MANUFACTURE OF A NEW MACHINE FOR TRANSPLANTING SUGAR CANE CROP

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Abstract

Sugar cane is a labor intensive crop, where the most of the cane operations are carried out manually and the use of machinery is limited only for land preparation. The present study aims to manufacture a new prototype machine for transplanting sugar cane crop. Electronic circuit and servo motor control the movement and orientation of carriage belt of transplanting, whenever the infrared rays control the movement of seedling and determine their positions of transplanting tray. Timeliness of opening and closing has been adjusted by precisely by electronic air valves.

The experimental work was carried out at Etay Elbaroud Agricultural Research Station, Behera Governorate. Performance of the machine was evaluated under four forward speeds (0.6, 0.9, 1.2and 1.5 km/h) and three seedling spaces (27, 37and 47 cm). The results indicated evaluated that the highest value of longitudinal scattering and transverse scattering were 4.1 and 3.7 cm at forward speed of 1.5 km/h. While the highest value of energy consumption and transplanting efficiency were 26.49 kW.h/fed and 94.1% at forward speed of 0.6 km/h. On the other hand, missing, floating and dead seedlings increased as forward speed and seedlings spacing increased. The highest values of missing, floating and dead seedlings were 3.8, 3.5 and 3.7% at forward speed of 1.5 km/h and at seedling space 47 cm.

Keywords: Electronic valve, sensor, efficiency, energy, seedlings and scattering.

INTRODUCTION

Sugar cane, *Saccharum officinarum L.*, is considered the main source for sugar production in Egypt and in an over the world. In Egypt sugar cane is planted in the Upper Egyptian for two seasons namely autumn and spring. Sugar cane productivity in Egypt comes at the fore in the world. The Productivity of sugarcane was reached to about 50.4 tons/fed on the basis of the growth season (12 months). The cultivated area of sugarcane in season 2012 was about 330000 Fed. (Agricultural Statistics 2012). Egypt ranks fourth in terms of sugar consumption per capita by 34 kg annually, after Brazil, the European Union and the United States.

Since planting of sugarcane is done by vegetatively propagation (cane setts), there are many obstacles facing the planting process. The long interval between planting and emergence, the slow seedling growth, the wider row spacing, liberal fertilizer applications during planting and frequent irrigation during the early crop season are the main factors which upholding weed growth between the sugarcane rows. Sugar cane takes about 6-8 weeks to complete its sprouting and further 80-90 days its phase after planting (Malavla, *et. al.* 1991).

The yields of sugarcane could be increased considerably if optimum number of millable cane per area could be ensured with the existing cane varieties. This can be achieved by maintaining a uniform plant population per unit area. The potential millable cane per unit area can be obtained by using spaced transplanting technique (Imam *et. al.,* 1982 and Rahman *et. al.,* 2003).

In tropical and eastern counties, transplanting plant material in seedling stage is a common agricultural practice. Transplanting which implies the proper spacing of plants has become an acceptable practice in many agricultural enterprises (Rahman *et. al.,* 2003).

Settling transplanted cane reduced 33% (fresh weight) and 34% (dry weight), and 43% (fresh weight) and 42% (dry weight) of weed at weeding and at the harvesting time, respectively, compared with sett planted cane. Tiller, millable cane and stalk length were reduced by 24%, 36% and 45%, respectively in sett planted cane compared with settling transplanted cane. The settling transplanted cane increased the total stalk dry weight, the total shoot dry weight and the yield of cane by 79%, 69% and 85%, respectively over sett planted cane (Yukio *et. al.,* 1994).

Sugar cane is a labour intensive crop, which requires about 250 to 400 labour mandays per hectare. Most of the cane operations are carried out manually and the use of machinery is limited only for field preparation. The human labor cost constitutes more than 50% for labor intensive sugarcane crop.

Due to the scarcity of labourers, there is an urgent need to mechanically transplant sugarcane seedlings. After 4 years testing, evaluating and modifying the RT-2 vegetable transplanter (Lannen Company, Finland) was considered suitable for sugarcane seedling transplanting. Compared with manual transplanting, the mechanical transplanting of seedlings saves about 50% in labour costs (Wang and change, 1998).

Morad *et. al.* (2010) studied the effect of forward speed on longitudinal and transverse dispersion under two spacing rows. They found that, increasing forward speed from 2.5 to 3.88 km/h, increased longitudinal dispersion from 2.47 to 2.88 cm and from 2.66 to 3 cm for 20 and 30cm spaces between plants, respectively. Also, transverse dispersion increased from 8 to12.12 cm and from 9.46 to 12.37 cm under the same previous conditions. El-Sheikha (1989) mentioned that, there are three common types of transplanting systems; conventional hand transplanting, manual feeding (transporting mechanism with disc types or dick with grabs) and power feeding. Conventional hand transplanting is slow and costly. Also, power-transplanting machines are expensive for small Egyptian farmers.

Drees (2005) stated that the optimum conditions for the mechanical transplanting were 1.25 km/h forward speed, spacing seedlings of 30 cm and seedlings age of 60 days. Genaidy (2008) evaluated the performance of small cotton transplanter, which consisted of disc, pocket arrangement with spring holders. Results indicated that the highest value of both theoretical and actual field capacities were 0.256 and 0.165 fed/h at forward speed of 1.5 km/h. Where in، the highest values of field efficiency and transplanting efficiency were 83%, and 94.3%, respectively at energy requirement of 76.8 kW.h/fed.

