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Development and Performance Evaluation of Precision Metering Unit For Wheat Planting

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ABSTRACT

Planting wheat crop at equal in rows distance between them can be accurately achieved, only when using vacuum precision planters (VPP). Accordingly, the grain metering device of imported precision vacuum planter under this study was developed for planting rows with 150 mm apart instead of 300 mm compared with other imported VPP in the market. The developed precision vacuum planter is tested in Gemeza Research Station (2013-2014) under three forward speeds (2.5, 3.1 and 4.8 km h^{-1}), and four disc speeds 25 (0.28), 31 (0.34), 37 (0.41) and 49-rpm, (0.54 m/s). The dual interaction effect between different forward speeds and disc speeds resulted in 12 grain rates. The performance evaluation was conducted to determine the effect of the different grain rates (12 grain rates) on grain and straw yields. Measurements were taken for mean grain spacing, number of grains per meter square, grain miss index, grain multiple index, quality of feed index, spacing uniformity, the amount of grain rates /fed and grain and straw yields/fed was investigated under field conditions. The optimum parameters were obtained at 34 kg /fed grain rate with high grain yield (2.8 ton/fed) and straw yield (4.5 ton/fed). The developed precision vacuum planter for wheat grains reduced grain rate by 43.3 % of the recommended grain rate in Egypt (60 kg/fed) with obtaining similar grain yields when using 34, 41, 44 and 56 kg/fed grain rates. Therefore, the new developed grain metering vacuum device is considered an effective solution for precise controlling of grain rates per feddan that invade Egyptian wheat area.
Keywords: planter, vacuum, grain rates, wheat grains.

INTRODUCTION

The total cultivated area of wheat is about 3.4 million feddans (1.43 million ha). This area produces about 8.7 million tons of wheat grains. Currently, the majority of this area is sowing using the traditional graining methods with a recommended rate 60 kg/fed (the total required amount to cover all the targeted area is 204 million ton). In the meantime, the quantity of grain production is about 167.4 million ton which causes a shortage about 36.6 million ton. While a few of the cultivated area is sowing by mechanical wheat seeder FAO (2013).

Improving wheat production through increasing the productivity per unit area together with decreasing the amount of planted grains per feddan is the most important national target in Egypt. Moreover, the reduction in grains amount per feddan reduce the production cost.

Therefore, a precision vacuum seeder represents an important factor to reduce the costs and increase the productivity. Lan *et al.* (1999) and Ismail (2008-a) determined that uniform grain spaces are important for crops because grain spacing uniformity is a significant factor affecting production yield and cost.

On the other hand, the mechanical wheat seeder causes high rate of damaged grains and unstable graining quantity (Zhao *et al*., 2005; Hui, 2003 and Liu *et al*. 2011, 2009). Furthermore, traditional mechanical wheat grain-metering device has poor graining uniformity and consistency instability and high grain-injuring rate, which cannot match the wheat precise graining agronomic requirements. Generally, the disadvantages of using mechanical metering system for graining wheat grains are: The increasing in the needed grains amount per feddan, the spacing between wheat grains with in row is not controlled, the relatively long distance between the metering device and grain bed, this causes a lack of precise spacing, the excessive moving parts cause grain damage and the possibility limitation of operating speed (HGCA, 2000).

In contrast, the vacuum precision planters have the following advantages: more precise grain rates with lower rate of grain damage, better control and adjustment of upkeep and drift of grains, broader spectrum of applicability, more strict to the grain size, and no grain grading, it is tolerant to grains geometry for precision graining (He and Qiu, 2001; Huo *et al.*, 2003; Wang, 2006 and Ismail, 2008-b). Also, the singulation is more accurate and can adapt to the planting work at the higher speed and grains drilled by precision planting are sown with optimum row and within-row spacing depending on the graining requirements for each specific crop (Bracy *et al*. 1998 and Ismail, 1989).

As concerns, many researchers clarified that a precision metering mechanism and/or technology deals, gently, with the grains with no damage during planting, promotes its output and quality, being significant to stable and high yield (Zheliang *et al*., 2012 and Ruixue *et al*., 2009). It requires precise, quantitative and even graining, so that each wheat plant obtains equal space, sufficient water and fertilizer (Feng and Liu, 2004). On the other hand, the new types i.e. wheat precision graining grain-metering device (developed by China Agricultural University), small type pneumatic wheat precision graining sample machine (developed by Wheat Engineering Research Center in Shandong Province) and twin-disk pneumatic precision graining machine (developed by Hui (2003) in Shandong Agricultural University), have some defects and are not available in the markets (Liang *et al*., 2001; Jun *et al.*, 2000 and Hui *et al*., 2002). Other problems associated with using the imported precision vacuum planters for planting wheat grains under Egyptian conditions are: The imported precision vacuum planter in the Egyptian market is too limited for planting wheat grains, it requires special skills for operating, the design of the metering system and the distance between precision units is not suitable to the most of the local wheat grains, the precision vacuum planter doesn't perform the appropriate distance between wheat rows and row planting allows me to cultivate the weeds during the early stages of plant growth.

