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DESIGN AND FABRICATION OF A SUGAR BEET HAND PLANTER

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ABSTRACT

This study aims to design and fabricate a sugar beet hand planter to suit the small holding farms and avoid the problems of the manual planting and imported planters. Factors such as picker wheel speed, ratio of cup diameter to seed diameter (D/d), ratio of metering gate height to picker wheel radius (h/r), and the transmission ratio (i) were investigated. Results indicated that the best uniformity was accomplished with picker wheel speed of 0.205 m/s that placed over 85 % of the seed in a proper space. To ensure a good seed rate of not less than 100 %, optimum seed spacing uniformity and minimum missing percent the ratio of gate height should be limited to about 0.46. The optimum distribution of seed was obtained at transmission ratio of 0.4. Data indicated that there was no significance difference between seed germinations before and after passing through the fabricated metering system. The best performance of the fabricated planter was obtained at 0.205 m/s picker wheel speed, 0.46 height gate ratio, and 0.4 transmission ratio. Multiple linear regression was performed to obtain the prediction equation of seed spacing uniformity: $C_p = 197 - 6.8\ (r\omega^2/g) - 5.16\ (i) + 4.12\ (h/r) + 0.34\ (D/d)$. Where: C_p= seed spacing uniformity, D = diameter of metering cups, d = diameter of beet seed, r = radius of picker wheel, ω= angular velocity of picker wheel, g = gravitational acceleration, h = height of feeder gate, and i = transmission ratio.

INTRODUCTION

Up till now, the sugar beet sowing is essentially done manually in Egypt. This is because introduction of mechanization generally involves big machinery, although most local farmers own small land holdings. In addition, different varieties of uncoated beet seeds with irregular shape and different dimensions are planted. Second problem with using row planters is that of ungraded seed. Therefore, a simple hand planter with cup metering system was designed and fabricated that can plant ungraded beet seeds appropriate to the small farm holdings.

Wilson (1980) developed equations, which related the release error from seed delivery to the seed distribution along the rows. Using these equations, he studied the effects of several design parameters on the seed distribution and suggested that the peripheral velocity of the releasing mechanism should be equal in magnitude and opposite to the forward velocity in direction.

Kepner *et al.* (1982) mentioned that the diameter of cell should be about 10 % greater than the maximum seed dimension, and the cell depth should be about equal the average seed diameter or thickness.

Korayem (1986) reported that increasing cell speed generally reduced cell fill and increased seed damage and seed spacing along the row.

Chhinnan *et al.* (1975) studied the effect of various factors on seed metering and seed placement errors. The higher metering plate speed resulted in more skips, higher seed placement errors and higher average spacing.

Kachman and smith (1995) indicated that the mean and sample standard deviation are not appropriate methods for summarizing the distributions of seed for single seed planters. The multiples index, miss index and quality of feed index are good for summarizing seed distributions. Those measures were based on the theoretical spacing (X_{ref}).

Ahmed and Gupla (1994) designed and developed a manually operated electrostatic planter for small seeds. It can be substituted for manual planting to reduce labor requirement, reduce seed rate per hectar and to reduce operational drudgery.

Klenin *et al.* (1985) reported that for high quality sowing, each cell should be packed with a single seed such that is ejected by the plate. Seed packing is greatly affected by the relationship between the cell size and the seed thickness.

Senapati, *et al.* (1988) stated that uniform placement of seeds along the line is an important factor which affects the crop growth and thus the yield. Therefore, the design of metering devices is one of the most important aspects of seed drills.

RNAM, 1991, reported that to enable the cell plate to pick the seed at 100% efficiency from seed hopper, its peripheral speed should not exceed 300 mm/s.

The current study was devoted to:

1- Design and fabricate a hand planter to replace manual planting and solve the major problems of sugar beet planting.
2- Conduct the laboratory experiments to study some engineering design factors and identify the scientific parameters at which it can be commercially manufactured.
3- Develop an equation to predict seed spacing uniformity and the performance of the hand planter.

MATERIALS AND METHODS

During this study a hand planter with a cup metering device was designed and fabricated. Figure 1 is a diagram of the fabricated push planter. It suits the needs of small farms. The cup pick up mechanism was specifically designed for sugar beet to plant ungraded beet seeds and avoid seed damage due to rough mechanical handling. It will pick up individual seeds of various sizes and shapes with high degree of accuracy. The main components of the fabricated machine are as follows:

Seed hopper:

It was fabricated from iron sheet of 1.5 mm thickness. Hopper bottom is inclined at 45 degree to horizontal. It stores seeds to be delivered during sowing operation.

