MODIFICATION AND FABRICATION OF A LOCAL PRECISION PLANTER SUITABLE FOR SUGAR BEET SOWING

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Abstract

The main aim of this study was to develop, fabricate and adapt a local precision planter, which may be appropriate for Egyptian sugar beet sowing. The experiments were conducted at Sakha Research Station season 2002-2003. Factors such as forward speed, type of drive wheel, type of covering device, and type of furrow opener were taken into consideration. Field experiments were carried out to determine the following points: sowing uniformity, germination, wheel slip percent and power requirements. The results illustrate that the seed spacing uniformity and the germination percent were decreased with forward speed increase, while, slippage percent and power requirement increased. No significant differences were found for speed of 2.5 and 5.4 km/h. However, significant differences were found with the speed of 7.2 km/h, which gave the lowest uniformity and germination. Moreover, it gave the highest slippage and power requirement. The data indicated that, the knife and scraper covering devices did not achieve the objective of these devices. The drag chain-covering device allows satisfactory emergence since it does not compact the soil because it is wide and light, minimize crusting and the formed seed zone is not disturbed. Results showed that, the shoe type opener was found to be the most suitable for sugar beet sowing and works well under normal soil conditions. Maximum slip percent (15%) resulted from rear press wheel drive at 7.2 km/h. Minimum slip percent (4.03%) was recorded at 2.5 km/h with ground wheel drive. The draw pull increased with the increase of the sowing depth and forward speed. A curve fitted draw pull may be presented by: $D = -12.78 + 3.31\,d + 2.73\,v$.

INTRODUCTION

The majority of farmers in Egypt are planting sugar beet manually by labors. This method can't accurately adjust rows planting, at uniform depth of seeds, also it consumes more seeds and requires thinning. Mechanical planting is very important in saving hand labor, improving production, and allowing further mechanization to take place.

Abernathy and Porterfield (1969) concluded that the runner type openers reduced soil density to a depth greater than the operating depth of the opener. This may be due to its large vertical angles and large wedge angles. This opener is therefore not suitable for sowing under conditions of limited soil moisture availability, since a compact seedbed and good contact between seed and soil is recommended.

Mostafa et al. (1993) found that fuel consumption rate increased by increasing forward speed during planting operation. This was due to the increase in the field capacity (fed / h) to the increase in forward speed.

El-Zawahry (1994) found that the increase of planter forward speed would decrease the depth of seeds in the soil and increase the seed scattering around the furrow centerline. The mechanical planting time was 5.2 % from the manual planting. The planting cost by machine was equal to 34.4% from the manual planting system.

Klenin et al. (1985) mentioned that the main aim of seed distribution is to obtain the maximum possible yield with the minimum expenditure in the cultivation of the crop.

Allam et al. (1988) reported that the mechanical planting of sugar beet in Egypt is very economical as it reduced labor and time requirements and hence cost per ton, in the mechanical drilling reduced the labor by 90%, time needed by 91.5% and the cost of drilling/feddan was reduced by 96 % from manual drilling.

Agness and Luth (1975) reported that the important criteria of planter design included factors such as population control, accuracy of seed spacing in the row, seed depth, and seed soil contact.

El-shal (1993) reported that by increasing opener speed, the rate of soil collapse increases, and consequently more soil clods will fall into the furrow and as a result, different seed depths could be expected.

Jafari and Fornstrom (1972) developed a punch planter for sugar beet. They found that the planter gave more accurate seed spacing and depth control than the manual methods. The cited studies showed that planters developed especially for a particular crop tended to be more accurate than those developed for more than one.

Stout et. al. (1961) found that planters should be designed to apply higher pressures to soil at seed level, but should place relatively loose soil above the seed.

Jaggard (1990) reported that uniform seed spacing has been demonstrated to be a significant factor in quality and yield for sugar beet. With uniform spacing, the root can grow to a uniform size and fill the row space root. This ensures that all plant roots can be gathered from the row by the harvester. With uneven plant spacing some roots may be too small to be gathered by the harvester or some roots may be too large and may be damaged by the topping implements or lifting wheels of the harvester.

The current study is therefore devoted to:

1-Develop, fabricate and adapt a local precision planter to suit Egyptian beet planting.

2-Study some of operating factors affecting sowing uniformity, seed emergence, and power requirements of the fabricated planter.

3-Determine the most favorable combinations of planter components to be recommended to manufacturers and growers for the development of planter.