Chaney *et. al.* (1986) developed an automatic control system for a sugarcane planter. A planter was equipped with an automatic control system for cane feed to eliminate the need for an operator to ride on the planter. Three sensing methods were tested: sensing pressure in the hydraulic line to the drum motor, sensing the mass of cane falling onto a flap in the discharge area and a photocell to count the rate of stalks falling from the planter. Each of these sensing systems controlled the table feed and could also control the speed of the drum. Varying the drum speed proved to be unnecessary. The pressure sensing system was the most effective, since it gave uniformity comparable with that obtained with an experienced operator and manual control.

Ramanand *et. al.* (2007) indicated that, effect of transplanting spacing on growth and yield of tissue culture raised crop of sugarcane. The effects of spacing on the growth and yield of micro propagated plants of sugarcane (cv. CoS 99259) were studied in Shahjahanpur, Uttar Pradesh, India, during 2006-07. Tissue-cultured plantlets were transplanted at a spacing of 90x45, 90x60, 90x90 and 120x60 cm. Results indicated that, plant growth, number of tillers, number of millable canes, cane height and cane yield were greatest under a spacing of 90x60 cm. Thus, this spacing was the most suitable for transplanting tissue-cultured plantlets of sugarcane.

The literature survey indicated the remarkable reduction of crop yield for competition between weeds and crops at early stage of growth. Settling transplanting system may be one of the ways to reduce the competition between weed and sugarcane at early stage of growth.

Mechanization of planting sugarcane is facing a big challenge, since there is no transplanting machine currently available in the market. In addition there is a lack of information about sugarcane mechanization in Egypt.

From the foregoing, i) It must find a way suitable for transplanting sugarcane in order to reduce the amount of used sugarcane setts. ii) Provide a large amount of water used in irrigation and process during the germination period in the nursery (4-5 irrigations). iii) Provide an occupancy time for sustainable land up to two and a half months added to the previous crop or for good service.

Therefore this investigation aims at design, manufacture and evaluate the performance of new developed machine to suit transplanting sugarcane crop, based on electronic system controls.

MATERIALS AND METHODS

Infield experimental site:

The experiments were carried out in the premises of Etay Elbaroud Agricultural Research Station, Behera Governorate during agriculture season of 2013. The cane variety of C9 is used

New transplanting prototype.

The new prototype of transplanting machine was fabricated locally at the workshop of Rice Mechanization Center, Kafr El-Sheikh Governorate. The main idea is the electronic circuit and servo motor control the movement and orientation of carriage belt of transplanting, whenever the infrared rays control the movement of seedling and determine their positions of transplanting tray. Timeliness of opening and closing has been adjusted by precisely by electronic air valves. The feature of the new fabricated machine is that it has a simple mechanism which can meet the Egyptian farmers' requirements.

Power source:

Kubota motor model 6206 is used as the power source. Technical specifications presented in Table 1.

Table 1.The technical specifications of power source.

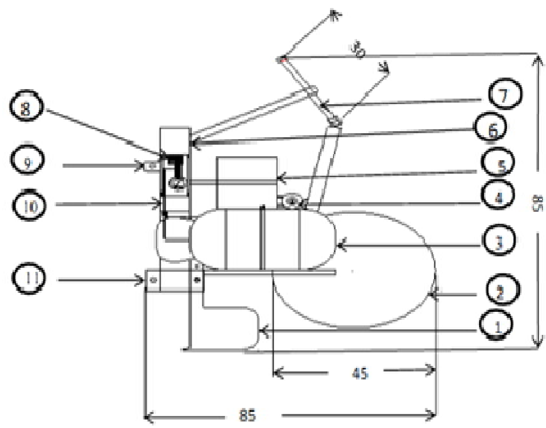
Items	Specification
Type	Kubota model 6206
Made	Japan
Type of drive	2 W.D.
Engine	Otto
Fuel	Gasoline
Number of cylinder	1
Engine power at 2500 rpm	6 hp (4.41 kW)
Cooling system	Air

Developed transplanting unit:

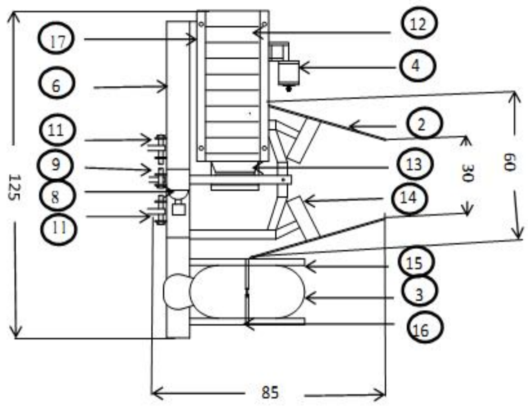
The general specifications of the transplanting unit are main overall dimensions of 1250 mm length, 850 mm width, 850 mm height and 60 kg overall mass. Feeding the seedlings were done using a conveyor belt operated by servo motor which controls its speed, starting and stopping positions. Compressed air through electronic valves can open and close the transplanting box in the exact timing accurately

In case of orienting the seedlings from nursery to the main field, the developed transplanting unit needs two labourers to fulfill the required work. One labourer to steering the transplanter while the other one will feed the seedlings to the conveyer belt. The sketched plan and side views of transplanting unit are shown in Figs. (1 and 2) show side and plan viewer of conveyor belt. The main components of the transplanting unit are depicted in Fig. 3.