Generally, among different sowing techniques, precision sowing is the preferred method since it provides more uniform grain spacing than other methods. However, the most commonly adopted precision vacuum planters are equipped to release single grain in furrows in accordance with the desired plant spacing, by using a modular rotating grain disc under negative pressure. Plant spacing is directly related to grain spacing uniformity and it can affect both vegetative, reproductive growth and yield. As stated by (HGCA, 2000), 15 varieties of wheat were investigated using two grain rates (320 grains m^{-2} and 80 grains m^{-2}). The results showed that varieties had similar mean yields (ton ha^{-1}) and had no effect on optimum plant production. Considering that the quality of feed index for precision graining should be at least greater than or equal to 82.3 %. Yasir *et al.* (2012) developed the pneumatic precision metering device for wheat. The performance of the device, including quality of feed index, multiple index, miss index and grain rate expressed in number of grains per meter length (SPM), was investigated under laboratory conditions in Wuhan using a test stand with camera system. The (SPM) was less than the recommended compared to previous hypothesis. The best grain was 53 SPM at rotating speed of 34 rpm and negative pressure of 4.5 kPa, it can be observed that the pneumatic precision metering device for wheat could achieve a uniform distribution and grain rates estimated at 40 KPM and 53 KPM in case of 12 cm and 15 cm row spacing, respectively.

In Egypt, few studies were observed that related to vacuum precision seeder for planting wheat grains. Consequently, it is necessary to develop new vacuum precision metering device, in particular, to meet the sowing wheat grains requirements within the recommended grain rate for increasing productivity and decreasing the production cost of wheat cultivations. The recommended wheat grain rate for all irrigated schemes is very high, which is 143 kg ha^{-1} (El-Awad *et al.*, 2003).

The main objective of the present study is to develop grain metering device suitable for wheat grains and tolerant to grains geometry for vacuum precision planter to meet the following requirements:

1. Plant rows with 150 mm apart instead of 300 mm apart as the most imported machines in the market do.
2. Reducing grain rates per feddan.
3. Generate a suitable vacuum pressure to pick the grain for the two rows.
4. Place the grain at proper depth and distance.

MATERIALS AND METHODS

Field experiment has done in 2013/2014 in Gemiza Research Station, Gharbia gov., Egypt by developing grain-metering device for planting wheat grains into two rows at 150 mm spacing rows apart instead of 300 mm like other imported precisian vacuum planters as maximum extent in the local market. The grain metering device is fabricated in private workshop and connected in the same imported VPP. To evaluate the performance of developed grain metering vacuum device, three main steps were done as follows:

1. Physical characteristics of wheat grains:

Moisture content (%)

The moisture content of wheat grains was determined using a gravitational method **(ASAE Standard, 1999)** from the following equation:

$$\text{Moisture content, \%} = \frac{\text{Mass of samples} - \text{Mass of dry samples}}{\text{Mass of dry samples}} \times 100 \qquad (1)$$

Linear dimensions: Three samples of wheat grains (Gemeza 9) (100 grains per each sample) were taken to determine the three linear dimensions *(L: length, W: width and T: thickness)* in mm. The measurements were done using a digital caliper with a sensitivity of 0.01 mm.

Geometric mean diameter *(Dg)*

The geometric mean diameter *(Dg)* of grains wheat is very essential for designing the hole diameter on the grain plate. The geometric mean diameter *(Dg)* was determined from the samples of linear dimensions of wheat grains according to **(Singh and Saraswat, 2005)** as the following equation:

$$D_g = (LWT)^{1/3} \qquad (2)$$

Table 1: Physical characteristics of wheat grains:

Physical properties of wheat	*Sample 1*	*Sample 2*	*Sample 3*	*Mean*	*SD*
Length, L (mm)	6.23*	6.22*	6.24*	6.23	±0.54
Width, W (mm)	3.29*	3.32*	3.34*	3.31	±0.39
Thickness, T (mm)	2.71*	2.74*	2.73*	2.72	±0.30
Geometrical mean diameter, Dg (mm)	3.81*	3.83*	3.84*	3.83	±0.02
1000 grain mass (g)	41.11	40.12	39.99	41.41	±1.37
Moisture content (db) (%)	8.96**	9.31**	10.4**	9.56	±0.70

***: Average of 100 readings**
****: Average of 5 readings. SD: Standard division.**

2. Grain- metering mechanism and grain suction performance:

Vertical grain plate

A modification including redesigning of the grain metering device is done to planting two rows with 150 mm apart instead of one row with 300 mm. The new grain plate with outer diameter (OD) of 230 mm fabricated from Steel heating treated with 2 mm thickness. The holes in each grain plate were drilled into two cells (Fig. 1). The pitch circle diameters of the holes were 211 mm and 200 mm for the first and second cells, respectively. The number of cells in each row was 40 holes. The calculated diameter of the cells was 1.9 mm based on ≤ 50 % size of the geometric mean diameter for wheat (Singh and Saraswat, 2005).