MATERIALS AND METHODS

The original planter was Hassia, German made. This machine did not meet wide acceptance because of: 1-The planter can only plant the mono-germ coated beet seed which is too expensive. 2- It has a large heavy frame and complex attachment of the planting units to its main frame. 3-It is considered a very expensive planter. Abd El-Tawwab (1999) fabricated and developed its first prototype to suit the Egyptian conditions as: 1- Plant multi-germ beet seeds by fabricating a new metering device considering the shape, dimensions and other physical properties of seed. 2-Simplifying the design of the machine frame and the attachment unit to the main frame.

The field evaluation for this experimental prototype indicated that: 1-Seed spacing uniformity was low and the seed distribution must be more accurate. This may be due to soil disturbance caused by the furrow opener. 2-The metering device was driven from the front gauge wheel on hard soil where furrow openers which were not able to penetrate the soil causing the wheel to be lifted thereby interrupting the metering of seeds. 3-A knife covering device tended to plug in trashy conditions and a partial groove left by the furrow opener. 4-Since the planting operation needs limited power, it is recommended that the local Nasr tractor (65 hp) operating in the Egyptian fields may be used to operate a six units planter economically.

In the present study a second prototype Fig. (1) was modified and fabricated as a commercial local planter and to overcome all the above mentioned problems facing the first prototype. The following features were introduced: 1- It was fabricated based on the results of the laboratory tests (Abd El-Tawwab, 2003) as: periphery speed ratio of seed metering plate to seed deflector wheel was 5:1, and periphery speed of seed metering plate to drive wheel ratio close to 1:4. 2-It consists of six planting units to be suitable for operation, by the general Nasr tractor. 3-Common types of covering devices such as drag-chain and scraper were installed, tested and compared with the knife covering type. 4-Other factors such as wheel type drive (carrying wheel, front gauge wheel and rear press wheel) as well as type of furrow openers (hoe, shoe and runner) were taken into consideration.

Table 1. Planter components and their specifications.

Part	Materials specifications
1- Seed box	Iron sheet 1.0 mm thick
2- Metering device (casing)	Cast iron
3- Cell plates	Aluminum casting
4- Furrow opener (shoe)	Cast iron (gray casting)
5- Covering device	Round pipes and flat (steel 37 low carbon steel)
6- Main frame and other parts like hitches, row markers and adjustment levers	Flat, angles and round pipes (steel 37 low carbon steel)
Shafts and axis	Shaft steel (1040 high carbon steel)
Standards finish	Chains, sprockets, springs, gears, split pins, bolts and nuts, plain and spring washers, etc., be as per standards used in light engineering industry

The main parts of the modified planter are as follows: metering plates were fabricated using vertical aluminum plates of 30 mm thickness and 160 mm diameter. The seeds hopper was fabricated from a 2 mm steel sheet. Hopper bottom inclined 45^0 to horizontal. The planting unit was provided with two rubber wheels of 260 mm diameter. Power is transmitted from the ground wheel to the metering device by sprocket and chain arrangements. The machine frame with three-point hitch was fabricated from 80*80*6 mm square tubes.

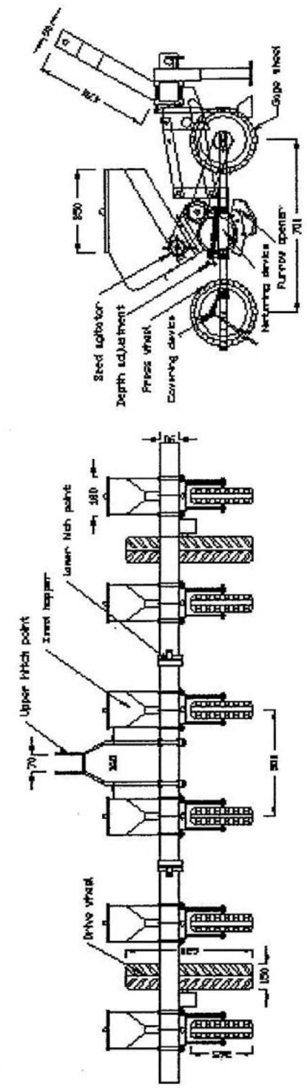

Fig . 1 : Elevation and side view of the experimental planter prototype .

Dim. in mm.