No.	**Part name**
1	Furrow opener
2	Covering disks
3	Air tank
4	Servo control motor
5	Armrest seedlings
6	Frame
7	Helix to control the depth of covering disks
8	Compressor
9	The high hitch link
10	Hoses connect the air
11	The bottom hitch link
12	Seedling belt
13	Seedling box
14	Ball bearing for covering disks
15, 16	Carrier air tank
17	Installing screws to the belt



s. view



Plan

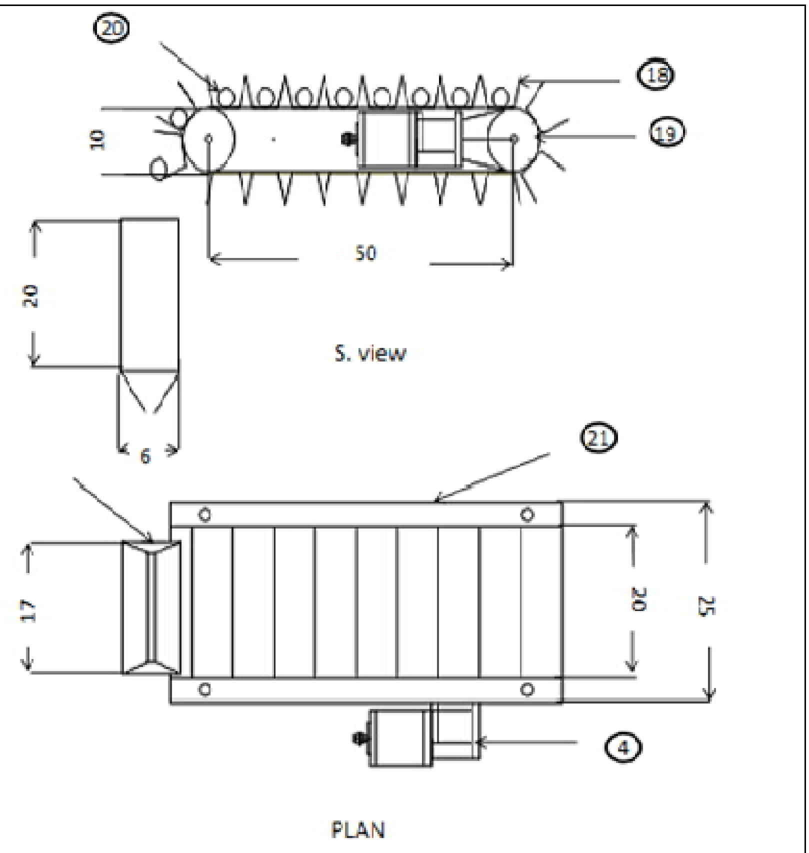
Dimension in cm

Fig.1. The schematic plan and side views of the transplanting unit.

Feeding unit:-

The feeding unit is consisted of leatherette flat belt of 120 cm length, 20 cm width and 0.5 cm thickness. The belt is mounting on two drums each drum has 10 cm diameter, 20 cm length and supported with ball bearing of 20 mm diameter. The central distance between the two drums is 50 cm. To ensure regular feeding of seedlings, there are 20 conical cans made from aluminum and fixed on the conveyer belt. These pockets have been formed in U shape (20 cm length, 5 cm height, 3 cm at the bottom and 5 cm at the top) and used to transfer the seedlings that feed by labour to the seedling drop box. A servo motor is used to operate an electronic system to control the conveyer belt speed and its positions. Infrared is used to control the movement of seedlings from the conveyer and determine their positions until they reach the transplanting box. In order to drop the seedlings in exact time, the transplanting box is opened and closed accurately using compressed air through electronic valves

No	**Part name**
4	Servo control motor
18	Aluminum box
19	Gear
20	seedling
21	Frame belt
19	Gear



Dimension in cm

Fig.2. Side and plan views of conveyor belt of transplanting unit.

