Development Of Agricultural - Engineering Technologies In The Arab and Islamic World.

The 10th Conference of the Misr Of Ag. Eng., 16-17 October, 2002 : 187-201

FIELD PERFORMANCE AND EVALUATION FOR TOMATO TRANSPLANTING

A. Lotfy, H.A. El-Gendy, and E.M. Arif

ABSTRAT

The aim of this work is to study the energy consumption and cost analysis for tomato transplanting. It is established by using different tractor powers (18.4, 29.4, 47.8, and 58.82 kW) to select the proper tractor power to minimize the energy and cost requirements.

The transplanter performance in terms of seedling losses, transplanting energy requirement, and costs were investigated as a function of change in transplanting speed. The results indicated that: The use of tractor power (18.4 kW) reduced the energy with (35.41, 59.7, and 67.2 %) and cost with (15.75, 35.42, and 47.69 %) of transplanter comparing with other tractors. The average transplanting speed of 1.0 km/h is the optimum for transplanter by using different tractor powers, and the mechanical transplanting was more economical to use for the lowest consumption of the energy 891 MJ/fed, and also to the least seedling losses 7.9%. Subsequently, it increased the production 14.5 ton/fed compared with manual transplanting, which consumed 1840 MJ/fed and gave 20.8 % seedling losses, and yield of 9.78 ton/fed.

INTRODUCTION

Tomato is the first valuable vegetable crop in monetary terms in Egypt. Therefore its planted area is always growing. Its area increased from 331000 feddans with an average production of 7.44 ton/fed in 1980 to 401000 feddans with an average production of 14.67 ton/fed in 1998 *(Agricultural Economic Statistics, 1999)*. The minimizing of the vegetable crops price is necessary to increasing its yield, by improving the techniques of agricultural processes such as planting mechanization. However,

---

* Res. Ag. Eng. Res. Inst.

mechanization becomes a heavy load on the producer to cover the high cost of production and to achieve a reasonable profit. Therefore, the optimization of the consumed energy in tomato transplanting is an important factor to reduce the cost of planting operation. ***Mohamed et al. (2000)*** concluded that the total costs of transplanting tomato with Holand and Lanenn roulette (Semi-automatic transplanters) were less than manual transplanting by 59.1 and 35.5%, respectively. ***Harb et al. (1993)*** compared the mechanical with the manual tomato transplanting by using two different types of transplanting machines. The results indicated that the coefficients of variation on row spacing were 7.13, 26.01 and 35.14% for the disc pocket, disc and manual transplanting respectively. ***EL-Zemeity (1994)*** recommended that depending on transplanting speed of 1.4 km/h leads to the lest parameters of horsepower, the missed hill, damaged hill, unfixed hills and slippage of transplanter. ***EL-Attar (1999)*** found that, the vegetable crops depend on mechanical transplanting the seedlings quickly and efficiencly with minimum labour requirements. ***Saleh (1990)*** reported that there are two common types of transplanting systems presently available to the farmer , which are manual and mechanical transplanting. Hand transplanting is arduous work, slow process and needs consuming more labor than any other operation in vegetable planting. ***Salama et al. (1995)*** found that mechanical transplanting significantly increased fruit weight and number of fruits per plant covered with manual transplanting. ***Younis et al. (1991)*** reported that the fuel requirement for chisel plow, disc harrow, land leveler, seed drill, transplanter and small combine (Yanmar) were 4.47, 3.15, 2.74, 1.22, 3.15 and 5.83 lit /fed respectively. ***Odigboh and Akubuo (1991)*** reported that the field efficiency decreased by increasing forward speed. ***EL-Shazly and Morad (1994)*** found that the shape of field and its dimensions have a high effect on energy consumption and L/W ratio of 2 is considered the best ratio. ***Amin, et al. (1998)*** found that the increases of transplanting speed from 0.5 to 1.25 km/h was accompanied with the increasing in field capacity, human error ,damaged hills, seedling slope angle, and decreased the energy consumed and costs of transplanting operation. The objectives of the present work are:

Evaluate the energy requirements in tomato transplanting - Investigate the effect of the forward speed and tomato seedling space on the machine performance - Select the proper tractor power.

