Misr J. Ag. Eng., 26(2): 580-596 FARM MACHINERY AND POWER

A STUDY ON MECHANIZING SOME PLANTING AND HARVESTING SYSTEMS FOR JERUSALEM ARTICHOKE CROP

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ABSTRACT

Different mechanized systems were investigated for planting and harvesting of Jerusalem artichoke crop. The mechanized planting operations were accomplished using the automatic and semi-automatic feeding planters, which were tested at four different forward speed levels. While, the mechanized harvesting operations were accomplished using potato digger and ridger machinery. These machines were also tested at four different forward speed levels. Each mechanized system was compared with the traditional manual methods by taking into consideration, the required energy, distribution uniformity of plants, tubers losses, total yield and system cost. The gained results revealed the following : The planting results showed that the tubers yield increased by 19.95% and 13.1% with automatic and semi-automatic system respectively, 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 17.564Mg/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 18.02 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 lowest tubers yield of 16.32 Mg/fed and highest value of criterion cost of 4582.89 L.E/fed at forward speed of 2.52km/h. Results show promises of using the automatic planter to do planting operations, and using the potato digger to

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do harvesting operations. Future research is needed to test the ability of the digger to do different farm operations.

INTRODUCTION

Jerusalem artichoke *(Helianthus tuberosus L...)* is classified in family Asteraceae. The plant originates from North America. It was first cultivated in Egypt in 18th century (1805-1875).Tubers of crop are good source of inulin, protein, having high mineral content especially is rich in iron, calcium, potassium, sodium, phosphor and vitamin B, C and β carotene. Tops and leaves may be used for obtaining ethanol, biogas, gasoline additives, pulp for paper, fiberboard. In Egypt Jerusalem artichoke is planted and harvested manually, mechanization of planting and harvesting had not been applied till now. The cultivated area in Egypt is limited due to some problems facing agriculture produces to deal with plants as the stem arises for 2-3m on the field surface**. Bernacki et al. (1972)** reported that operational speed of potato planter at manual filling of buckets is very low. It must not be above 1.5-1.6 km /h. But in automatic feeding potato planter the operational speed is ranged from (3 to 8 km /h. He added that in case the number of planting voids should not excess of 2 percent. **Kosaric et al. (1984)** mentioned that, tuber seeds are planted in rows, on the level, in individual small hills or in ridges. The proper planting distance is of 50 to 60 cm between seed tubers (plants) within rows, and 70 to 130 cm between rows, These is usually recommended, for 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 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 and manual methods for potato harvesting. They found that the mechanical harvesting reduced the labor requirements of man h / Mg by about 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-Magd (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)** discussed the use of potato harvesting machinery to harvest Jerusalem artichoke is, 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 aimed to select the proper mechanizing systems to perform planting and harvesting operations for Jerusalem artichoke crop. The selection was based on determining the energy requirements, and cost, that accomplished each system, and compared with the traditional manual methods.

MATERIALS AND METHODES

The field experiments were carried out through two agricultural seasons of 2005/2006 and 2006/2007 at Abo-Soltan village- Abo Hammad district Sharkia Governorate.