Plate of vacuum flow

The plate of vacuum flow was made from Teflon with outer diameter 230 mm. Two circular air chambers (canals) were bored into plate as air path for the first and second rows (Fig. 2). The function of the two vacuum canals was delivered the vacuum from the vacuum pump to grain plate. Where, the grain could pick up on the holes by the action of vacuum canals. The grain plate and plate of vacuum flow where mounted to the drive shaft of the precision vacuum planter. The negative pressure was measured for two rows using vacuum gauge under 1.9 mm hole diameter of grain plate. The negative pressure values ranged from 4.5 to 5.5 kPa **(Yasir *et al.*, 2012)**.

Grain delivery device

Grain delivery devices were fabricated from iron material and fixed in the bottom of planter up the pitch circle diameters of grain plate for two rows. The stuck grain is released from the rotating grain plate with the help of vacuum-cut which is situated over the rearward furrow opener. The absence of suction allows the grain to be dropped into a short dropper tube of grain delivery device to rearward furrow opener.

The dimensions of the grain delivery device were 105 mm length and 14 mm thickness for the first and the second rows (Figs.3 and 4).

A rearward curve of furrow opener

It was used to enable the developed metering vacuum device to plant two rows instead of one row for each unit. The cutting edge of the opener is 15 mm width and 200 mm length. The total length of the rearward curve is 165 mm and 185 mm height. Each unit of vacuum precision planter is connected with two openers below the units and the openers are mounted on the frame. To adjust the distance between rows the openers can be sliding on the frame by increasing or reducing to the required distance between two rows (15 cm).

A rearward curved furrow opener is used to include a wide range of tine mounted dedicated furrow openers that can have a near vertical, rearward curved leading edge with side plates that enclose the grain delivery system or otherwise assist in preventing soil movement back into the furrow before grain placement. Figs. 5 and 6 show the general forms of this type.

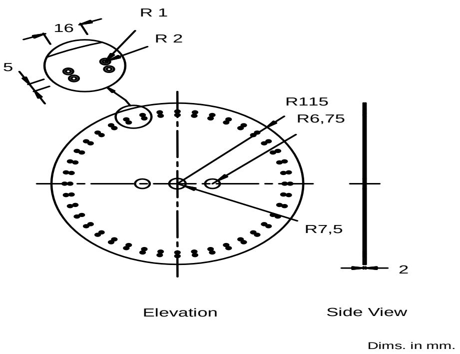

Fig. 1: Schematic diagram of the vertical grain plate.