MATERIALS AND METHODS

The experiments were performed at EL-Serw Agric. Res. Station Damietta Governorate (محطة السرو ، محافظة دمياط) in 2000/2001 season in an area about one feddan to evaluate the tractor power and the energy requirements for tomato transplanting. The transplanting machine was pulled by four different tractor powers (Table 1).

Table (1): The specifications of tractors and transplanter machine.

Specification	Tractors			
Manufacture	Byelarus	Egypt	Japan	Japan
Model	MT3-80	DM-34	E-384	L.B-2850
Fuel type	Diesel			
Power, kW	58.82	47.8	29.4	18.4
Total mass, kg	3160	2255	1250	970
No. of labourers	1			
Labour mass ,kg	70			
Total mass, kg	3230	2325	1325	1040

Machine specifications:

The semi-automatic transplanter used in transplanting tomato seedlings (variety: PETO 86) of 60 days age and 15 cm mean height, had the follwing specifications: disc pocket arrangement with spring loading, Holland type model 1700, USA manufacture, with 130 cm length, 245 cm width, 90 cm height, and 150 kg mass + 4 labourers. The machine covered 2 rows and was attached with the tractor by the 3 – point hitch.

Mechanical and chemical analyses of the experimental soil:

Mechanical and chemical analyses of the experimental soil was performed at soil and water laboratory, EL-Serw Agric. Res. Station Damietta Governorate (معمل تحليل الأراضي والمياه ، محطة السرو ، محافظة دمياط) Sand 28.20%, Silt 17.15 %, Clay 54.65 %, Soil pH 7.9, E.C. m-mohes 3.2, Organic matter 1.96 %, available nitrogen 18.33%, available phosphorus 6.65%, and available potassium 250%

Transplanting density:

The transplanter was adjusted by changing the number of gear teeth on drive shaft to transplant the seedlings on three different spacings of 25, 30 , and 35 cm on the row (named d_1, d_2 and d_3) and the transplanter rows were adjusted to give 1 m spacing in between.

Transplanting speed:

Four different forward speeds were in the averages of 0.5, 1, 1.5. 2, 2.5 km/h as used in the experiments.

The consumed energy:

The mathematical model of predicting the consumed energy was modified by *Kassem (1986)*. From this model the energy could be classified and computed by using the following equation:

A- Transplanting energy requirement (E_f)

$$E_f = (C_f/f.c.)\ p\ F_e$$

Where: $F_e = 2.64 X + 3.91 - 0.2 (\sqrt{(788 X + 173)})$, E_f = energy used as fuel ,MJ /fed., C_f = energy input coefficient used to present the energy values of the fuel = 47.2 MJ /L (*Lower et al., 1977*).,
P = power used, kW., F_e = fuel efficiency, L/kW.h., X = load factor = 0.2 to 0.8 for transportation and agricultural operation (*Shaibon, 1985*).

B- Human Labour energy (E_{hL})

$E_{hl} = (C_h/f.c.)\ N$, Where; E_{hl} = human energy ,MJ/ fed.,

C_{hl} = energy input coefficient representing the human labour = 2.3MJ/man.h, (*Pimental et al., 1973*).,

N = number of labourers required to perform any operation.

Machine losses:

The percentage of the damaged, voided, and dropped seedlings were counted after each treatment and calculated by the following equations (*Hossary et al., 1981*):

$M_S = (N_m / N_t) x\ 100$, $D_S = (N_d / N_t)\ x\ 100$, $F_S = (N_f / N_t)\ x\ 100$,

Total losses = $M_S + D_S + F_S$

Where: M_S = voided seedlings %., D_S = damaged seedlings %., F_S = dropped seedlings %., N_m = number of missed seedlings per unit length., N_d = number of damaged seedlings per unit length., N_f = number of droping seedlings per unit length., N_t = theoretical number of seedlings per unit length.,

Transplanting efficiency:

Transplanting efficiency (T_e) for each treatment was determined using the formula: $T_e = (N_t - M_S + D_S + F_S\ X\ 100) / N_t$

Seedling scattering:

A - Longitudinal scattering, the distances between seedling along the row were measured. The longitudinal scattering was determined by the deviation, according to the following equation:

$$\sigma_{n-1} = \sqrt{((\sum X - (\sum X^2 / n)) / (n-1))}$$

Where: σ_{n-1} = standard deviation, cm., X = distances between hills within the row, cm., n = number of observation.