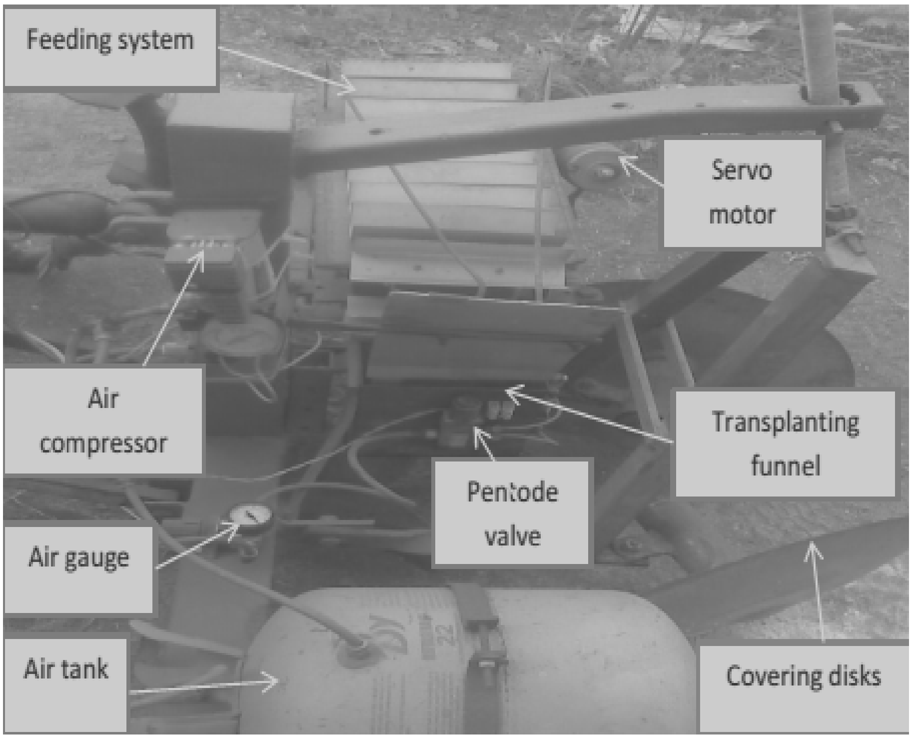


Fig. 3. The main components of the developed transplanting unit.

Chisel furrow-opener.

The developed transplanting unit is equipped with chose furrow-opener has 300 mm cutting width and 150 mm height. The furrow opener has the flexibility to move in vertical direction in order to select the proper depth that required for transplanting.

Covering device.

The covering device consists of two steel disks (Fig. 3). Each covering disk has concave shape with 45 cm diameter and 3 mm thickness. The covering device is attached to the main frame of transplanter using rectangular steel beam of 5 x 2 cm.

Electronic cycle:

The wheel diameter of the developed machine is 60 cm, hence the wheel circumference is 188.4 cm. For the developed machine, initially during the rotation of the ground wheel, the aperture distance that exists on the disc comes in front of toothed circular motion detector (Infrared sensor for measuring distance), which gives the motor ordered to operate. The order comes in the form of electric pulse equal to 12 volts and its time ranged from 1/1000 s to infinity. Thereafter the seedling carrier (aluminum can) comes in front of the positioning bulb (reception). Hence, the light reflected to the receiver, which recognizes the frequency immediately and sends a signal to stop the engine within 1/1000 s. When the engine stopped, it takes about

0.15 - 0.2 s, and then released a signal from the electronic unit which is responsible for opening the transplanting can (Box). The time required for opening the transplanting box can be adjust to 0.2 - 0.6 s. The electronic unit gives an order for pentode valve to open the seedling box. The normal position of pentode valve is locked or closed position. In case of there is no reflected rays, there is an auxiliary circle which restart (revolves) the engine for a moment to come out from the rays reflection and wait for the response of the following reflection of the transplanting box. This circuit is working based on phase locked looped control movement.

Air circulation:-

Air cycle consists of DC air compressor (12-13.5 V, maximum ampere is 15 A, max pressure is 150 psi, discharge is 35 l/min) works by 12 V battery, air tank, air gauge, air regulator, pentode valve, non-return valve, piston …etc. as shown in Fig. 4.

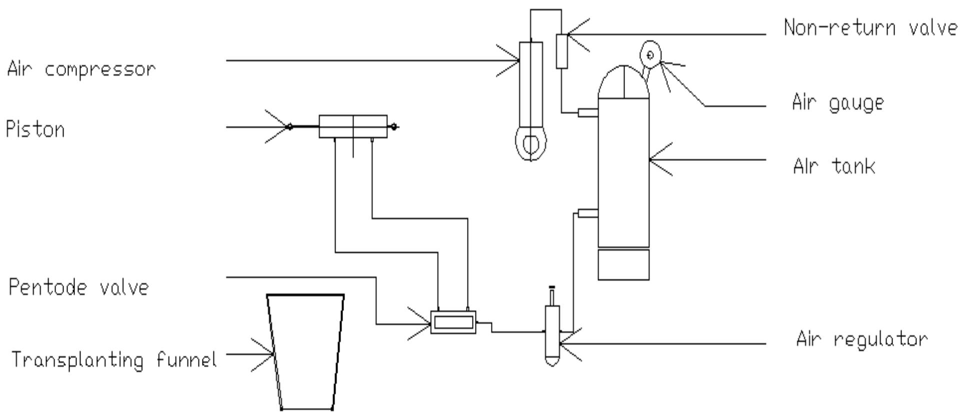


Fig.4. Main components of air circulation.

The compressor is used to compress air through air links to the air tank. The air pressure is controlled through a safety device which works to stop the compressor when the pressure in the air tank reaches to 4 bar. Pressure is going through the stages until be outreach to transplanting can which operates by air pressure (opening and closing). Initially air passes from compressor to pressure gauge and non-return valve then enters the air tank, which ends stopcock out through a combination of air pressure gauge, to another air tank and then to the pentode valve that controls the opening and closing transplanting can.

To evaluate the performance of the developed mechanical transplanter, the following variables were studied: forward speeds of 0.6, 0.9, 1.2 and 1.5 km/h. seedlings spacing of 27, 37 and 47 cm at seedling age of 70 days. Experimentations were carried out to evaluate the effect of studied variables on the following parameters: Longitudinal and transverse scattering; missing, floating and dead seedlings; specific fuel consumption; energy consumption and transplanting efficiency. Table 2 shows properties of cane stalk before bud separation.