Gear ratio was chosen to give the recommended distance between seeds about 20 cm, the following formula was used to determine gear ratio (RNAM 1991):

$$i = d_g I / d_p L$$

where:

i = transmission ratio of the drive.

I = distance between cells on the plate periphery.

d_g = ground wheel diameter.

d_p = metering plate diameter = (16 cm).

L = desired distance between seeds in the row =(20 cm).

The present study was carried out at the Experimental Farm of Sakha Agricultural Research Station season 2002-2003. The experimental area was about 2 feddans. The soil texture under tests was clay soil. The mechanical analysis of the soil was 30.96 % silt, 13.80 % sand, 52.96 % clay and 2.28 % $CaCo_3$. The soil was prepared by using chisel plow of seven blades (twice) at a depth of 15 cm and followed by a disk harrow of 32 discs and a hydraulic land leveler before the planting operation. The soil moisture content was measured at depth of zero – 10 cm, the average value was 13.23%, and soil bulk density was measured at the same depth. The average bulk density of 10 samples was 1.12 g/cm^3. The aggregate structure was measured as a mean diameter to evaluate seedbed preparation. The average M. W. D. was 2.52 cm, 80 % less than 2 cm. Multi germ uncoated beet seeds were used in the present work.

During the field experiments, the following parameters were examined:

1-Forward speed:

The experiments included four forward speeds of 2.5, 3.6, 5.4, and 7.2 km/h. Speed has been determined by marking of distance of 350 m. in the field, drive the measured distance at the speed required to plant, check the number of seconds required to drive between the markers with a stop watch and calculate the speed in km/h.

2-Seed covering device:

A covering device should place moist soil in contact with the seeds, press the soil firmly around the seeds, cover them to the proper depth, and yet leave the soil directly above the row loose enough to minimize crusting and promote easy emergence. In this investigation, three types of covering devices were tested for their effect on the germination percentage at different forward speeds. Used types of covering devices were: knife, drag-chain, and scraper blades.

3-Drive wheel type:

In this work, three types of drive wheel were used to turn the seeding mechanism. Used drive wheels were: carrying wheel, front gauge wheel, and rear press wheel. Power to turn the seeding mechanism is transmitted through a drive chain and sprockets.

4-Furrow opener:

Three different types of furrow openers were investigated. Hoe, shoe, and runner openers were fabricated for this research.

The following measurements were carried out to investigate the effect of the above-mentioned parameters on the experimental planter's performance.

1-Seed spacing uniformity:

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

2-Germination percent:

The number of plants (seedlings) per 10 square meters was counted for all treatments. The germination percent was estimated according to the following formula:

$$\text{Germination, \%} = (P/ S) * 100$$

Where:

P = Average number of plants per 10 square meters.

S = Average number of delivered seeds per 10 square meters. It was calculated during the planter calibration.

3-Slip percent:

Slip of machine ground wheel is an important factor, which affects sowing rate per area. The percentage of slip was estimated for three different types of drive wheel, and four forward speeds. Slippage percentage was calculated by using the following equation (Awady, 1997):

$$\text{Slippage,\%} = \frac{\text{Actual distance} - \text{Theoretical distance}}{\text{Theoretical distance}}$$

4- Draft force and power requirements:

Draft force: In order to measure the force required to pull the fabricated beet planter a dynamometer model (DILLON) was used. Measurements were taken at three depths of 1, 3, and 5 cm, and four traveling speeds between 2.5 and 7.2 km/h.

Power: The power required is defined as pull force times speed as given in the following formula:

Drawbar power, kW = drawbar force, (kN) × speed, (m/s)

RESULTS AND DISCUSSION

1-Seed spacing uniformity:

As shown from Fig. 2, the seed spacing uniformity was highly affected by the drive wheel type and the forward speed. The majority of the seeding distance is in the range of 10 cm to 30 cm. It was found that, the highest seed spacing uniformity (79.4 %) was recorded at 2.5 km/h with carrying wheel drive. Meanwhile the lowest seed spacing uniformity 50 % resulted from rear wheel drive at 7.2 km/h speed. These results may be due to the increase in forward speed causes variation in seed spacing as affected by planter wheels slip %. In addition, planter vibration increases with increasing the forward speed. And hence reduces the efficiency of the seed metering devices.