B - Transverse scattering.

The transverse scattering was calculated by measuring the scattering of seedlings around the center line of row by using the same previous equation, with "X" representing lateral spacing.

Transplanting cost:

Cost analysis was performed according to method of (*Kepner et al 1982*) for estimating both fixed and variable costs.

RESULTS AND DISCUSSION

Energy:

Figures (1-A and 1-B) show the relationship between different tractor powers and transplanting forward speed on the energy consumption (MJ/fed).

1- Fuel energy required "E_F":

The results showed negative relation between fuel energy required and forward speed. By increasing the forward speed from 0.5 to 2.5 km/h, the fuel energy required decreased from 4935.65, 4010.95, 2466.99, and 1543.96 MJ/fed. to 1269.17, 1031.40, 634.36, and 397.02 MJ/fed. with using 58.82, 47.8, 29.4, and 18.4 kW tractors power, respectively.

3- Human (Labour) energy "E_L":

Human (Labour) energy "EL" was constant under different tractors because the number of laborers were constant and did not change by the changing of the tractor type. The human energy decreased from 58.08 to 14.94 MJ/fed. by increasing the forward speed from 0.5 to 2.5 km/h. Also the consumed energy for tomato manual transplanting was 1840 MJ/fed, nearly about 1.08, 2.065, 3.59, and 4.185 times larger than the total energy in mechanical transplanting by using 58.82, 47.8, 29.4, and 18.4 kW tractors power, respectively under different forward speeds (from 0.5 to 2.5 km/h).

Losses:

Figure (2) shows the relationship between forward speed and transplanting losses (damage, drop, void, and total), at the different planting spacing distances 25, 30, and 35cm.

1- Damaged seedling losses:

The damaged seedling losses increased by increasing the forward speed. The obtained results indicated that the

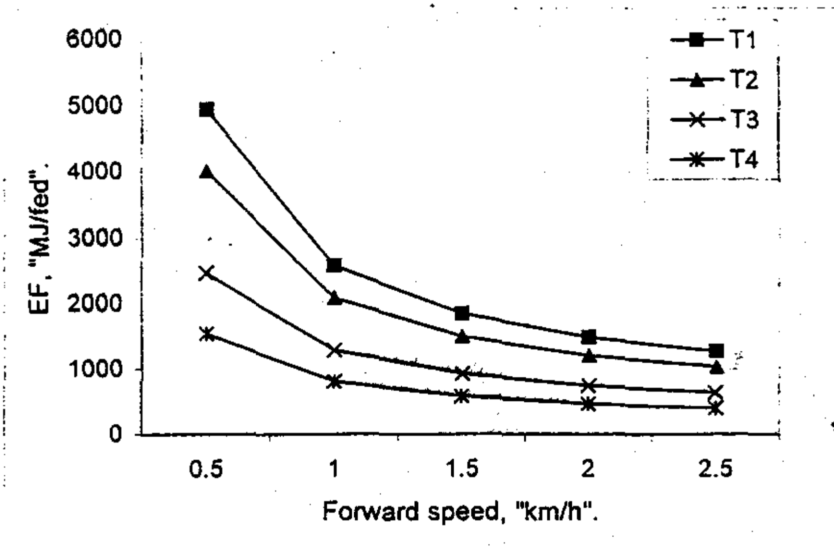

Fig. (1-A): The effect of the forward speed, "km/h" on the fuel energy required, "EF" at different tractor power.