Metering device:

It is used to meter seeds, and control their rate of delivery as single seeds. It is a cup metering type that consists of a shaft carrying a vertical picker wheel with a ring of cups attached to its periphery. The picker wheel with set of cups rotates in a compartment of the metering housing which is placed at the bottom of the seed hopper. The seeds are fed from the hopper into a reservoir of the metering housing by gravity through a gate to regulate the seed level. As the cup moves through the seeds in the reservoir, it scoops them up and discharge in into the top of the coulter tube. The housing of metering device is made of cast iron. The picker wheel inside the metering housing was fabricated using aluminum plate of 30 mm thickness and 170 mm diameter. The number of cups was estimated as a function of seeding rate, and speed ratio of the picker wheel to ground wheel according to (RNAM 1991) as follows:

$$N = (\pi \times d_g \times b \times S) / i$$

Where: N = number of cups, d_g = ground wheel diameter, b = distance between rows, S = seeding rate, seeds/m^2, and i = transmission ratio.

The distance between cups L_0 on the plate was adjusted to be 18 mm, since it must not be smaller than twice the maximum size of the seeds L_c = 8mm (RNAM 1991). $L_0 \geq 2 L_c$

The rotation speed n, rpm of the picker wheel was arranged as a function of the sowing pattern and the speed V, m/s of the machine according to (Klenin 1985).

$$n = 60 V / a N i \quad \text{rpm}$$

Where: a = spacing between seeds in a row, N = number of cups on the metering plate, and i = speed ratio of picker wheel to ground wheel (transmission ratio).

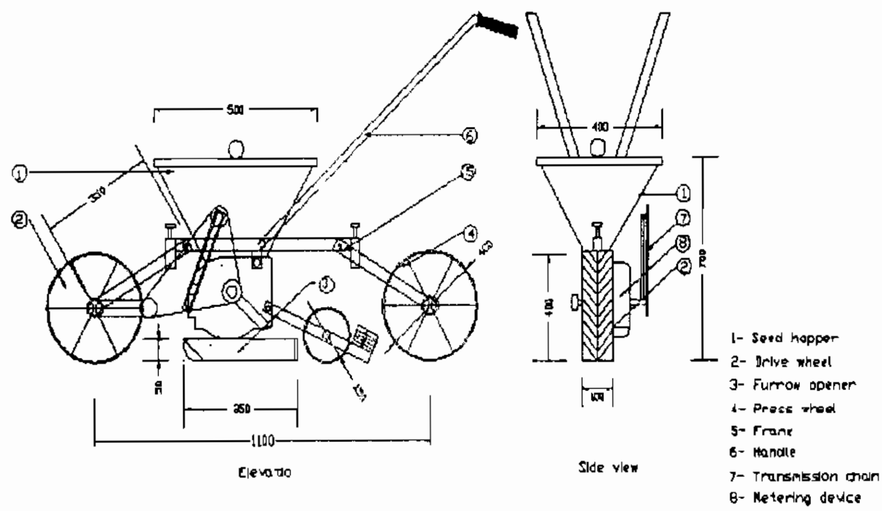

Fig. 1: An elevation and side view of the developed hand planter.

Dims. in mm

Furrow opener:

The furrow opener of the fabricated machine was chosen as a runner type. Its leading edge is typically curved upward. The bottom edge is a v shaped (at rear). Typical dimensions are 300 mm in length, 80 mm in depth at rear and 30 mm in width at rear (According to ASAE standards 1997). The depth of penetration of the opener is governed by wheels setting which can be adjusted vertically.

Firming wheel:

It presses seed into soil at the bottom of the seed furrow to improve seed to soil contact. Its width is narrower than the seed furrow width (5mm) and its diameter is of (150 mm). It has down force weights to reduce wheel bounce and apply additional firming force.

Press wheel:

A single steel wheel has a width of 10 cm and 20 cm radius is centered over the seeded row. That wheel accomplishes the following: a) to complete seed covering and seed closure. b) to improve soil to seed contact. c) to control or gauge the depth of sowing operation.