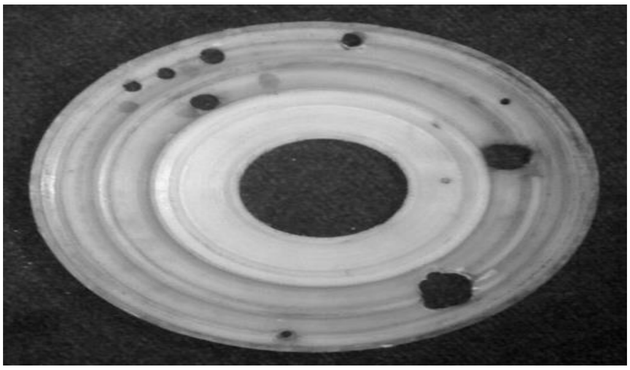

Fig. 2: Plate of vacuum flow

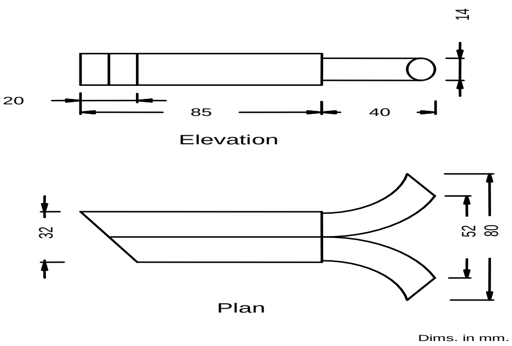

Fig.3: Grain delivery device

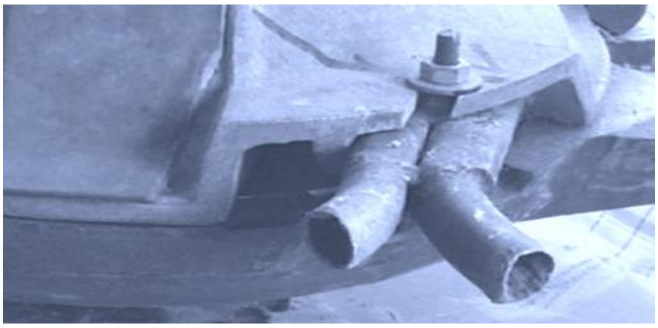

Fig. 4: Photo of the grain delivery device

Fig. 5: A rearward curve furrow opener

Fig. 6: After ridging rearward curve furrow opener

3. Field Test

Experimental field design

The experimental design was laid out in a randomized completely block design, with three replications and included (1) three forward speeds (F) (2.5, 3.1 and 4.8 kmh^{-1}), and (2) four disc speeds (D) 25 (0.28), 31 (0.34), 37 (0.41) and 49-rpm, (0.54 m/s). An area of about 3888 m^2 was divided into 36 plots, with plot area of 108 m^2 (20 m length and 5.4 m width). All treatments were sown with the same variety (Gemeza 9). The standard deviation was calculated to test the quality of grain metering device according to (Singh *et al.,* 2005). As shown Figs. 7 and 8 the precision vacuum planter was adjusted to deliver grain at a theoretical grain spacing (nominal grain spacing) to used different amount of grain rates per feddan. The vacuum metering device developed and adjusted to put the grains with a 150 mm distance between two rows and at 50 mm depth of planting. The developed vacuum planter was operated by a Massy Ferguson tractor model 290, 2WD, of about 75 hp. The tractor travel speed was selected according to the tractor gear box; then the actual travel speed during tests was measured three times for each nominal speed. The pneumatic type is vacuum and made in Italy and it has 6 units. The precision vacuum planter was adjusted to deliver grain at grain spacing of 26 to 80 mm in row. The grain-metering device driven by land wheel, it rotates through chain drive. The grain rates adjacent to each plot by different forward speeds and disc speeds and checks seedlings within fifteen days after graining.

Fig. 7: Gear box for change grain plate speeds.

Fig.8: Vacuum precision planter.

MEASURMENTS

Grain spacing:

The grain spacing in the field was measured manually in one meter length, for each plot, and then the actual grain spacing, grain miss index, grain multiple index, quality of feed index and precision in spacing were calculated.

The theoretical spacing is given by the following simple formula **(Yasir *et al.*, 2012)**:

$$\text{Theoretical spacing (mm)} = \frac{\text{Forward speed}(kmh^{-1}) \times 1000000}{60 \times \text{rotational speed (rpm)} \times \text{number of holes}} \quad (3)$$

The performance parameters for the precision planter are as follows:

Miss index:

The miss index is the percentage of number of spacing greater than 1.5 of actual spaces (n_1) relative to the total number of measured spacing (N) (Ismail, 1989).

$$I_{miss} = \frac{n_1}{N} \times 100 \quad (4)$$

Where: n_1 is number of spacing > 1.5 S; and N is total number of measured spacing.

Multiple index:

The multiple index (I_{multi}) is the percentage of number of spacing that are less than or equal to half of the set plant distance S in mm relative to the total spacing N. **(Ismail, 1989)**.

$$I_{multi} = \frac{n_2}{N} \times 100 \quad (5)$$

Where: n_2 is number of spacing ≤ 0.5 S.

Quality of feed index:

The quality of feed index (I_{qfi}) is the percentage of spacing that are more than half but not more than 1.5 times the set planting distance S in mm. The quality of feed index is an alternate way of presenting the performance of misses and multiples (singh *et al.,* 2005).

$$I_{qfi} = 100 - (I_{miss} + I_{multi}) \quad (6)$$

Spacing uniformity:

The precision of grain spacing is a measure of the variability (coefficient of variation) in spacing X_{ref} between grains after accounting variability due to both multiple and miss indexes (singh *et al.*, 2005).

$$P_r = \frac{S_2}{X_{ref}} \times 100 \quad (7)$$

Where:

P_r:precision in spacing (%), and

S_2:standard deviation of the measured spacing more than half but not more than 1.5 times the theoretical spacing(X_{ref}).

Graining rate:

Table 2 shows the grain sowing rates for all plots under experiment.