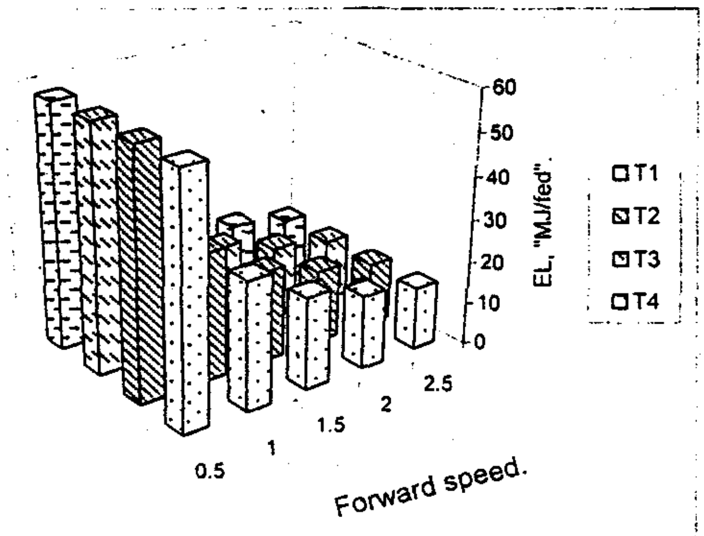

Fig. (1-B): The effect of the forward speed, "km/h" on the labour energy required, EL, "MJ/fed" at different tractor powers.

damaged seedling losses increased from 3.8, 2.8, and 2.2% to 12.5, 9.6, and 5.7% by increasing the forward speed from 0.5 to 2.5 km/h at 25, 30, and 35 cm planting spacing distance, respectively.

2- Dropped seedling losses:

The dropped seedling losses increased by increasing the forward speed. The obtained results indicated that the dropped seedling losses increased from 4.4, 2.7, and 1.9% to 13.2, 10.4, and 8.2% by increasing the forward speed from 0.5 to 2.5 km/h at 25, 30, and 35 cm planting spacing distances, respectively.

3- Void seedling losses:

The void seedling losses increased by increasing the forward speed. The obtained results indicated that the void seedling losses increased from 3.6, 3.5, and 2.9% to 13.7, 9.6, and 8.3% by increasing the forward speed from 0.5 to 2.5 km/h at 25, 30, and 35 cm planting spacing distances, respectively.

4- Total transplanting losses:

For tomato transplanting operation, the total losses increased as the transplanting forward speed increased. The total transplanting losses was low with the lowest forward speed 0.5, and 1km/h than others, and it was low at the 35cm planting spacing distance than others.

The field capacity:

Figure (3) shows that the theoretical (T_{FC}) and actual (A_{FC}) field capacity increased with increasing of transplanter forward speed. So, the lowest value of theoretical and actual field capacities of 0.2 and 0.13 fed/h, was obtained at the lowest transplanter speed of 0.5 km/h. Meanwhile, the highest value of theoretical and actual field capacities of 1.0 and 0.8 fed/h were obtained at the highest transplanter forward speed of 2.5 km/h. That may be due to decreased time required in performing the unit area.

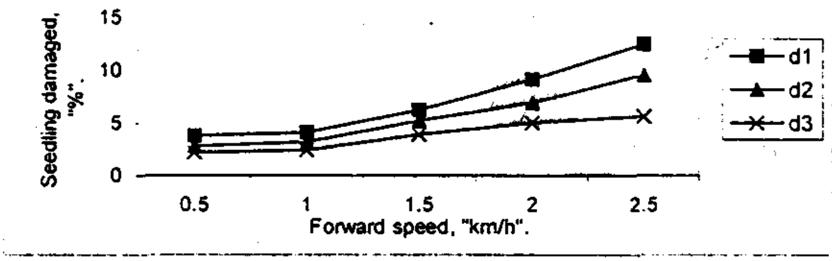

Fig. (2-A): The effect of the forward speed, "km/h" on the seedling damaged, "%" at different planting spacing distances.

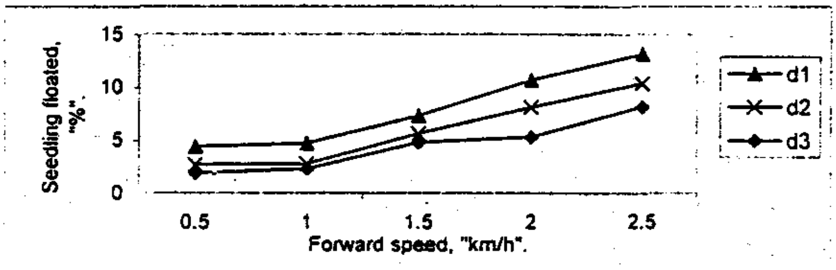

Fig. (2-B): The effect of the forward speed,"km/h" on the seedling floated, "%" at different planting spacing distances.