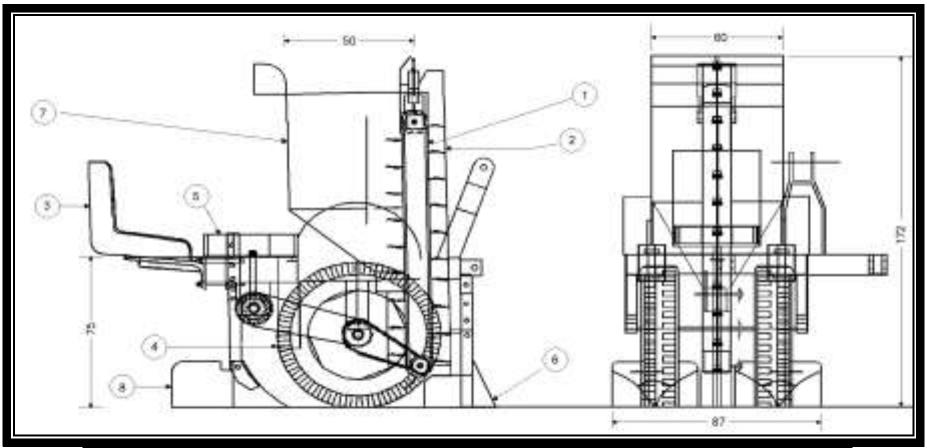
Materials

1-The deduced planting systems

The mechanized planting systems included using the techniques of automatic and semi-automatic feeding potato planters. Whereas, a locally one row machine could be adapted, and used as semi-automatic, and as automatic feeding planter. The mass of that planter was 300 kg, while working width was 80 cm The main components, and dimensions of the used planting machine are sketched and shown in **Fig.(1).**

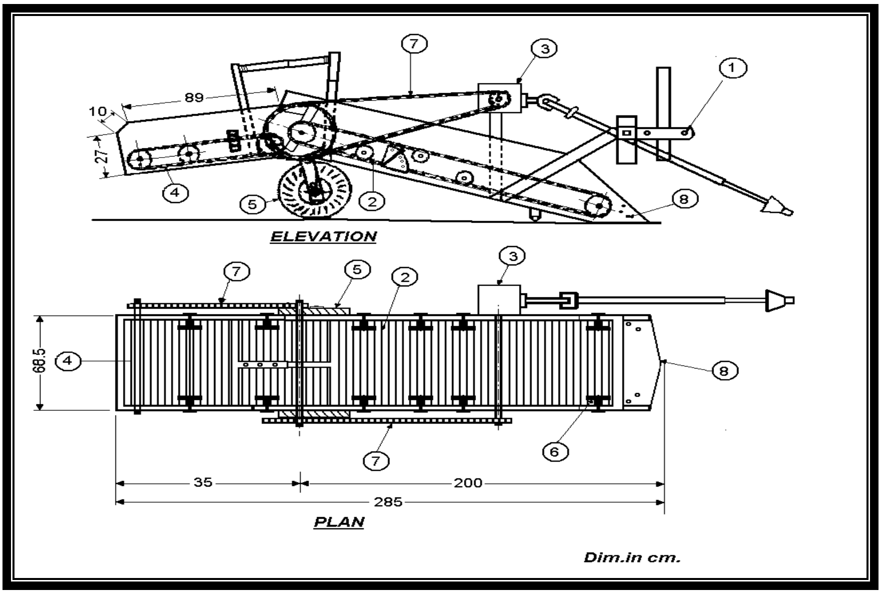
2-The deduced harvesting systems

The investigated mechanized harvesting systems included using a potato digger and a ridger machinery techniques. The used potato digger was one row, and with 2 sequence chains harvester the total mass of that harvester was about 400 kg, while its share width was 70 cm. The main components, and dimensions of the used potato digger are sketched and shown in **Fig.(2).**The used ridger was a single tine. That ridger was locally made with a total mass of about150 kg, working width of 100 cm.



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

Fig.(1): Schematic diagram of the used planting machine



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

Fig.(2). The main components and dimensions of the used potato digger

3-The used Tractors

Two tractors types were used for accomplishing the field experiments of the present study. Whereas, a Massey–Ferguson tractor with an engine of 38 hp (28.35 kW) and PTO speed of 540 r.p.m, was used for accomplishing the planting experiments. While a Roman tractor with an engine of 75 hp (55.15 kW), and PTO speed of 540 r.p.m was used for accomplishing the harvesting operation experiments.

4-Tested crop Variety and specifications

Tested crop variety was (Fuseau variety). The average dimensions of the tubers of crop were: - diameter of 5cm, length of 9cm, and mass of 80 g. While, the main specifications of the stems of crop were:- average stem number /plant=3, average stem height of 300cm, average stem diameter of 2.2cm, and average Rhizomes length of 30 cm

Experimental Procedures

The mechanized planting operations were accomplished using the automatic and semi-automatic feeding planters, which were tested at four different forward speed levels (the automatic system was operated at forward speeds of 2.05, 2.89, 3.21 and 3.88 km/h. While the semi-automatic system was operated at forward speeds of 1.21, 1.48, 1.85 and 2.27 km/h). The mechanized harvesting operations were accomplished using potato digger and ridger machinery. These machines were also tested at four different forward speed levels (Both potato digger and ridger were operated at different forward speeds of 1.5, 2.04, 2.52 and 3.06km/h,). Each mechanized system was compared with the traditional manual methods by taking into consideration, the required energy, uniformity of plants, tubers losses, total yield and system cost.