Table 2: Graining rates for different disc speeds and forward speeds

Disc revolution per minute	Forward speed (Km/h)	Graining rates (Kg/ fed)	No. of grains/m	No. of grains/m^2
	2.5	27	23	161
25	3.1	22	19	133
	4.8	14	12	84
	2.5	34	29	203
31	3.1	27	23	161
	4.8	17	15	105
	2.5	41	35	245
37	3.1	33	28	196
	4.8	21	18	126
	2.5	56	48	336
49	3.1	44	38	266
	4.8	28	24	168

Field capacity

The field capacity for the precision grainer was determined under different levels of forward speeds using the following equation (Elmo, 1981):

$$FC = \frac{W \times FS \times \eta f}{4.2} \quad (8)$$

Where:
FC:Field capacity, (fed/h), W: Operation width, (m),
FS:Forward speed, (km/h) η_f: Field efficiency, (%).

Yield and yield components

After harvesting all plots under our study, three random readings of grains and straw yields per plot were taken. Sample of 20 % was randomly selected on the basis of fresh weight, the weight is recorded. The spike wheat was then removed and the spike wheat and straw dried in oven till constant weight. The dry spike wheat was threshed to separate the grain and the chaff and then grain were weighted.

RESULTS AND DISCUSSION

Actual Grain Spacing

Data illustrated in Fig.9 show the effect of the forward speed on the actual grain spacing at different levels of disc speeds for the first row. Results show that the actual grain spacing is decreased by increasing the disc speed at various levels of forward speed. On the other hand, the actual grain spacing increased as the forward speed increased at various levels of disc speed. The decreases in the actual grain spacing were 43.4%, 49.1%, and 47.5 % as the disc speed increased from 25 to 49 rpm for 2.5, 3.1 and 4.8 km/h forward speed, respectively. The increase in the actual grain spacing were 42.5%, 43.7%, 32.6% and 38.1% as the forward speed increased from 2.5 to 4.8 km/h for 25 (0.28), 31 (0.34), 37 (0.41) and 49-rpm, (0.54 m/s) disc speed, respectively.

At 3.1 km/h forward speed, the actual grain spacing decreased by 21.8 % as the disc speed changed from 0.28 m/s to 0.34 m/s. On the other hand, the changed in the actual grain spacing were 13.9 % and 24.3 % as the disc speed changes from 0.34 m/s to 0.41 m/s and 0.41 m/s to 0.54 m/s, respectively. The highest values of the actual grain spacing were obtained at 24.4-rpm (0.28 m/s) disc speed. These values are 4.6, 5.5 and 8.0 cm at 2.5, 3.1 and 4.8 km/h forward speeds, respectively. However, the lowest values of the actual grain spacing were obtained at 49-rpm (0.54 m/s) at different forward speeds. These values are 2.6, 2.8 and 4.2 cm at 2.5, 3.1 and 4.8 km/h forward speeds, respectively. The middle values of the actual grain spacing were obtained at 0.34 and 0.41 m/s disc speeds. Comparative performance between row1 and 2 in respect of the disc speed almost gave similar results. The previous results may be attributed to the ratio of speed reduction between the forward speed and the disc speed decreased with an increase in the disc speed at any level of forward speed, which may cause decreasing in the actual grain spacing. These results are in agreement with previous findings by (Karayel *et al.,* 2004)

Grain Miss Index

Fig.10 shows the effect of the forward speed on the grain miss index, % at different levels of disc speeds for the first row. It shows that, the grain miss index increased as the disc speed increased at various levels of forward speeds. The increase in the grain miss indices were 50.4 %, 43.7 % and 27.8 % as the disc speed increased from 25 (0.28 m/s) to 49 rpm (0.54 m/s) for 2.5, 3.1 and 4.8 km/h forward speeds, respectively. At 3.1 km/h forward speed, the values of the grain miss indices were less than the values of the grain miss indices at 2.5 and 4.8 km/h forward speeds. On the other hand, the changes in the grain miss indices were 6.8 %,10.7% and 32.2 % as the disc speed change from 25-rpm (0.28 m/s) to 31-rpm(0.34 m/s) , 31-rpm(0.34 m/s) to 37-rpm (0.41 m/s) and 37-rpm(0.41) to 49-rpm (0.54 m/s), respectively.

The highest values of the grain miss index were obtained at 49-rpm (0.54 m/s) disc speed. These values are 12.3, 9.6 and 9.7 % at 2.5, 3.1 and 4.8 km/h forward speeds, respectively. However, the lowest values of the grain miss indices were obtained at 25-rpm (0.28 m/s) at different forward speeds. These values are 6.1, 5.4 and 7.0 % at 2.5, 3.1 and 4.8 km/h forward speeds, respectively. These results due to that the grain plate at high disc speed does not get enough time to pick up grains, which resulting a higher values of miss indices. Comparative performance between row 1 and 2 in respect of the disc speed almost gave similar results.