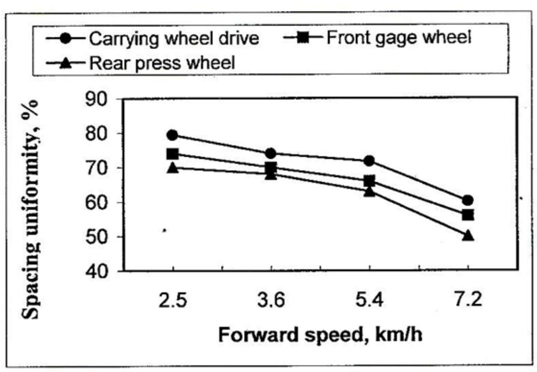

Fig. 2. Effect of forward speed and drive wheel type on the seed spacing uniformity.

2-Germination percent:

Fig. (3) indicates the effect of machine forward speed and the furrow opener type on the beet germination percent. As can be seen from the field results, the highest germination percent (86%) was recorded at 2.5 km/h forward speed with shoe opener. Meanwhile the lowest germination percent was 63 % resulted from hoe opener at 7.2 km/h. This may be due to the hoe opener that creates more soil disturbance than the other opener types. Soil disturbance in the furrow causes soil moisture loss from the loosened soil and adversely affects seed germination. In addition, shoe and runner openers placed the seed at the required depth and provide sufficient contact between the soil and the seed. While hoe-opener placed the seed deeper than the target depth.

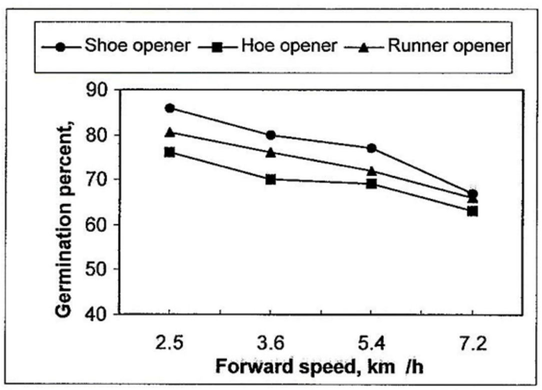

Fig. 3. Effect of forward speed and furrow opener type on the germination percent.

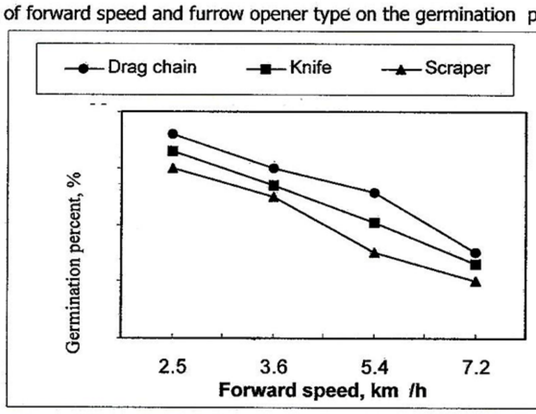

Fig. 4. Effect of forward speed and covering device type on the germination percent.

Fig. (4) shows the relationship between forward speeds, covering types and germination percentage. It was found that, the maximum seed germination was 86 % resulted with drag chain covering type at 2.5 km/h speed. Meanwhile the minimum germination 60 % resulted with scraper coverer at 7.2 km/h speed. Poor seed emergence occurred with scraper blade cover due to greater resistance of compacted soil on top of seed. Meanwhile Drag chain type mostly cover the seed with surface soil to maintain uniform depth and reduce field roughness. It does not compact soil because it is wide and light.

3- Slip percent of drive wheel:

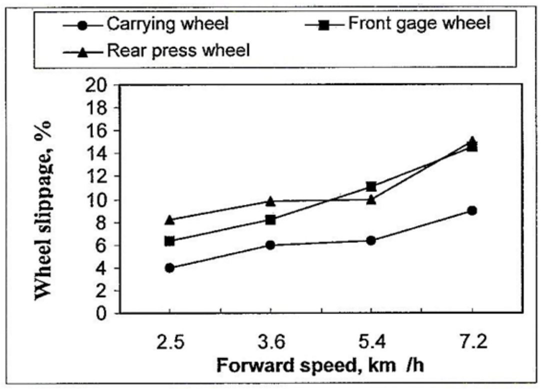

Fig. 5. Effect of forward speed and drive wheel type on the slip percent.