To perform the different planting and harvesting systems, an experimental area of about 1.5 feddan was divided into three equal main plots according to the used planting system each main plot was of (72 x 28 m) shown in **Fig.(3).** Each main plot was divided into three subplots, each of (28 x 24 m) according to the used harvesting system. The first main plot **(P1)** of was planted using 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 **(P2)** was planted using semi-automatic system at four different forward speeds of an average about 1.21, 1.48, 1.85 and 2.27 km/h. And the third main plot **(P3)** was planted manually.

Automatic planting (P_1)	**Semi-automatic planting (P2)**	**Manual planting(P3)**
P1-H1	**P2-H1**	**P3-H1**
P1-H2	**P2-H2**	**P3-H2**
P1-H3	**P2-H3**	**P3-H3**

Fig.(3). Layout of the experimental treatments on the field plots

In additions, the first subplot was harvested using potato digger **(H1)**. The second subplot **(H2)** was harvested using ridger. And the third subplot **(H3)** was harvested manually. Both potato digger and ridger were investigated at four different forward speeds of an average about 1.5, 2.04, 2.52 and 3.06km/h.

Measurements

To evaluate the different mechanized and manual systems for planting and harvesting of ***Jerusalem artichoke*** crop, the following quantities were measured and estimated.

The actual field capacity and efficiency (Fc_{act})

1-The theoretical field capacity (Fc_{th})

$$Fc_{th} = \frac{w \times v}{4.2}$$

Where:

W= theoretical machine width, m,

V= machine travel speed, Km/h.

2- The actual field capacity (Fcact)

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

Where:

T_u= utilization time per feddan in minutes,

T_i = summation of lost time per feddan, in minutes.

3-The field efficiency (F_{ef} %)

The Field efficiency that corresponding each mechanized system for planting or harvesting operations was calculated as follows

$$F_{ef}\,\% = \frac{Fc_{ac}}{Fc_{th}} \times 100$$

4-The Power and energy requirements

The power consumed by each mechanized system for planting or harvesting operations was calculated using the measured fuel consumption by the used tractor during the operation. The following formula was used to estimate power consumption by the mechanized system according to **Hunt, (1983), and Rangasamy et. al., 1993** as follows:

$$P = \frac{FC}{3600} \times \rho_f \times LCV \times 427 \times \eta_{th} \times \eta_{mec} \times \frac{1}{75} \times \frac{1}{1.36} \ldots\ldots\ldots\ldots\ldots\ldots, KW$$

Where:

FC= fuel consumption, L/h,

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

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

427= thermo-mechanical equivalent, J / Kcal,

η_{th} = thermal efficiency of engine(≈ 35%for diesel engines),

η_{mec} = mechanical efficiency of engine (≈ 80%).

While, the energy required for each mechanized system was estimated using the following equation: -

$$Energy\ requirements\ (kW.h/\ fed.) = \frac{Power\ requirement\ (kW)}{Effective\ \ field\ capacity\,(\,fed/h)}$$

5-The Lifted tubers percent (R_{lf} %):

$$\boldsymbol{R_{lf}}\,(\%) = \frac{\boldsymbol{W_L}}{\boldsymbol{W_T}} \times 100$$

Where:-

W_L= mass of tubers lifted on surface, kg,

W_T= mass of total tubers in row, kg.

6-The tubers losses (Damaged and Buried tubers)

The damaged tubers (Dt %) percentages due to each mechanized harvesting system was estimated using the following equation :-

$$D_t(\%) = \frac{M_1}{W_T} \times 100$$

While, the percent of buried tubers (B_t%) due to eeach mechanized harvesting system was estimated using the following equation :-

$$B_t(\%) = \frac{M}{W_T} \times 100$$

Where:

M_1= mass of damaged tubers, kg,

W_T= mass of the sample, Kg,

M= mass of buried tubers, kg.