Grain Multiple Index

Data in Fig.11 shows the effect of the forward speed on the grain multiple index at different levels of disc speeds for the first row. It shows that, the multiple index decreased as the disc speed increased at various levels of forward speeds. The decrease in the grain multiple index were 6 %, 8.7 %, 20.3 % and 19.8 % as the forward speed increased from 2.5 to 4.8 km/h for 25, 31, 37 and 49-rpm disc speeds, respectively. The highest values of the grain multiple indexes were obtained at 25-rpm (0.28 m /s) disc speed under different levels of forward speeds. These values were 7.9 %, 5.4 % and 7.0 % at 2.5, 3.1 and 4.8 km/h forward speed, respectively. However, the lowest values of the grain multiple indices were obtained at both 3.1 km/h forward speed under different levels of disc speeds. The change in the disc speed from 25-rpm to 49-rpm produces a decrease in the grain multiple index by 59.4%, 48 .1% and 27.8 % for 2.5, 3.1 and 4.8 km/h forward speeds, respectively. These results due to that the grain plate at low disc speed get enough time to pick up more than one grain, which resulting a higher in multiple indices. These results are in agreement with (Panning *et al*., 2000).

Results of the second row showed similar trends with the first row at different levels of disc speeds (Fig. 11) except for the grain multiple index for the second row increased by 10% and 20% as a compared with the first row for 2.5 and 3.1 km/h forward speeds, respectively under different levels of disc speeds. However, the grain multiple index for the first row increased by 32 %, 12 % and 10 % as a compared with the first row for 25, 37 and 49 rpm disc speeds, respectively. These results may have been due to the increase in the cross-sectional area of air chamber for fist row as a compared with that for second row.

Quality of Feed Index

Fig.12 shows the effect of forward speed on the quality of feed index under various levels of disc speeds. It is indicated that, the highest values of the quality of feed indexes were obtained at 3.1 km/h forward speed under different levels of disc speeds. These values were 89.1 %, 90.9 %, 91.3 % and 85.6 % at 25, 31, 37 and 49 rpm disc speed, respectively. However, there were no potential differences in the quality of feed index under 2.5 and 4.8 km/h forward speeds under different levels disc speeds for the first row. These resulted may be due to that the increase in the grain miss index (40 %) is closest the decrease in the grain multiple index (60%) as the disc speed changed from 25 to 49-rpm at any levels of forward speeds. The quality of feed index for the second row does not increase by not more than 1 % as a compared with the first row at different levels of forward and disc speeds (Fig.12).

Fig. 9: Effect of the forward speed on the actual grain spacing at different levels of disc speeds for the first and second row.

Fig. 10: Effect of the forward speed on the grain miss index at different levels of disc speeds for the first and second row.

Fig. 11: Effect of the forward speed on the grain multiple index at different levels of disc speeds for the first and second row.

Spacing uniformity

Data illustrated in Fig.13 show the influenced of forward speed on the uniformity in spacing under various levels of disc speeds. It is found that, the highest values for the uniformity in spacing were resulted under 2.5 km/h forward speed through 25, 31, 37 and 49 rpm of disc speeds, respectively. However, the lowest values for the uniformity in spacing resulted with 3.1 km/h forward speed under 25, 31, 37 and 49 rpm disc speeds, respectively. The Spacing uniformity decreased as the forward speed increased from 2.5 to 3.1 km/h. whereas, the spacing uniformity increased as the forward speed changed from 3.1 to 4.8 km/h. Results of the second row in the uniformity in spacing showed similar trends as the first row at different levels of forward speeds and disc speeds.

Actual field capacity for the vacuum precision planter

Since the developed vacuum precision planter was used to plant two rows. Therefore, six developed units were inserted to the same frame. The data show the effect of forward speed on the actual field capacity for the developed precision vacuum planter under three replicates at different levels of disc speeds (Fig.14). The actual field capacity increased with an increase in the forward speed. The highest values in the actual field capacity were obtained at 4.8 km/h forward speed. However, the lowest values of the actual field capacity were obtained at 2.5 km/h forward speed. The increase in the forward speed from 2.5 to 4.8 km/h produced an increase in the actual field capacity by about 39.4 %. These results may have been attributed to the following reasons:

Fig. 12: Effect of the forward speed on the quality of feed index at different levels disc speeds for the first and second row.

Fig. 13: Effect of the forward speed on spacing uniformity at different levels of disc speeds for the first and second row.

Fig. 14: Effect of forward speeds on actual field capacity for the vacuum precision wheat planter with three replicates.