Table 2. Some physical and mechanical properties of cane stalk before bud separation.

Properties	**Max**	**Min**	**Mean**
Stalk length ,L, cm	210	170	190
Stalk diameter ,D, cm	3	1.5	2.25
Stalk mass ,M, kg	1.3	0.75	1.01
The number of buds of stalk	16	8	12
The stalk curvature ,r_c, cm	79.7	72	-
Cane hardness ,F_{hard} , N	200.4	120.4	165

Measurements and calculations

Longitudinal and transverse scattering:

The dispersion of seedling about the center of row is determined according to the following formula (Stell and Torrie, 1980)

$$\text{Scattering} = \sqrt{\frac{\sum (x - \mu)^2}{N}} \qquad (1)$$

Where:

$\sum (x - \mu)^2$ The sum of squares of variance of seed scattering**.**

N = The number of hills

Missing hills percentages:

The percentage of vacant hills was calculated according to Hossary et al. (1980) by using following formula.

$$MR = \left(\frac{N_R}{N_{th}}\right) \times 100 \qquad (2)$$

Where:

MR = vacant hills, percentage,

N_R = Number of vacant hills/30 m length and

N_{th} =Number of the theoretical hills/ 30 m length

Specific fuel consumption (SFC),

Specific fuel consumption as function of the amount of work being done by the engine defined as follows:

$$\text{SFC} = \frac{M_f}{P} \qquad (3)$$

Where:

SFC = Specific fuel consumption in kg/kW.h

M_f = Fuel consumption rate in kg/h and

P = Power in kW

The power requirement

Power required is calculated using the measured fuel during transplanting operation under different variables of the study according to Embaby (1985):

$$P_{required} = (F_c /3600) \times F_f \times L.C.V. \times 427 \times \eta_{th} \times \eta_m \times (1/75) \times (1/1.36) \qquad (4)$$

Where:

$P_{required}$ = power requirement, kW;

F_c = fuel consumption, l/h;

F_f= density of fuel, for gasoline fuel = 0.72 kg/l;

L.C.V. = lower calorific value of fuel, 10000 kcal/k g;

427 = thermo–mechanical equivalent, kg. m / kcal;

η_{th} = thermal efficiency of the engine, 35% and

η_m= the mechanical efficiency of engine, 80%.

Energy consumption

$$\textit{Energy consumption} = \frac{P}{F.C_{ef}} \quad kW.h / fed \qquad (5)$$

Where:

P = power requirement kW,and

$F.C_{ef}$ = Effective field capacity fed/h.

Transplanting efficiency:

The transplanting efficiency was measured according to RNAM (1991) using the following equation:

$$\eta_t = \frac{1-(N_d + N_m + N_f)}{N_t} \times 100 \qquad (6)$$

Where:

η_t = Transplanter efficiency,%;

N_t= Theoretical number of seedling per unit length;

N_d = Number of dead seedling, %;

N_m = Number of missed seedling, %;

N_f = Number of floating seedling, % and

RESULTS AND DISCUSSION

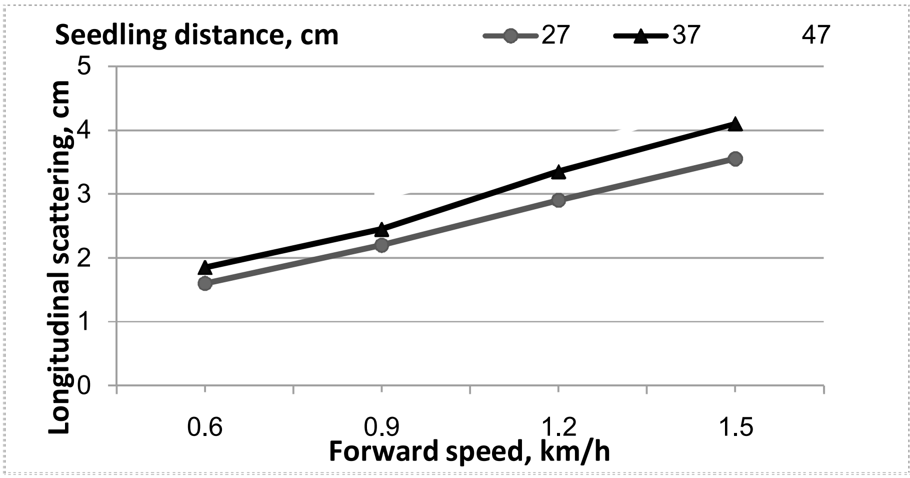
Effect of different variables on longitudinal and transverse scattering, (cm)

As shown in Fig. 6, the longitudinal and transverse scattering increased as both of forward speed and as transplanting spaces increased. The highest values of the longitudinal and transverse scattering were 4.1 and 3.7 cm at forward speed of 1.5 km/h. On the other hand the lowest values were 1.9 and 1.5 cm at 0.6 km/h respectively.

Meanwhile, results indicated that, the highest values of the longitudinal and transverse scattering were 3.4 and 2.9 cm at seedling space of 47 cm while the lowest values were 2.6 and 2.1cm at seedling distance of 27 cm respectively.