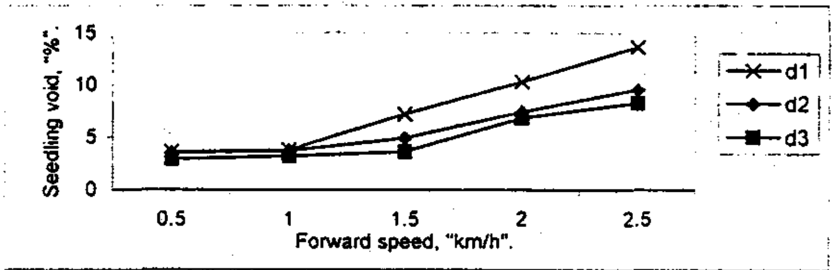

Fig. (2-C): The effect of the forward speed, "km/h" on the seedling void, "%" at different planting spacing distances.

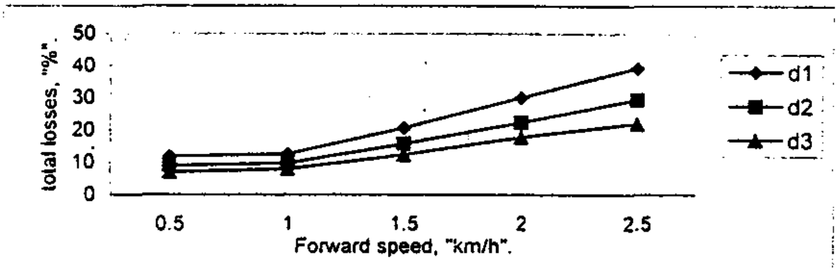

Fig. (2-D): The effect of the forward speed, "km/h" on the total losses, "%" at different planting spacing distances.

Transplanting efficiency:

Figure (4) shows that the highest value of transplanting efficiency of 88.2% was obtained at the 0.5km/h transplanting forward speed with 35cm distance between seedlings. Meanwhile, the lowest transplanting efficiency of 61.0% was recorded at machine forward speed of 2.5 km/h and distance between seedlings of 25 cm.

Generally, the increase of transplanting speed had negative effect on transplanting efficiency. On the other hand, increasing the forward speed tended to decrease the number of seedlings per unit area and increase seedling losses per unit area. This is due to the higher speeds, which were always associated with high angular velocity of transplanting disc, and that is due to decrease the chance of pocket to catch the seedlings, and results in increasing the total losses (damaged, missed and dropped) of seedlings, subsequently decreasing the transplanting efficiency.

Seedlings scattering:

Effect of transplanting speed on both longitudinal and transverse scattering values at 30 cm hills spacing is shown in fig (5). It is illustrated ,that increasing transplanting forward speed from 0.5 to 2.5 km/h tended to increase both longitudinal from 2.1 to 4.6 cm and transverse scattering from 1.4 to 4.2 cm. In general, the distribution uniformity of seedlings over the unit area decreased by increasing both of the longitudinal and the transverse scattering values, resulting due to the increase of transplanting forward speed.

Transplanting cost:

From figure (6) it can be stated that the increase of the mechanical transplanting forward speed from 0.5 to 2.5 km/h decreased the costs of transplanting. And also the transplanting cost decreasing by decrease the tractor power. The lowest value of transplanting cost were 65.35, 34.03, 24.47, 19.67 and 16.82L.E/ fed by using tractor power of 18.4 while highest values of

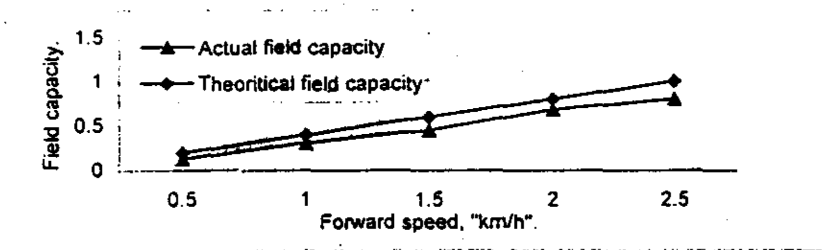

Fig. (3): The effect of the forward speed,on the field capacity, "fed/h"

