of mechanical planting unit

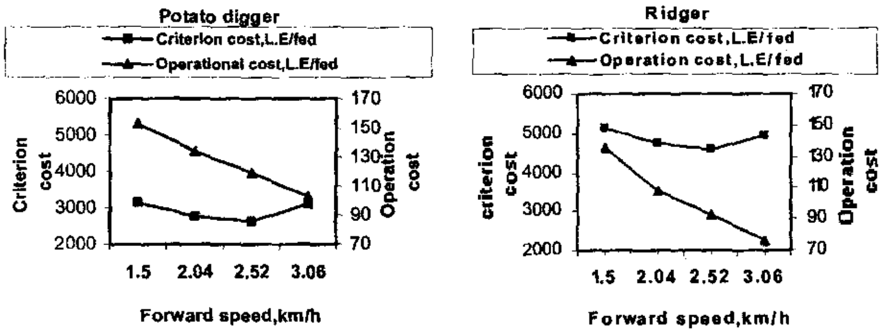


Fig.13. Effect of harvesting machines on the criterion cost and operation cost

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دراسة عن ميكنة بعض النظم لإنتاج محصول الطرطوفة

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أجريت التجارب الحقلية خلال موسمى ٢٠٠٥/ ٢٠٠٦ و ٢٠٠٦/٢٠٠٧ بقرية أبوسلطان مركز أبوحماد بمحافظة الشرقية وذلك لميكنة زراعة وحصاد محصول الطرطوفة صنف (فيوزا). تم إجراء التجارب لميكنة عملية الزراعة خلال موسم ٢٠٠٥/ ٢٠٠٦ بهدف تحديد انسب نظام للزراعة (آلى – نصف آلى) ومقارنته بالنظام اليدوى وذلك عند أربع سرعات أمامية مختلفة أخذا في الاعتبار معدل الأداء واحتياجات الوقود والطاقة المستهلكة والإنتاجية والتكاليف، كما تم إجراء تجارب عملية الحصاد خلال موسم ٢٠٠٦/٢٠٠٧ بهدف تحديد انسب نظام للحصاد (آلة حصاد البطاطس – الخطاط) ومقارنته بالنظام اليدوى وذلك عند أربع سرعات أمامية مختلفة أخذا في الاعتبار فواقد الحصاد وكفاءة الحصاد ومعدل الأداء ومتطلبات القدرة والطاقة المستهلكة والإنتاجية والتكاليف.

وأظهرت النتائج التجريبية ما يأتي من نقاط:

١. بإستخدام الزراعة بنظام التلقيم الآلى كانت أعلى قيمة لإنتاجية المحصول هي ١٨,٠٢٠ ميجاجرام/فدان وذلك على سرعة أمامية حوالي ٢,٠٥ كم/ساعة واحتياجات الطاقة هي ٥٧,٢٣كيلووات.ساعة/فدان و تكاليف التشغيل هي ٧٠ جنية/فدان.

٢. بإستخدام الزراعة بنظام التلقيم النصف آلى كانت أعلى قيمة لإنتاجية المحصول هي ١٧,٥٦٤ميجاجرام/فدان وذلك على سرعة أمامية حوالي ١,٢١ كم/ساعة واحتياجات الطاقة هي ٨٠كيلووات.ساعة/فدان وتكاليف التشغيل هي ١٢٥,٢٦ جنية/ فدان.

٣. بإستخدام الزراعة اليدوية كانت أعلى قيمة لإنتاجية المحصول هي ١٦,٠٤٣ميجاجرام/فدان ساعة واحتياجات الطاقة هي ٥٥,٢٢كيلووات.ساعة/فدان وتكاليف التشغيل هي ١١٩,٩ جنية/ فدان

٤. عند الحصاد باستخدام آلة حصاد البطاطس كانت أعلى قيمة لإنتاجية المحصول هي ١٨,٠٢٠ميجاجرام/فدان وذلك عند سرعة أمامية حوالي ٢,٥٢كم/ساعة واحتياجات الطاقة هي ٤٩,٧كيلووات.ساعة/فدان وتكاليف التشغيل الحدية هي ٢٦١٨,٩٧جنية/فدان.

٥. عند الحصاد باستخدام الخطاط كانت أعلى قيمة لإنتاجية المحصول هي ١٦,٣٢ميجاجرام/فدان وذلك عند سرعة أمامية حوالي ٢,٥٢كم/ساعة واحتياجات الطاقة هي ٦٣,٧كيلووات.ساعة/فدان وتكاليف التشغيل الحدية هي ٤٥٨٢,٨٩جنية/فدان.

٦. يوصى باستخدام آلة الزراعة ذات نظام التلقيم الآلي لزراعة محصول الطرطوفة على سرعة أمامية حوالي ٢,٠٥ كم/ساعة لأنها تحقق اكبر إنتاجيه يليها نظام التلقيم النصف آلي ثم الزراعة اليدوية على التوالى.

٧. يوصى باستخدام آلة حصاد البطاطس لحصاد محصول الطرطوفة على سرعة أمامية حوالي ٢,٥٢ كم/ساعة لأنها تحقق أعلي إنتاجية بأقل تكلفة يليها الخطاط.