Fig. (5) shows the effect of forward speed (2.5, 3.6, 5.4, and 7.2 km/h) and drive wheel type on wheel slippage. It was found that, the slippage of planter wheels increased with forward speed for the three ground wheel types. The minimum slip percent (4.03%) was recorded at the lowest forward speed (2.5 km/h) with carrying wheel drive. Meanwhile the maximum percent of slip (15 %) was recorded at the highest forward speed (7.2 km/h) with rear press wheel. This increase in slip may be due to the sweeping of crushed soil under planter land wheel due to vibration of planter wheels caused by increasing forward speed. Slippage of rear press wheel drive may be greater than when the carrying wheel is used because the press wheel is running in loosened soil by the furrow opener. Also the weight or down pressure on the press wheel may not be enough to prevent slippage. Meanwhile, the wide diameter and width of carrying wheel decrease slippage with a reduced rolling resistance. Moreover, the presence of lugged provide good contact with the soil surface and develop efficient traction for the drive mechanism. This slippage must be determined to enable the operator to make necessary changes to increase the planting population to the desired number.

4- Draft force and power requirements:

Table (2) shows the average values of draw pull and power requirements for the designed precision planter under different forward speeds and sowing depths. It was obvious that, the draft force and power requirement increased with increasing the forward speed and the sowing depth. And was clear that, the speed had a low effect on the draft force at speed range under 3.6 km/h and a higher effect at speed range over 3.6 km/h. It was found that, the maximum draft force 14.4 kN and power requirement 28.8 kW were recorded with the highest forward speed (7.2 km/h) and greatest depth of 5 cm. Meanwhile the minimum 2.13 kN draft force and power requirement 1.48 kW were recorded at the lowest forward speed of 2.5 km/h and depth of 1 cm. The variation in draft force and power requirement with sowing depth due to increasing soil reaction against the wheel and soil resistance against furrow opener.

Table 2. Draft force (D) and power requirement (P) at different forward speeds and sowing depths.

Sowing depth, Cm	Forward speed, km/h							
	2.5		3.6		5.4		7.2	
	D, kN	P, kW	D, kN	P, kW	D, kN	P, kW	D, kN	P, kW
1	2.13	1.48	2.22	2.22	2.52	3.78	2.88	5.76
3	6.43	4.47	6.69	6.69	7.56	11.34	8.64	17.28
5	10.71	7.44	11.16	11.16	12.6	18.9	14.4	28.8

Table (3) shows the variance analysis of the relationship between draft force, forward speed and sowing depth. As shown, it is clear that the two independent variables used significantly affect the draft force. Multiple regressions shown in table (4) was performed on the calculated values of draft force. The general form of the equation used in this analysis was a function of forward speed and sowing depth. The developed model that can be used for predicting draft force is expressed as follows:

$$D = -12.78 + 3.316\,d + 2.733\,v$$

Where:

D = Draft force, kN.

d = Sowing depth, cm.

v = Forward speed, km/h.

Table 3. Variance analysis of draft force.

ANOVA

Source of Variation	*df*	*SS*	*MS*	*F*	*P-value*	*F crit*
d	2	351.9205	175.9602	12.34373	0.007474	5.143249
v	3	289.1758	96.39193	6.761958	0.023676	4.757055
Error	6	85.5302	14.25503			
Total	11	726.6265				

R-square=0.937

Table 4. Multiple regression analysis of draft force.

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-12.7842984	3.023690847	-4.22804	0.002213	-19.624368	-5.9442293
D	3.31625	0.552993483	5.996906	0.000203	2.0652909	4.5672091
V	2.73345064	0.505058345	5.412148	0.000426	1.5909284	3.8759729

R-square=0.878

Conclusions

From the obtained data it can be concluded:

1-The overall, performance index of shoe type opener was better as compared to the other two openers.

2-The carrying wheel drive gave less slippage percent and better seed spacing uniformity as compared to front gage wheel and rear press wheel drives.

3- It was found that, the highest seed spacing uniformity 79.4 % was recorded at 2.5 km/h with carrying wheel drive.

4- The highest germination percent 86 % was recorded at 2.5 km/h forward speed with shoe opener, and drag chain covering device

5- The minimum slip percent (4.03%) was recorded at the lowest forward speed (2.5 km/h) with carrying wheel drive.

6-The maximum draft force 14.4 kN and power requirement 28.8 kW were recorded with the highest forward speed (7.2 km/h) and greatest depth of 5 cm.