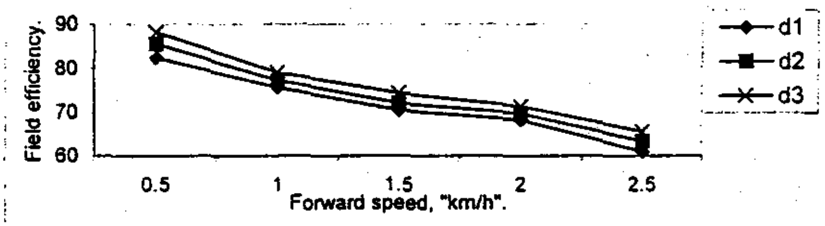

Fig. (4): The effect of the forward speed, on the field efficiency, "%"

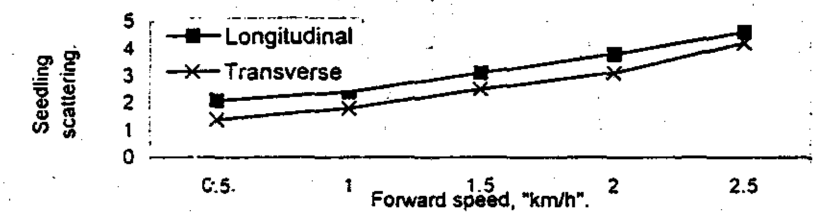

Fig. (5): The effect of the forward speed, on the seedling scattering, "%"

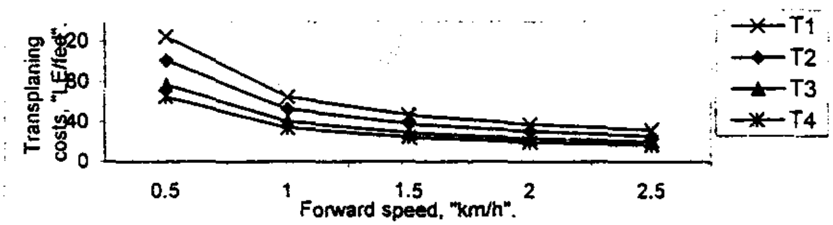

Fig. (6): The effect of the forward speed, on the transplanting costs.

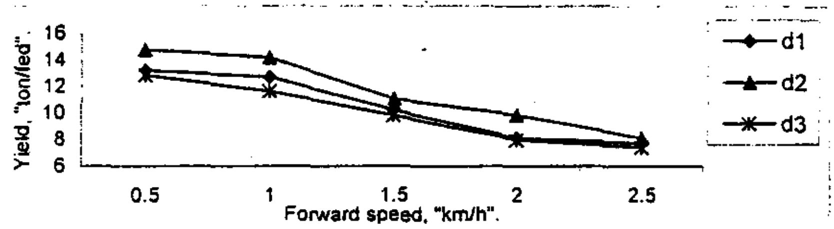

Fig. (7): The effect of the forward speed, "km/h" on the yield, "ton/fed"

- Increase transplanting speed from 0.5 to 2.5 km /h tended to increase field capacity, seedlings losses, and decrease the energy consumption and cost of transplanting operation
- The consumed energy during manual transplanting operation was 1840 MJ /fed nearly about 1.08, 2.065, 2.88, 3.59 and 4.165 times larger than the energy consumed in mechanical transplanting by using small tractor power (18.4 kW) at speed of 0.5 to 2.5 km/h.
- The data showed a little difference in the transplanting efficiency and seedlings uniformity at speeds of 0.5 and 1.0 km /h.

REFERENCES

Agricultural Economics Statistics, 1999, Ag. Econo. Central Administration, Econo. Affairs Sector, Ministry of Ag. And Land Reclamation :450.

Amin, E. E. A. A; Y. M. EL-Hadidi, and K. E. S. Hegazy, (1998).Field performance evaluation for tomato transplanter. Misr.J.Agric.Eng. 15(1)33-46.

EL-Shazly. M. A. (1989).The energy required for producing main crops under Egy. condition .Egypt App. Sci. 4(2)268-281.

EL-Shazly,M.A and M.Morad (1994). Optimizing the energy consumed in harvesting and threshing wheat crop. Miser .J. Agric. Eng. 11(4)1128-1138.

EL-Atter, R. M. M. (1999).Mechanization of transplanting of some different vegetable crops under Egyptian condition. M. Sc Thesis. Faculty of Agric. Zagzig Univ.