7-The Harvesting efficiency (η_H %)

The harvesting efficiency (η_H %) for each mechanized harvesting system was estimated using the following equation :-

$$\eta_H(\%) = \frac{W_L - M_1}{W_T} \times 100$$

Where:

W_L= mass of tubers lifted on surface, kg

M_1= mass of damaged tubers, kg,

W_T= mass of total tubers in row, kg.

8-The operation system cost

The hourly cost for machine operation was determined using the following equation, (**Hunt, (1983**)

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 per Fed was determined using the following equation:-

$$Machinery..operating.\cos t = \frac{hourly.\cos t(LE / Fed)}{machine.actual.field..capcity(Fed / h)}$$

Criterion cost =harvesting operation cost /fed +tubers losses cost/fed + planting operation cost /fed

RESULTS AND DISCUSSION

The obtained results will be discussed under the following headings: For each investigated system, the required energy, distribution uniformity of plants, tubers losses, total yield and system cost were determined and compared. The results revealed the following points:

1. The Planting operation

A. Field capacity and Field efficiency : Results in **Fig. (4)** 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% 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. And the field efficiency of the manual planting was 87%.

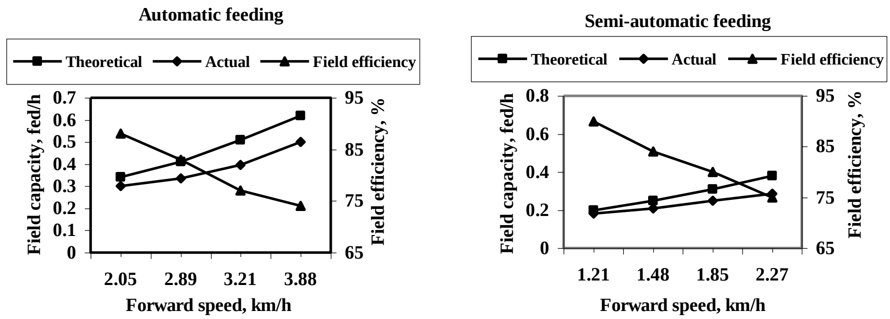


Fig.(4).The field capacity and field efficiency of mechanical planting unit

B. <u>Power and energy requirements :</u>Results in **Fig. (5)** revealed that, the power requirement for mechanical planting increased with increasing of forward speed. The power requirement in semi-automatic recorded the lowest value of 14.40 kW at speed of 1.21 km/h. On the other hand the highest value of the power requirement 22.49 kW recorded with automatic planting at forward speed of 3.88km/h. 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

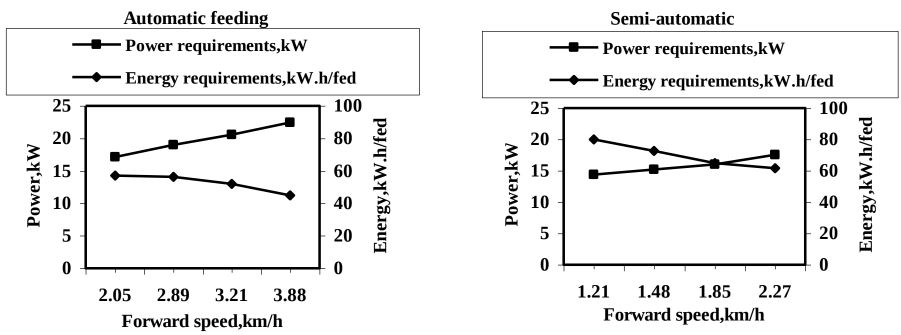


Fig.(5).Power and energy requirements of mechanical planting unit.