Power transmission:

The metering device is driven by the front ground wheel by means of chains and sprockets. It has been fabricated from steel sheet of 5 mm thickness, 100 mm width and 200 mm radius. The recommended distance between seeds is about 20 cm the following formula was used to determine gear ratio (RNAM 1991): $i = d_g L_0 / d_p L$

Where: i= drive transmission ratio, d_g = ground wheel diameter, d_p = picker wheel diameter, L = distance between seeds, and L_0 = distance between cups on metering plate.

Main frame:

It fabricated from steel angles, pipes and plate sections. All other parts were mounted to the frame. The frame was carried on the main-wheel axle. Two handles are provided with the frame to push the planter forward during operation.

Uncoated multi-germ beet seeds were used in this work. Seeds are nearly round in shape with an average diameter of 6 mm.

The fabricated hand planter was tested and for performance was evaluated under laboratory conditions by using a special greased belt. The following parameters were investigated for the laboratory evaluation:

1- Picker wheel speed:

Four picker wheel linear speeds of 0.117, 0.205, 0.321, and 0.468 m/s were studied.

2- Diameter ratio between metering cup and beet seed:

Three diameter ratios of metering cup to beet seed namely 1.1, 1.27, and 1.45 were compared.

3- Metering gate height to picker wheel radius ratio:

The efficiency of the feed mechanism is dependent upon a steady supply of seed from the main hopper to the feeder reservoir through the metering gate. Therefore, four different ratios of gate height to picker wheel radius (0.22, 0.46, 0.70 and 0.94) were investigated.

4- Speed ratio between picker wheel and forward speed (transmission ratio):

The factor which is the ratio between the picker wheel peripheral speed (release points on the metering mechanism) and the forward speed of the planter (linear speed of test rig belt) was studied. Four speed ratios of picker wheel to forward speed (transmission ratio) were tested (0.4, 0.7, 1.09, and 1.59).

The following measurements were determined to investigate the effect of design factors on the fabricated hand planter performance.

1- Seed spacing uniformity, and Missing percent:

These indices were based on the theoretical spacing (X_{ref} = 20 cm). The quality of seed spacing uniformity index was the proportion of spacing between 0.5 to 1.5 X_{ref}. The multiple index was the proportion of spacing equal to or less than 0.5 X_{ref} , and the missing index represented the percentage of spacing greater than 1.5 X_{ref}. Kachman and Smith, (1995).

2- Seed rate ratio:

The ratio of actual number of dropped seeds to the theoretical number of seeds were computed as seed rate ratio.

3- Germination percent:

This measure was conducted by keeping 100 seeds on filter paper socked with water in a petri dish. After 10 days, the germinated seeds were counted to determine the germination percent. Germination percent was determined before and after passing through the metering device.

RESULTS AND DISCUSSION

1- Seed spacing uniformity:

Figure 2 shows the relation between picker wheel speed (0.117, 0.205, 0.321, and 0.468 m/s), and seed spacing uniformity. High seed spacing uniformity values indicate the metering system is doing well singulating seed and dropping it uniformly. It was observed that practically 84.5 % seed spacing uniformity was achieved at up to 0.205 m/s of the picker wheel speed. But above that, the seed spacing uniformity dropped dramatically. It decreased to 72.3 and 60.2 % when picker wheel speed increased to 0.321 and 0.468 m/s respectively. Therefore, to ensure a good uniformity of not less than 85 %, the picker wheel should be operated to about 0.205 m/s. Excessive picker wheel speed must be avoided to prevent seed from being shaken out of the cups. This result trend may be due to the fact that the forces acting on the seed at the point of contact with the cup are gravitational force (mg) and centrifugal force due to the rotational speed (C_f) of picker wheel. Therefore the seed will fall off the cup if C_f > mg. Also figure 2 shows that the diameter ratio of cup to seed had no sensible effect on the uniformity for all picker wheel speed.

Figure 3 shows the effect of gate height to picker wheel radius ratio on the seed uniformity. These results show that the uniformity increased from 70.3 to 83.1 % when the ratio increased from 0.22 to 0.46. Above 0.46 ratio there is a minimal effect upon spacing uniformity. This may be due to the cups may not holding the seeds if there are not enough seeds in the feeder reservoir for picking seeds by cups. The layer of 4 cm (0.46 ratio) was considered optimum for picking seeds by cups. The thick of layer in the reservoir is kept at the desired value by changing the position of feeder gate. Also it was observed that, when the ratio between picker wheel speed and forward speed (transmission ratio) was 0.4 the release errors would have a minimal effect upon spacing uniformity. It can be concluded that an increase in transmission ratio was accompanied a decreasing in seed uniformity after a certain speed ratio (0.7) reached.