The recorded results revealed that by increasing seedlings space from 27 to 47 cm, the longitudinal and transverse scattering increased by 46.87% (i.e. from 1.6 to 2.35 cm) and 45.83% (i.e. from 1.2 to 1.75cm), respectively at the same forward speed of 0.6 km/h. The maximum values of longitudinal and transverse scattering were 4.55 and 4.15 cm, respectively at seedling distance of 47 cm and 1.5 km/h (Fig. 6). While the minimum values of longitudinal and transverse scattering were 3.55 and 3.3 cm, respectively at 27 cm seedling distance and 1.5km/h. This would be attributed to the increase of slip and vibration caused by increasing forward speed.

(a)



(b)

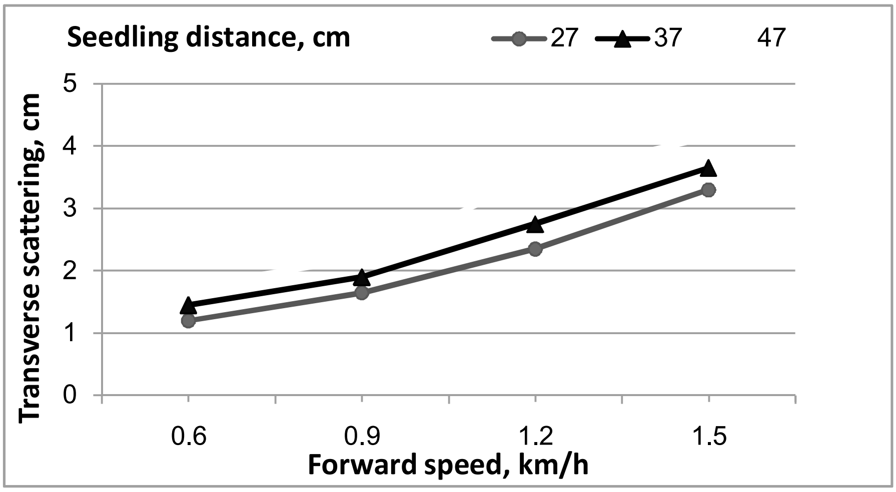


Fig. 6. Effect of forward speeds and seedling spaces on (a) longitudinal and (b) transverse scattering.

Effect of seedling spaces and forward speed on missing seedling:

The results showed in Fig. 7 revealed that by increasing seedlings spaces from 27 to 47 cm, the missing seedlings decreased from 2.45 to 1.9 % at the same forward speed of 0.6 km/h. The maximum and minimum values of missing seedlings of 4.3 and 3.4 % were recorded at 47 and 27cm seedling distance, respectively and forward speed of 1.5 km/h. This would be attributed to the increase of time that required for labourer to feeding the seedlings.

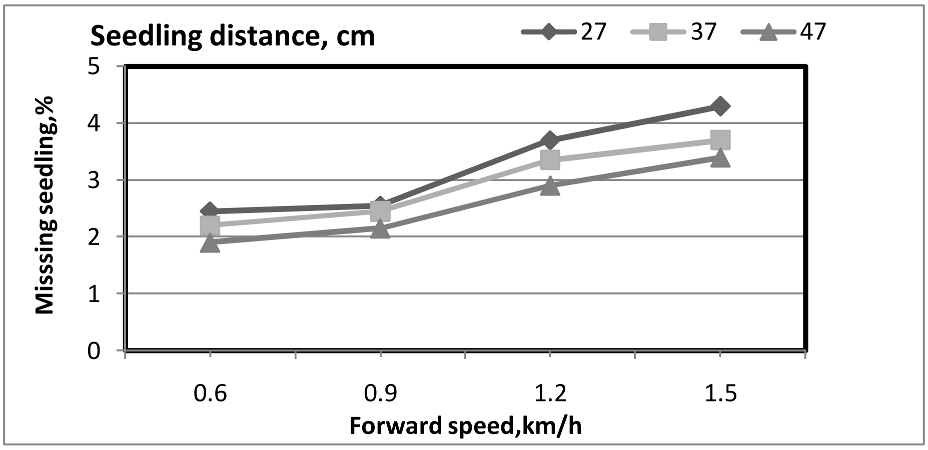


Fig. 7. Effect of forward speed and seedling distances on missing seedling.

Effect of seedling spaces and forward speeds on floating seedling:

From the recorded results, it is obvious that, the floating seedling increased as the seedling space and forward speed increased. Fig. 8 shows that by increasing seedlings distances from 27 to 47 cm, the floating seedling increased from 1.65 to 2.3% at forward speed 0.6 km/h. The maximum and minimum values of floating seedlings of 3.75 and 3.25 % were recorded at seedling spaces of 47 and 27 cm, respectively and at forward speed of 1.5 km/h. This would be due to the decrease in actual number of seedlings per unit of area comparing with the theoretical number of seedling.