C. <u>Tubers Yield :</u> The results in **Fig. (6)** showed that, the tubers yield was highly affected by the forward speed of planting unit, 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 were18.020, 17.580, 17.250 and 16.800Mg/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 16.364Mg/fed with semi-automatic at forward speeds of 1.21, 1.48, 1.85and 2.27 km/h respectively. While the manual planting recorded 17.043 Mg/fed

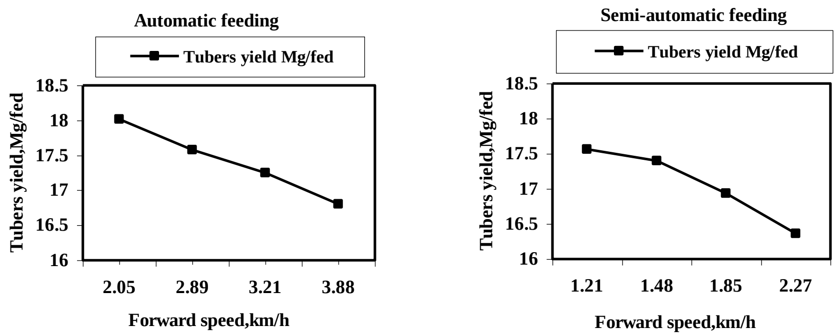


Fig.(6). Effect of forward speed on tubers yield of mechanical planting unit.

<u>2. Harvesting operation</u>

<u>A- Field capacity and field efficiency :</u>Results in **Fig. (7)** 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.

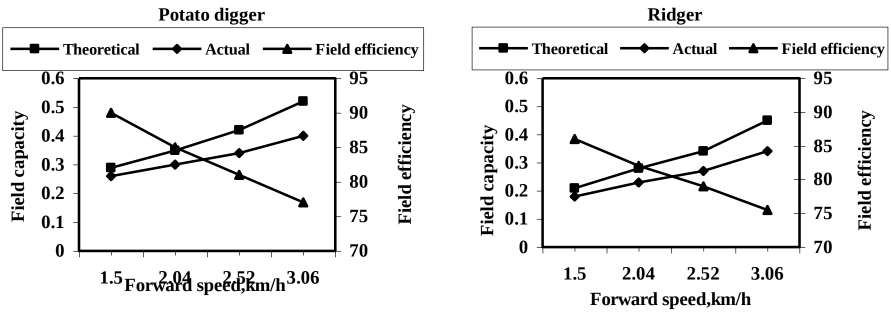


Fig.(7). Field capacity and field efficiency of harvesting machines.

<u>B- Energy requirements</u> : The results in **Fig.(8)** 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 14.4 kW 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.

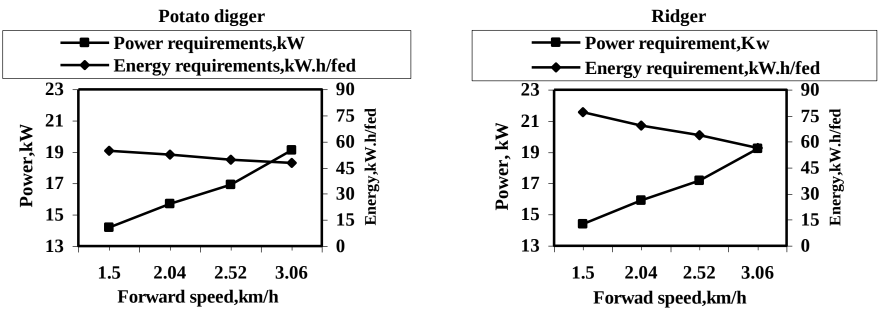


Fig.(8). Effect of harvesting machines on power and energy.

<u>C- Harvesting efficiency</u> : Results illustrated in **Fig.(9)** 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.

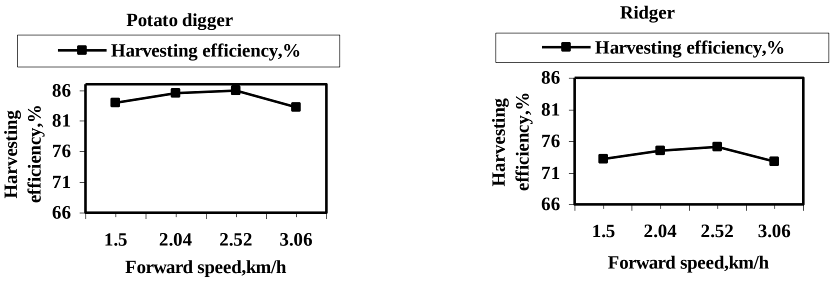


Fig.(9). Effect of harvesting machines on harvesting efficiency.

<u>D- losses and yield</u>

The results illustrated in **Fig.(10)** 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 ratio 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.