1- The theoretical field capacity increased as the forward speed increased under experimental conditions. The increase in the theoretical field capacity was 15.3 % as the forward speed increased from 2.5 to 3.1 km/h. While the increase in the theoretical field capacity was 28.4 % as the forward speed increased from 3.1 to 4.8 km/h.
2- The planting time decreased as the forward speed increased. On the other hand, the losses time, which includes turning time, filling and adjusting time were constant at different levels of forward speeds. The decreases in the planting time were 19.1 % as the forward speed increased from 2.5 to 3.1 km/h. While the decrease in the planting time was 29.6 % as the forward speed increased from 3.1 to 4.8 km/h.
3- The field efficiency decreased as the forward speed increased. The decrease in the field efficiency was 5 % as the forward speed increased from 2.5 to 3.1 km/h for two rows. While the decrease in the field efficiency was 9.9 % as the forward speed increased from 3.1 to 4.8 km/h.

Effect of the grain rates on the grain and straw wheat yields

Wheat grain yield

Data presented in Table (3) revealed that the differences between grain rates for wheat grain and straw yield per feddan. It shows that, the grain rate per feddan decreased as forward speed increased at various levels of disc speeds. It is also indicated that, the highest values of the grain rate per feddan were obtained at 2.5 km/h forward speed under different levels of disc speeds. These values were 27, 34, 41 and 56 kg/fed. However, the lowest values of the grain rate per feddan were obtained at 4.8 km/h forward speed under different levels of disc speeds. These values were 14, 17, 21 and 28 kg/fed at 3.1 km/h forward speed, the grain rates per feddan were 22, 27, 33 and 44 kg/fed under different levels of disc speeds.

At 2.5 km/h forward speed and 25, 31, 37 and 49 rpm disc speeds. The grain yields were 2488.0, 2765.3, 2761.3 and 2758.6 kg/fed for 27, 34, 41 and 56 grain rates/fed., respectively. It is important to notice that the lowest values of the grain yield per feddan were obtained at 27 kg/fed grain rate. However, the grain yields fixed for the grain rate 34, 41 and 56 kg/fed. The same trend was found for 3.1 and 4.8 km/h.

It is clear from Table (3) that the wheat grain yield was higher as amount of grain rates increased from 14kg/fed to 33kg/fed. However, the wheat grain yield were equal (2670 kg/fed) at the grain rates were 34, 44, and 56 kg/fed. Therefore, the lower grain rate of up to 34 kg/fed (43.3% of the recommended) could be used. These results are in harmony with those obtained by (HGCA, 2000). The developed precision vacuum planter for wheat grain could be used successfully with reducing grain rate by 43.3 % from the recommended grain rate organization in Egypt. Similar grain yields were obtained with feeding rates 41, 44 and 56 kg/fed grain rates.

Table 3. Effect of the grain rates on the grain and straw wheat yields

Forward speed (km/h)	Disc revolution per minute	Required grain rates (kg/fed)	Number of grains/ m^2	Av. yield grain (g/m^2)	Av. yield straw (g/m^2)	Av. yield grain (kg/fed.)	Av. yield straw (kg /fed.)
2.5	25	27	161	621.6	1067.6	2488.0	4269.3
	31	34	203	690.6	1130.3	2765.3	4521.3
	37	41	245	690.3	1130.3	2761.3	4521.3
	49	56	336	689.6	1129.6	2758.6	4518.6
3.1	25	22	133	579.6	1029.6	2258.6	4118.6
	31	27	161	621.6	1067.6	2488.0	4269.3
	37	33	196	680.3	1120.3	2721.3	4481.3
	49	44	266	690.3	1130.3	2761.3	4521.3
4.8	25	14	84	529.6	919.6	2118.7	3678.6
	31	17	105	549.3	1004.3	2197.3	4017.3
	37	21	126	552.3	1029.6	2209.3	4118.6
	49	28	168	649.3	1104.3	2597.3	4417.3

Wheat straw yield

Table (4) shows the effect of the grain rates on the straw wheat yields. It is indicated that, the highest values of the straw yields per feddan were obtained at 34, 41, 44 and 56 kg/fed grain rates. However, the lowest values of the straw yields per feddan were obtained at 14, 17 and 21 kg/fed grain rates. While the middle values were obtained at 22, 27, 28 and 33 kg/fed grain rates.

Table 4. Cost of required grain rates for all treatments and grain yield income

	Methods of wheat growing	Treatments	Required grain rates (kg/fed)	Grain rates cost per fed. (LE /fed)	Grain yield income (LE/fed)
1	Vacuum precision planter	F1D1	27	135	6966.4
		F1D2	34	170	7742.8
		F1D3	41	205	7731.6
		F1D4	56	280	7724.1
		F2D1	22	110	6324.1
		F2D2	27	135	6966.4
		F2D3	33	165	7619.6
		F2D4	44	220	7731.6
		F3D1	14	70	5932.4
		F3D2	17	85	6152.4
		F3D3	21	105	6186.04
		F3D4	28	140	7272.4
2	Traditional sowing		60	300	7560.0

F1, 2 and 3: Forward speeds (km/h)
D1, 2, 3 and 4: Disc speeds (rpm)
Price grain rates = 5LE /kg   Price grains = 2.8 LE /kg

It is important to notice that the grain rate 34 kg/fed produced the same straw yields from the grain rates 41, 44 and 56 kg/fed. These results are in harmony with those obtained by **(Spink *et al.* 2000)**.