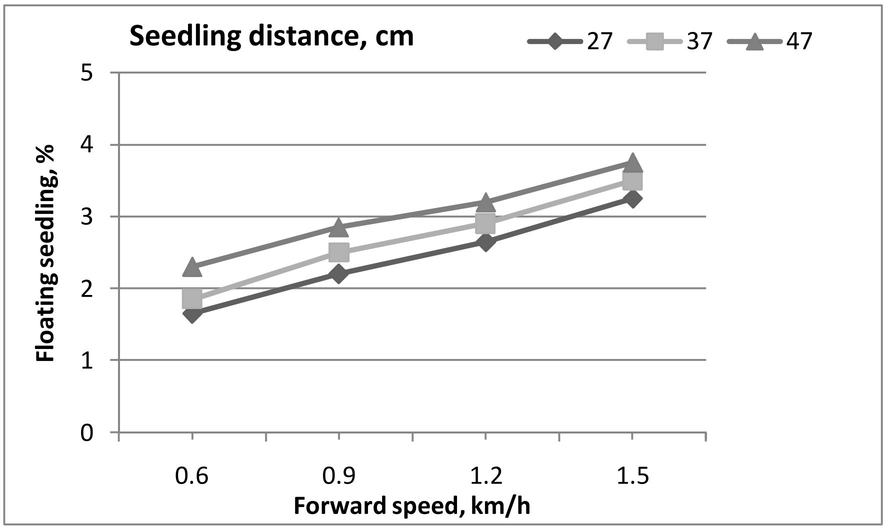


Fig. 8. Effect of forward speed and seedling spaces on floating seedlings.

Effect of seedling spaces and forward speeds on dead seedling:

Observed results in Fig. 9 indicated that, the dead seedlings increased as the seedling spaces and forward speed increased. The recorded results revealed that by increasing seedlings spaces from 27 to 47cm, the dead seedling increased from 1.0 to 2.5% at the same forward speed of 0.6 km/h. The maximum and minimum values of dead seedlings of 4.35 and 3.2 % were recorded at seedling spaces of 47 and 27 cm and at forward speed of 1.5km/h. This attributed to decrease in actual number of seedling in the unit of area comparing with the theoretical number of seedling.

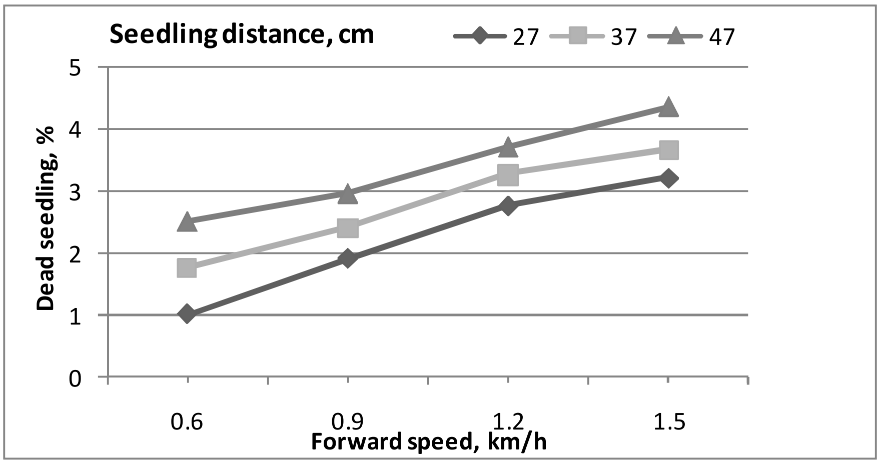


Fig.9. Effect of forward speeds and seedling spaces on dead seedling

Effect of seedling spaces and forward speeds on power requirement:

Fig. 10 indicated that, the power requirement decreased as the seedling distances increased for all forward speed. The recorded results revealed that by increasing seedlings distance from 27 to 47 cm, the power requirement decreased from 2.8 to 2.5 kW at constant forward speed of 0.6 km/h. The maximum and minimum values of power requirement of 3.22 and 2.55 kW were recorded at 27 and 47cm seedling distance and at forward speed 1.5 km/h.

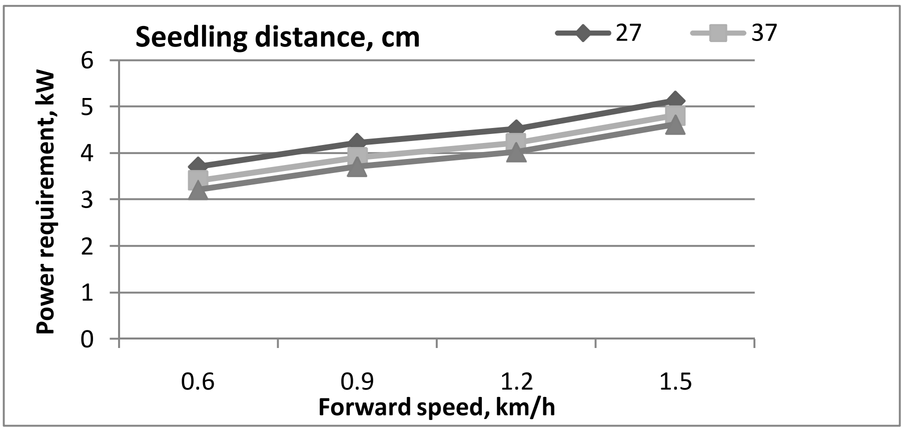


Fig.10. Effect of forward speeds and seedling spaces on power requirement.