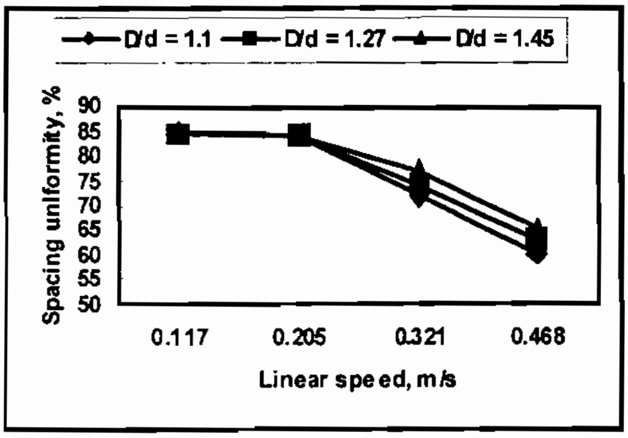

Fig. 2: The effect of the picker wheel speed and the metering cup to seed diameter ratio on the seed spacing uniformity.

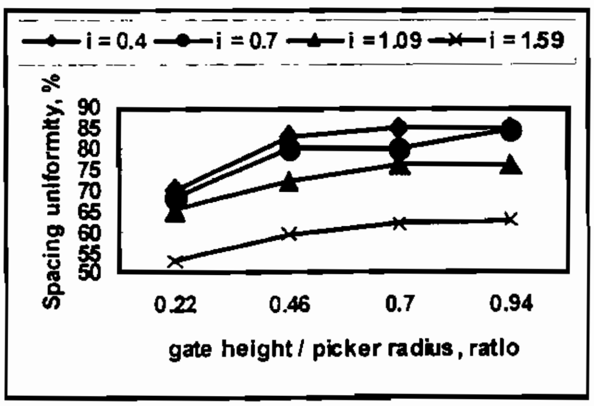

Fig. 3: The effect of metering gate height to picker wheel radius ratio and the transmission ratio (i) on the seed spacing uniformity.

Table 1 shows the analysis of variance of the seed spacing uniformity C_p as a dependent variable and the four independent variables. From this table it can be seen that the C_p was significantly affected by all the investigated parameters with a determination coefficient of 0.913.

Multiple linear regression was performed to obtain an equation predicting seed spacing uniformity. $C_p = f\ (D/d), (r\omega^2/g), (h/r), (i) \qquad R^2 = 0.834$

$$C_p = 197 - 6.8\ (r\omega^2/g) - 5.16\ (i) + 4.12\ (h/r) + 0.34\ (D/d)$$

Where:

C_p= seed spacing uniformity, %.

D = diameter of metering cups, cm.

d = diameter of beet seed, cm.

r = radius of picker wheel, cm.

ω= angular velocity of picker wheel, s^{-1}.

g = gravitational acceleration, cm/s^2.

h = height of feeder gate, cm.

i = transmission ratio.

Table 1: Analysis of variance of seed spacing uniformity and the independent variables.

	df	SS	MS	F	Significance F
Regression	4	21644.66	5411.165	235.684	7.27E-72
Residual	187	4293.409	22.95941		
Total	191	25938.07			
	df	SS	MS	F	Significance F

Table 2: Multiple regression analysis of seed spacing uniformity and the independent variables.

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	197.0069	5 765701	34 16876	2.47E-82	185.6327	208.381	185.6327	208.381
$(r\omega^2/g)$	-6.80875	0.309296	-22.0137	8.27E-54	-7.41891	-6.19859	-7.41891	-6 19859
(i)	-5.16833	0.309296	-16.71	6.01E-39	-5 77849	-4.55818	-5.77849	-4.55818
(D/d)	0.340625	0 423521	0.804269	0.422263	-0.49487	1.176119	-0.49487	1.176119
(h/r)	4.129583	0.309296	13.35154	5.4E-29	3.519425	4.739742	3.519425	4.739742

It may be noticed from the regression equation and table 2 that the seed spacing uniformity was directly related to the metering gate height ratio (h/r), and metering cup diameter ratio. However, it was inversely related to picker wheel speed $(r\omega^2/g)$ and the transmission ratio (i).