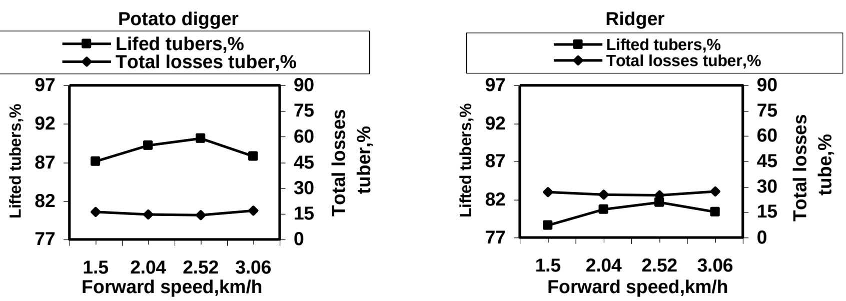


Fig.(10).Effect of harvesting machines on raised tubers and total losses percentage.

3- 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. (11)** represented the operational cost for planting operation under mechanical planting unit (automatic and semi-automatic feeding).

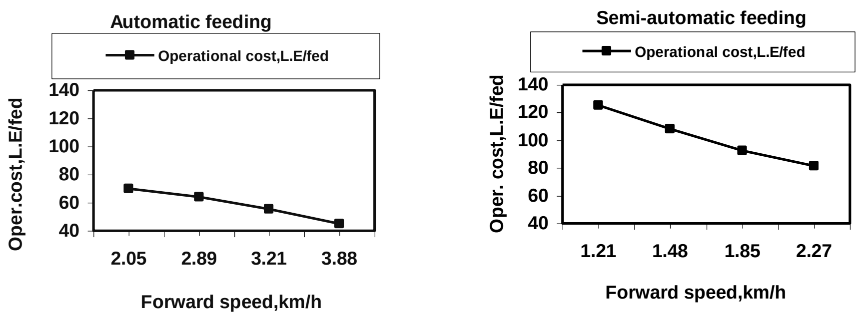


Fig.(11).Effect of forward speed on operational cost of mechanical planting unit.

4- Criterion cost: Results in **Fig. (12)** showed that the criterion cost decreased by increasing forward speed from 1.5 to 2.52 km/h. Any further increase in forward speed up 2.52 km/h increase the criterion cost. The lowest criterion cost values of 2618.97 and 4582.89L.E/fed were achieved at forward speed of 2.52 km/h for potato digger and ridger respectively. The highest criterion cost values of 3223.04 and 5185.61 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 2.52km/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.

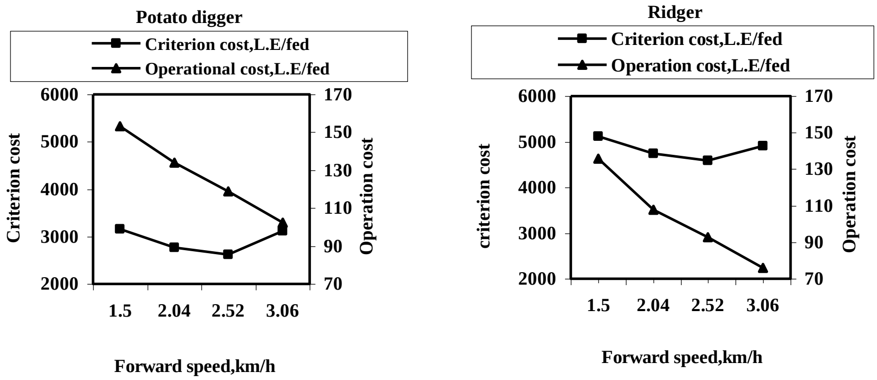


Fig.(12).Effect of harvesting machines on the criterion cost and operation cost.

CONCLUSION

The energy requirements and machinery cost of different mechanized systems, for planting and harvesting of Jerusalem artichoke crop were investigated. The determined data were compared with the traditional manual methods for planting and harvesting that crop, The gained results revealed 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 respectively.