EL-Zemaity.H.A(1994).Study on improving and development the transplanters performance under Egyptian condition. Ph.D Sc.Thesis Fac. of Agric. Zagazig Univ.

Harb. S. K.; H. Abdel Mowla, and G. M. Salama (1993). Comparison between mechanical and manual transplanting of tomato. Minia. J. of Agric. Res. and develop(special issue (15):- 361- 375.

Hossary, A. M., M. N. El Awady, A. I. Hashish, and A. El Beheiry (1981). Rice transplanting. Zagazig Univ., Fac. Of Agric., Res. Bul. No. 154, pp: 9 - 15.

transplanting cost were 124.94, 65.07, 46.76, 37.60 and 32.16 L.E/fed when working at 0.5, 1.0, 1.5, and 2.5 km/h transplanting forward speeds, respectively. Also the results indicate that, the use of small tractor power (18.4 kW) reduced transplanting cost by 47.2, 35.42, and 15.75% comparing with other tractors, and reduced transplanting cost by 65.97 % comparing with manual transplanting. Therefore, selecting tractor power is an important factor to reduce transplanting cost.

Tomato production

By increasing the mechanical transplanting speed from 0.5 to 2.5 km/h, the tomato yield decreased from13.24, 14.8, and 12.86 ton/fed. to 7.74, 8.12, and 7.41 ton/fed. by changing the seedling spacing distance from 25. 30 and 35 cm respectively as shown in Fig. (7). The transplanting forward speed of 0.5km/h and seedling distance of 25.0 cm, can be recommended to get the highest yield production of 14.8 ton/fed. While the minimum yield 7.41 ton/fed was found with the transplanting forward speed of 2.5 km/h and seedling distance of 35 cm, comparing with 9.78 ton/fed by using manual transplanting.

Manual transplanting:

The obtained data indicated that the manual transplanting gave field capacity of 0.1 fed /h and transplanting efficiency of 79.2, seedling damage of 2.9 %, void hills of 12.7 % and dropping seedling of 5.2 %, longitudinal scattering of 24.6 % and transverse scattering of 19.2% and operational cost of 100 L.E /fed.

CONCLUSION

This research aimed to optimize the energy for tomato transplanting and improve the performance of transplanter machine. From the obtained data it can be concluded that :

- The use of small tractor power (18.4 kW) saved the transplanting energy consumption with percentage of 67.2, 59.7, and 35.42 % and reduce the transplanting cost with percent of 47.69, 35.42, and 15.75 % comparing with higher tractor power.

Imbabi,A.T(1996).Effect of field dimension on the performance and productivity of the planter Machine for planting sunflower seeds in flat and furrow soil. Misr. Ag. Eng. 13(3) 558-575.

Kassem, A. S(1986).A mathematical model for determining total energy consumption for agricultural system. Misr J. Agric. Eng 3(1) 39-57.

Kepner R. A., R. Bainer and E.L Barger(1982).Principles of farm machinery ,third edition. The AVI Publishing Co. INC. West port. Connecticut, p. 392- 428.

Lower, O. J, E. M. Smith, S. Burgress, L. G. Wells, and D. Bebertins (1977). Production of beef with minimum grain and fossil energy input. Volume 1, 2. and 3 Report to NSF. Oct.

Mohamed, M. A., M. A. Aboamera, and N. A. Srour, (2000). Performance of semi-automatic transplanters in transplanting tomato. Misr J. Ag. Eng., 17 (3) p: 469– 482.

Odigbah, E. U and C. O. Akubuo (1991) A two automatic minisett yam planter. J of Agric.Eng. Res. 50, 189-196.

Pimental. D., B. Hurv, C. Pellotte, H. J. Forfter, I. N. Oks, O. B. Sholel and B.G Withman (1973)Food production and the energy crisis,Sci., vol 1,Nov. p:443-449.

Salama, G. M, A. M. Youssef and S. S. A. Fareg (1995).Tomato plant growth and productivity as affected by method of transplanting vegetable. Res. Section. Hort. Res. Inst. Agric. Res. Center. Cairo Egypt 22 (2)109-115.

Saleh, E. K. (1990).Mechanization of onion planting. M. Sc. Thesis Faculty of Agric. Mansoura Univ.

Shaibon, H. A. (1985).Effect of size and scattering of land holding on costs of mechanized service under Egyptian condition. Misr J. Ag. Eng. 2 (2) 15 -28.