2- Missing percent:

Data in figure 4 indicates that the picker wheel speed had a clear effect on the missing index. It was nearly around 8.5 % at picker speed up to 0.205 m/s and rapidly increased to 28.9 % when the picker speed increased to 0.468 m/s. This is may be due to the rotational speed of picker wheel affects the picking efficiency of the metering device because seeds may fall out of the cups. Also it can be noticed that the missing index was not influenced by the metering cup to seed diameter ratio.

Figure 5 shows the effect of gate height to picker wheel radius ratio on missing percent. The minimum percentage of missing was 8.2 % which was given with height ratio of 0.94. While the maximum missing percent of 25.8 % was recorded at height ratio of 0.22. Generally, the feeder gate height should not be less than 50 % of picker wheel radius to achieve the minimum missing percent. It can be noticed that the transmission ratio had a significant effect on the missing index. The minimum missing percent (8.5 %) were recorded at transmission ratios ranged from 0.4 to 0.7 and highly increased by about 60% and 130 % with ratios of 1.09 and 1.59 respectively.

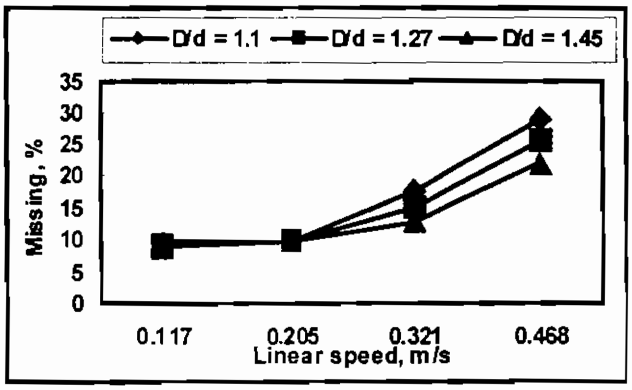

Fig. 4: The effect of picker wheel speed and the metering cup to the seed diameter ratio on the missing percent.

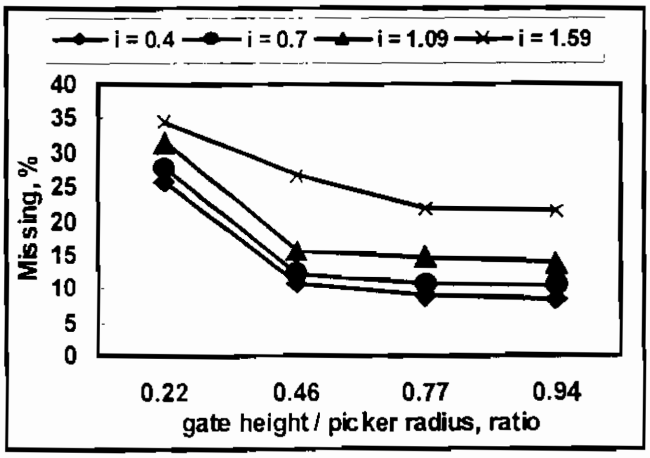

Fig. 5: The effect of metering gate height to picker wheel radius ratio and the transmission ratio on the missing percent.

3- Seed rate ratio:

Figure 6 represents the effect of picker wheel speed and cup diameter ratio on seed rate index. It can be noticed that an increase in picker speed was accompanied by a decrease in seed rate after a certain picker speed of 0.205 m/s was reached. Where at the first two speeds (0.117 and 0.205 m/s) the seed rate was nearly around 1.05. And rapidly decreased to 0.85 and 0.7 when the speed increased to 0.321 and 0.468 m/s respectively. In addition at low speeds of picker wheel (0.117 and 0.205 m/s), the feeder cup diameter ratio had no significant effect on seed rate index. While at higher speeds (0.321 and 0.468 m/s) the seed rate index increased when the cup diameter ratio increased.