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الملخص العربى

ميكنة بعض النظم لإنتاج محصول الطرطوفة

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أجري هذا البحث بهدف تحديد انسب النظم لميكنة عمليتى الزراعة والحصاد الملائمة محصول الطرطوفة. حيث تضمنت النظم المختبرة لميكنة عملية الزراعة استخدام كل من البلانترات اوتوماتيكية ونصف اوتوماتيكية التغذية بينما تضمنت النظم المختبرة لميكنة عملية الحصاد استخدام كل من آلة حصاد البطاطس ذات الحصيرة الرافعة و الخطاط العادى. وقد أجريت التجارب الحقلية لتتنفيذ النظم المختبرة لعمليتى الزراعة والحصاد خلال موسمى ٢٠٠٥/ ٢٠٠٦

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[٤] طالب دراسات عليا – قسم الهندسة الزراعية - كلية الزراعة – جامعة الزقازيق.

و ٢٠٠٧/٢٠٠٦ بقرية أبو سلطان مركز أبو حماد بمحافظة الشرقية وذلك باستخدام محصول الطرطوفة صنف (فيوزا).

وقد قورنت النظم المختبرة لميكنة عمليتى الزراعة والحصاد وذلك عند تنفيذها على أربع سرعات أمامية مختلفة بالانظمة اليدوية التقليدية .حيث تمت المقارنة للنظم المختبرة لعملية الزراعة على ضوء تحديد كل من انتظام توزيع النباتات ومعدل الأداء واحتياجات الوقود والطاقة المستهلكة والإنتاجية و وتكاليف النظام.، بينما تمت المقارنة للنظم المختبرة لعملية الحصاد على ضوء تحديد كل من فواقد الحصاد وكفاءة الحصاد ومعدل الأداء ومتطلبات القدرة والطاقة المستهلكة والإنتاجية وتكاليف النظام.

و أظهرت النتائج التجريبية ما يأتي من نقاط:

١. بإستخدام آلة للزراعة الزراعة بنظام الاوتوماتيكية التلقيم كانت أعلى قيمة لإنتاجية المحصول هي ١٨,٠٢٠ ميجاجرام/فدان وذلك على سرعة أمامية حوالي ٢,٠٥ كم/ساعة وإحتياجات الطاقة هي ٥٧,٢٣كيلووات.ساعة/فدان و تكاليف التشغيل هي ٧٠جنية/فدان .
٢. بإستحدام آلة للزراعة نصف آلى اوتوماتيكية التلقيم كانت أعلى قيمة لإنتاجية المحصول هي ١٧,٥٦٤ميجاجرام/فدان وذلك على سرعة أمامية حوالي ١,٢١ كم/ساعة وإحتياجات الطاقة هي ٨٠كيلووات.ساعة/فدان وتكاليف التشغيل هي ١٢٥,٢٦ جنية/ فدان.
٣. بإستخدام آلة حصاد البطاطس كانت أعلى قيمة لإنتاجية المحصول هي ١٨,٠٢٠ميجاجرام/فدان وذلك عند سرعة أمامية حوالي ٢,٥٢كم/ساعة وإحتياجات الطاقة هي ٤٩,٧كيلووات.ساعة/فدان وتكاليف التشغيل الحدية هي ٢٦١٨,٩٧ جنية/فدان.
٤. عند الحصاد بإستخدام الخطاط كانت أعلى قيمة لإنتاجية المحصول هي ١٦,٣٢ميجاجرام/فدان وذلك عند سرعة أمامية حوالي ٢,٥٢ كم/ساعة وإحتياجات الطاقة هي ٦٣,٧ كيلووات.ساعة/فدان وتكاليف التشغيل الحدية هي ٤٥٨٢,٨٩ جنية/فدان.
٥. يوصى بأستخدام آلة الزراعة ذات نظام التلقيم الآلي لزراعة محصول الطرطوفة على سرعة امامية حوالي ٢,٠٥ كم/ساعة لأنها تحقق اكبرأنتاجيه يليها نظام التلقيم النصف آلي ثم الزراعة اليدوية على التوالى.
٦. يوصى بأستخدام آلة حصاد البطاطس لحصاد محصول الطرطوفة على سرعه أمامية حوالي ٢,٥٢ كم/ساعة لأنها تحقق أعلي إنتاجية بأقل تكلفة يليها الخطاط.