Effect of seedling spaces and forward speeds on transplanting efficiency:

Fig. 11 indicated that, by increasing seedlings space from 27 to 47 cm, the transplanting efficiency decreased from 94.7 to 93.3% at forward speed of 0.6km/h. The maximum and minimum values of transplantnig efficiency of 89.3 and 88.5% were recorded at 27 and 47cm seedling space and at forward speed of 1.5 km/h.

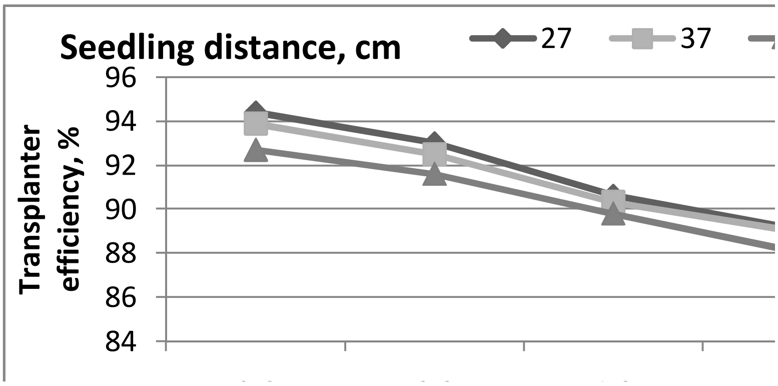


Fig.11. Effect of forward speeds and seedlings spaces on transplanting efficiency.

CONCLUSION

From the pevrous results the following conclusions are derived:

1. The longitudinal and transverse scattering increased as the seedling spaces and forward speeds increased. At seedling space of 27cm, since forward speed increased from 0.6 to 1.5 km/h, the longitudinal and transverse scattering increased from 1.2 to 3.3 and to 1.6 to 3.55 cm, respectively.
2. At seedling distance 27 cm, increasing forward speed from 0.6 to 1.5km/h led to increase the missing, floating and dead seedling from (1.9, 1.65and1.0%) to (3.4, 3.25and 2.1%) respectively.
3. The maximum and minimum values of energy consumption of 21.62 and 9.7 kW.h/fed were recorded at 27 and 47cm seedling space and at forward speed of 1.5 km/h.
4. The best transplanter efficiencies were recorded at 0.6 km/h forward speed for all seedling space.

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١. *معهد بحوث الهندسة الزراعية – الدقى* – جيزة
٢. *كلية الزراعة* – جامعة دمنهور
٣. *كلية الزراعة* – جامعة كفر الشيخ

يعتبر محصول قصب السكر من المحاصيل الإستراتيجية الهامة بالنسبة لجميع بلدان العالم حيث أنه يساهم بنسبة كبيرة جدا في الإنتاج العالمي للسكر. تم اجراء هذه الدراسة في محطة البحوث الزراعية بايتاي البارود محافظة البحيرة علي محصول القصب صنف C_9 في الموسم ٢٠١٣ باستخدام الآلة الجديدة(موضوع الدراسة) المصنعة لشتل محصول قصب السكر.

الهدف من الدراسة

١- تصنيع وتقييم آلة جديدة لشتل محصول قصب السكر تعمل عن طريق موتور سيرفو يتم التحكم في تشغيلة عن طريق دائرة الكترونية تعمل بالاشعة تحت الحمراء.

٢- تقييم أداء هذه الآلة تحت ظروف التشغيل المختلفة.

وقد تم دراسة بعض العوامل المؤثرة علي عملية الشتل وهي

١- اربع سرعات امامية (٠.٦ و٠.٩ و١.٢ و١.٥ كم/ساعة).

٢- ثلاث مسافات زراعة (٢٧ و٣٧ و٤٧ سم).

وقد تم تقييم الالة المصنعة محليا من حيث المتغيرات الاتية

١- التشتت الطولي والعرضي

٢- فواقد الشتلات (الغائبة – الشتلات العائمة – الشتلات الميتة)

٣- الاستهلاك النوعي للوقود والطاقة وكذلك كفاءة الشتل

وقد تم التوصل للنتائج الآتية

١- يزداد التشتت الطولي والعرضي بزيادة السرعة الأمامية وكذلك بزيادة مسافة الشتل فعند مسافة شتل ٢٧ سم مع زيادة السرعة الأمامية من ٠.٦ الي ١.٥ كم/ساعة يزداد التشتت الطولي والعرضي من ١.٦ الي ٣.٥٥ ومن١.٢ الي ٣.٣ سم علي التوالي.

٢- عند مسافة ٢٧ سم مع زيادة السرعة الامامية من ٠.٦ الي١.٥ كم/ساعة فإن الشتلات الغائبة والعائمة والميتة تزداد من ١.٩ الي ٣.٤ ومن١.٦٥ الي ٣.٢٥ ومن ١الي ٢.١ % علي التوالي.

٣- أقصي وأقل قيمة للطاقة المستهلكة كانت ١٤.٥٢ و ١٢.٩ كيلووات .ساعة/فدان والتي تم تسجيلها عند مسافة شتل ٢٧ و٤٧ سم وسرعة امامية ١.٥ كم /ساعةعلى التوالى.

٤- كفاءة الشتالة تنقص من٩٤.٧ الي٨٩.٣% بزيادة السرعة الامامية من ٠.٦ الي ١.٥ كم/ساعة وثبات مسافة الشتل عند ٢٧سم.