7-The developed planter works satisfactory at a traveling speed of 5.4 km/h with shoe opener and drag chain covering type.

8-The optimum design of the modified planter according to these results are recommended as:

No. of rows: six units

Furrow opener: shoe type

Covering device: drag–chain type

Drive wheel: carrying wheel

Forward speed: 5.4 km/h

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تطوير وتصنيع آلة زراعة دقيقة تناسب زراعة محصول بنجر السكر

إبراهيم محمد عبد التواب

معهد بحوث الهندسة الزراعية-مركز البحوث الزراعية

يعتبر بنجر السكر من المحاصيل الهامة في مصر حيث يحتل المرتبة الثانية بعد قصب السكر من حيث المساحة المنزرعة والإنتاجية. وتعتبر الزراعة الدقيقة لبنجر السكر ذات أهميه كبيرة حيث تعمل على تحقيق الكثافة النباتية المطلوبة والتوزيع المنتظم للنباتات مما ينعكس على تحسين صفات الجذور وبالتالي محتوى السكر بالإضافة الى ارتفاع إنتاجية الفدان كما سوف تسهم في خفض كمية التقاوي اللازمة للزراعة من ناحية وخفض تكلفة الزراعة من ناحية أخرى. وقد تمت هذة التجارب بالمزرعة البحثية بسخا-محطة البحوث الزراعية وكان الهدف من البحث هو دراسة تطوير وتصنيع آلة زراعة دقيقة لمحصول بنجر السكر وقد اختبرت عليها أربع سرعات أمامية، ثلاث أعماق زراعة، ثلاث أنواع من الفجاجات، ثلاث أنواع من أجهزة التغطية، ثلاث أنواع من عجل الإدارة وذلك بغرض تحديد انسب مكونات تصميميه ملائمة للآلة. هذا وقد أوضحت النتائج مايلي:

١- بزيادة السرعة الأمامية لآلة الزراعة تقل انتظامية توزيع النباتات، حيث بلغت النسبة المئوية لانتظام النباتات ٧٩,٤، ٧٤، ٧١,٧، ٦٠,٢% عند سرعات ٢,٥، ٣,٦، ٥,٤، ٧,٢ كم/ساعة على الترتيب.

٢-زيادة سرعة الآلة عن حد معين (٥,٤ كم/ساعة) يؤدى الى زيادة تذبذب الآلة وعدم استقرار البذور وتقلل من كفاءة انتظام توزيع البذور.

٣-أعطي الفجاج الحذائى أعلى نسبة إنبات (٨٦%) يليه الفجاج على شكل قارب (٨٠,٤%) ثم الفجاج العزاق (٧٦,٢%).

٤-وجد ان انسب جهاز تغطية كان السلاسل الحديدية ثم يليه السلاحى ثم الزحافى حيث وجد ان نسب الإنبات عند سرعة ٥,٤ كم/ساعة هي على الترتيب ٧٥,٧، ٧٠,٣، ٦٥,٠٨ % لأجهزة التغطية المذكورة.

٥-وجد آن اعلى نسبة انزلاق سجلت مع عجلة الضغط الخلفية واقل نسبة انزلاق مع العجلة الأرضية وكانت نسب الانزلاق عند سرعة ٥,٤ كم/ساعة وعمق ١سم هي ٦,٣، ١٠، ١١,٠٤ % للعجلة الأرضية، عجلة ضبط العمق الأمامية، عجلة الضغط الخلفية على الترتيب.

٦- أوضحت النتائج ان كلا من السرعة الأمامية وعمق الزراعة لهم تأثير معنوي واضح على قوة الجر. اجري تحليل الانحدار الخطى المتعدد أوضحت النتائج ان هناك علاقة قوية بين كل من السرعة الأمامية وعمق الزراعة وقوة الجر وكان معامل الارتباط يساوى ٠,٨٧٨

٧- بينت النتائج انه كلما زادت السرعة الأمامية وعمق الزراعة زادت قوة الجر. حيث وجد آن اعلى قوة جر هي ١٤,٤ كيلو نيوتن سجلت عند سرعة ٧,٢ كم/ساعة وعمق ٥ سم واقل قوة جر هي ٢,١٣ كيلو نيوتن عند سرعة ٢,٥ كم/ساعة وعمق ١ سم، ويرجع ذلك الى زيادة قوى مقاومة التدحرج ومقاومة التربة مع زيادة السرعة وعمق الزراعة.