Data in figure 7 indicate that the metering gate height ratio and transmission ratio had an obviously effect on the seed rate index. It can be noticed that the seed rate increased by about 35 % as the feeder gate height ratio increased from 0.22 to 0.46. While at higher gate height ratio the seed rate index did not change. Generally, the gate height ratio should not less than 0.46 to get the optimum seed rate. Also the figure shows that the transmission ratio had a high significant effect on the seed rate index. Where the seed rate index highly decreased when the transmission ratio increased. The maximum seed rate 1.07 was recorded at the lowest transmission ratio of 0.4. Meanwhile the minimum seed rate 0.62 resulted with the highest transmission ratio of 1.59.

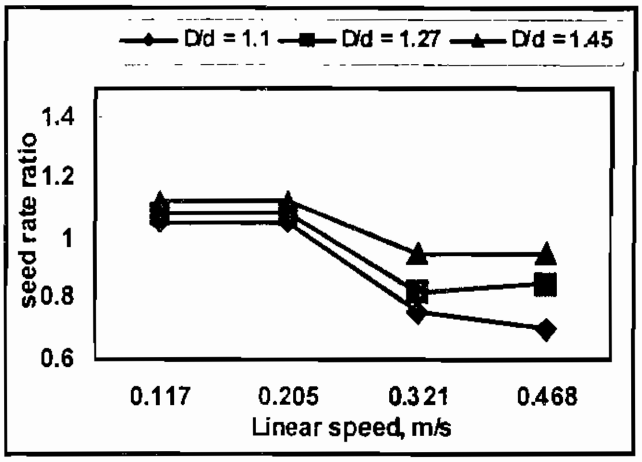

Fig. 6: The effect of picker wheel speed and metering cup to seed diameter ratio on the seed rate index.

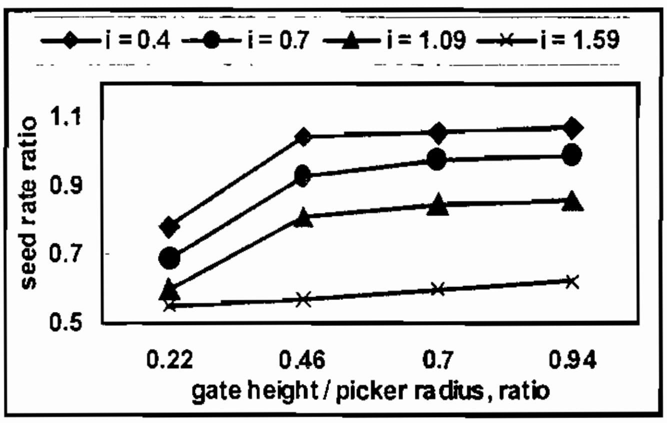

Fig. 7: The effect of metering gate height to picker wheel radius ratio and the transmission ratio on the seed rate index.

4- Germination ratio:

Germination percent and seed damage were carried out in the laboratory to study the effect of the fabricated metering system on beet seed. Results showed that the seed damage due to metering mechanism was nil. This is due to the seeds were handled gently because there is no cut-off device or deflector wheel in the fabricated metering system. Germination percent was measured before and after passing through the metering system. Germination percent did not vary radically with the feeding mechanism. They varied between 98.5 % and 98 % before and after passing through metering system respectively.

CONCLUSIONS

The main results in this study can be summarized in the following:

1- To ensure a good uniformity of not less than 85 %, the picker wheel should be operated at speed of 0.205 m/s.

2- The seed uniformity increased from 70.3 to 83.1 % as the feeder gate height ratio increased from 0.22 to 0.46. The seed thick layer of 4 cm obtained with 0.46 ratio of gate height to picker radius was considered optimum for picking seeds by cups.

3- An increase in transmission ratio was accompanied decreasing in seed uniformity after a certain speed ratio of (0.7).

4- The seed missing was nearly around 8.5 % at metering speed up to 0 205 m/s and rapidly increased to 28.9 % when the metering speed increased to 0.468 m/s.

5- The minimum missing percent (8.5 %) was recorded at transmission ratios ranged from 0.4 to 0.7 and highly increased by about 60% and 130 % with ratios of 1.09 and 1.59 respectively.

6- The optimum seed rate index (1.05) was recorded at 0.205 m/s metering plate speed, 0.4 transmission ratio, metering cup diameter ratio of 1.1, and feeder gate ratio of 0.46.

7- The seed rate increased by about 35 % when the feeder gate height ratio increased from 0.22 to 0 46. While at higher gate height ratio the seed rate index did not change.

8- Using the fabricated machine no damage to the seed was observed.