Younis S. M., Shaibon M. A and Zeinel-Din A. M. (1991).Evaluation of eleven tillage treatments used for cultivation of bean, wheat and cotton crop in Egyptian salty soil .Misr J. Agric. Eng. 8(1) 11-26.

الآداء الحقلى وتقييم شتل الطماطم

د. عبد المحسن لطفى* ، د. هانى عبد العزيز الجندى* ، د. الأمين محمد عارف*

أجـرى هذا البحث فى محطة بحوث السرو الزراعية بمحافظة دمياط بهدف تقدير الطاقــة المســتهلكة وحساب التكاليف اللازمة لشتل الطماطم، وذلك باستخدام مجموعة من الجرارات ذات قدرات مختلفة لجر آلة الشتل، وتمت المقارنة على أساس الطاقة الكلية (ميجا جول/ فدان) . كما استهدف البحث محاولة تحسين أداء آلة شتل محاصيل الخضر، وذلك عن طــريق دراســة العوامــل المؤثرة على أدائها مثل سرعة تقدم الآلة حيث تم إستخدم خمسة ســرعات تقدمية ٠,٥ ، ١,٠ ، ١,٥ ، ٢,٠ ، ٢,٥ كم /ساعة، وكذلك استخدام ثلاث مسافات بين النباتات فى الصف وهى ٢٥ ، ٣٠ ، ٣٥سم.

وقد تم تقييم أداء الآلة في:

- حســاب (الطاقــة اللازمــة لعملية الشتل – نسب الفواقد المختلفة – نسب التشتت الطولى والعرضي للالة – السعة والكفاءة الحقلية – كفاءة الشتل – تكاليف التشغيل).

وكانت أهم النتائج المتحصل عليها :

- اسـتخدام الجــرار المــنخفض القدرة (١٨,٤كيلو وات) لجر آلة شتل الخضر يوفر الطاقة المســتهلكة بنســب ٦٧,٢ ، ٥٩,٧ ، ٣٥,٤١ % مقارنة بالجرارات ٥٨,٨٢- ٤٧,٨-٢٩,٤ كيلو وات .كما أن الطاقة المستهلكة في الشتل اليدوى تعادل ١,٠٨-٢,٠٦٥-٢,٨٨-٣,٥٩-٤,١٨٥ مرة قدر القدرة باستخدام نفس الجرار.
- اســتخدام الجــرار المنخفض القدرة (١٨,٤كيلو وات) يوفر تكاليف الشتل بنسب ٤٧,٢-٣٥,٤٢-١٥,٧٥ %مقارنــة بالجرارات الأكبر قدرة (٥٨,٨٢- ٤٧,٨-٢٩,٤ كيلو وات) كما أنها تنخفض بمعدل ٦٥,٩٧%مقارنة بالشتل اليدوى.
- بيــنت نــتائج الــتجارب أن أقــل نسبة للشتلات التالفة ٣,٨% والشتلات الغائبة ٣,٦% والشتلات الواقعة ٤,٤% .كذلك أقل نسبة للتشتت الطولى ٢,١سم والتشتت العرضــى ١,٦ ســم وأعــلي نســبة لكفاءة الشتل ٨٨,٢% لوحظت عند السرعة الأمامية للشتل ٠,٥ كم/ساعة حيث كانت المسافة بين الشتلات ٣٥سم .
- بــزيادة السرعة الأمامية لآلة الشتل يزداد كلا من التشتت الطولى والعرضــى للنباتات وكذلك نســبة النباتات التالفة والغائبة والواقعة والسعة الحقلية للألة، بينما يقل كل من الكفاءة الحقلية والطاقة المستهلكة والإنتاجية والتكاليف.

توصــى الدراســة باستخدام الجرار المنخفض القدرة (١٨,٤ كيلو وات) لجر آلة شتل الخضــر عند سرعة أمامية فى حدود (٠,٥-١,٠ كم /ساعة)، ومسافة بين الشتلات ٣٠سم، حيث يؤدى هذا إلى زيادة الإنتاج و تقليل الطاقة المستهلكة، وبالتالي تقليل تكاليف الإنتاج .

---

* باحث بمعهد بحوث الهندسة الزراعية.