9- The germination percent varied between 98.5 % and 98 % before and after passing through the metering system respectively.

10- As a result of laboratory test, it may be concluded that the fabricated planter met the design objective when was operated at 0.205 m/s metering plate speed, 0.4 transmission ratio, metering cup diameter ratio of 1.1, and feeder gate ratio of 0.46.

11- Since it is predicted that the experimental hand planter works satisfactorily only on small plots and can achieve approximately 0.23 fed./h at a walking speed of 2.5 km/h. Therefore, it is recommended that a four units planter attached with a tractor of 5 km/h forward speed may be used to enable higher field capacity of about 2 fed/h, to be practical for the medium and large area and to sow sugar beet economically.

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تصميم وتصنيع آلة زراعة مدفوعة باليد لمحصول بنجر السكر

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معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية – الدقى – مصر

أن ميكنة عملية زراعة محصول بنجر السكر لم يصل إلى مدى الانتشار المطلوب لمثل هذا المحصول الحيوي والاقتصادي .وذلك نظرا لصغر المساحات وتفتت الحيازات الزراعية .كذلك فان تقاوي بنجر السكر المستخدمة في مصر من الأصناف غير المغلفة ذات الشكل والحجم غير المتجانس حيث تقف طبيعة هذة البذور عقبة في طريق ميكنة عملية زراعة البنجر .لذلك تم تصنيع نموذج لآلة زراعة بسيطة التركيب يمكن تشغيلها بدفعها بسهولة وبسرعة السير العادية بواسطة عامل واحد.وتناول البحث الموضوعات التالية :

١- تصميم وتطوير آلة زراعة مدفوعة باليد لزراعة بذور بنجر السكر عديدة الأجنة وتناسب متطلبات المزارع الصغيرة.
٢- دراسة تأثير أهم العوامل الهندسية والتصميمية على اداء الالة المصنعة.
٣- الحصول على النموذج الرياضي التى يمكن إن يتنبأ بانتظامية توزيع البذور تحت تأثير هذة العوامل .وقد تم اختبار الآلة معمليا باستخدام السير المعملى القياسى.

وكانت أهم النتائج المتحصل عليها ما يلي:

١- كانت السرعة 0.205 متر/ثانية لقرص التلقيم هي السرعة المثلي للحصول على انتظامية جيدة لتوزيع البذور لاتقل عن.85 %
٢- يزداد معامل الانتظامية لتوزيع البذور من 70.4% الى 83.1% عندما زاد معامل(ارتفاع بوابة التلقيم / نصف قطر قرص التلقيم)من 0.22 الى.0.46
٣- انسب ارتفاع للبذور بجهاز التلقيم هو4 سم ويمكن تحقيق ذلك عند نسبة ارتفاع للبوابة التلقيم 0.46.
٤- كانت نسبة البذور الغائبة8.5 % عند سرعة قرص التلقيم0.205 متر/ثانية وقد زادت الى 28.9% بزيادة سرعة قرص التلقيم الى 0.468 متر/ثانية .
٥- أتضح من التجارب إن انسب نسبة تخفيض بين قرص التلقيم والعجلة الأرضية هي 0.46وذلك للحصول على انتظامية مقدارها 84 %ومعدل تلقيم 1.05 ونسبة البذور الغائبة مقدارها ٨ %
٦- أظهرت النتائج ان جهاز التلقيم لآلة الزراعة ليس له تأثير معنوي على نسبة الكسر للبذور.
٧- بينت النتائج ان نسبة الإنبات للبذور كانت تقريبا 98 %- 98.5 % قبل وبعد المرور بجهاز التلقيم.
٨- للحصول على أفضل أداء للآلة المصنعة يجب ان تكون سرعة قرص التلقيم 0.205 متر/ثانية ,نسبة التخفيض لجهاز نقل الحركة ,0.4 معامل ارتفاع بوابة التلقيم.0.46
٩- اوضحت نتائج تحليل الانحدار الخطى المتعدد ان هناك علاقة قوية بين كلا من سرعة قرص التلقيم ,معامل ارتفاع بوابة جهاز التلقيم ,نسبة تخفيض جهاز نقل الحركة ,قطر ملعقة جهاز التلقيم ,انتظامية توزيع البذور حيث قدر معامل الارتباط (R^2)) بحوالى.0.834