Costs of grain rates and grain yield income

In Egypt, most farmers are sowing wheat by using traditional graining methods 325-400 grains/m^2, with a recommended rate 60 kg/fed with a cost of 300 LE/fed. However, 34 kg/fed of the same grain yield production, costing 170 LE /fed. (Table 4) is sufficient to achieve a grain rate of 203 grains / m^2, which allows for 43.3% losses to achieve target plant population.

SUMMARY AND CONCLUSION

The graining rate of wheat using vacuum precision planter (VPP) is 34 kg/fed instead of 60 kg/fed when using the tradition sowing method. The developed precision vacuum planter is tested under three forward speeds (2.5, 3.1 and 4.8 km h^{-1}), and four disc speeds (25, 31, 37 and 48 rpm). Vacuum precision planter provides the same wheat grain yield up to 2.8 ton/fed. The developed vacuum planter for wheat could be used successfully and should save about 43.3 % of the recommended grain rate (60 kg/fed) for wheat crop establishment in Egypt. This reduces the operation costs by 247,520,000 LE for total cultivated area in Egypt.

The obtained results may be attributed to:

1- Reducing the grain rate increase anchorage of the plant which increasing shoot number per plant. Thus, reducing grain rate may reduce lodging risk, and will be especially appropriate in early sown crops, as work by Spink *et al.* (2000) showed that with a longer growing period, crops sown at lower grain rates had more time to compensate for lower plant populations than crops with shorter growing periods (i.e. later sown crops).
2- Wheat plants can produce over 20 tillers / plant, particularly when sown early. Even plants of fast developing varieties continued to tiller until flag leaf emergence if growing conditions were good. Any varietal differences in tillers observed at normal plant populations largely disappeared at lower densities, when there was less competition between plants. Variety, therefore, has no effect on optimum plant population.
3- It is clear from results that sowing wheat in rows methods by using vacuum precision planter produced the higher grain yield/fed and for most of yield attributes. It can be concluded that these superiority may be due to the excellent plant distribution in the field between and in rows which reflected on best condition of space, light, air and high response to fertilization in turn on yield and most yield attributes.

RECOMMENDATIONS

According to the obtained results, it is recommended to use the developed precision vacuum planter for wheat crop with 43.3 % of the recommended grain rate (60 kg/fed) in Egypt.

Further investigations can be done using the same modified machine under ridging soil.

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تطوير وتقييم اداء وحدة تلقيم دقيقة تناسب زراعة القمح

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يهدف البحث الى تطوير جهاز التلقيم للبلانتر المستورد لزراعة حبوب القمح على مسافة 150 مم بين الصفوف بدلا من 300 مم (حيث ان المسافة بين كل وحدتين متجاورتين فى البلانتر المستورد لا يمكن تقليلها عن 300مم) كباقى آلات الزراعة المستوردة الموجودة بالسوق المحلى بالإضافة الى التحكم فى المسافات داخل الصف الواحد. تم اختبار البلانتر المعدل بمحطة بحوث الجميزة موسم 2013 – 2014 م تحت اربعة سرعات لقرص التلقيم (31,25, 37, 49 لفة / دقيقة) بالإضافة إلى ثلاث سرعات تقدم مختلفة (2.5, 3.1, 4.8 كم / ساعة). حيث ان تأثير تفاعل السرعات الأمامية مع سرعات قرص التلقيم اعطى 12 معدل تقاوى للفدان .وتم تقييم تأثير معدلات التقاوى الناتجة على كل من محصول الحبوب والتبن للفدان .وتم قياس كل من متوسط مسافات الزراعة وعدد البذور فى المتر المربع ومؤشر فقد البذور ومؤشر التعددية وجودة جهاز التلقيم ودقة مسافات الزراعة كعوامل لتقييم جهاز التلقيم المطور. حيث أوضحت النتائج تساوى معدلات التقاوي (34, 41, 44, 56 كجم / للفدان) في إنتاجية محصول القمح والتبن والتي كانت (2.8 طن/فدان حبوب, 4.3 طن /فدان تبن. على التوالي). ولذلك نوصى بإستخدام معدل التقاوى 34 كجم/فدان لزراعة بذور القمح الذى يؤدى بدورة الى تخفيض كمية التقاوى للفدان بنسبة 43 % مقارنة بمعدلات التقاوى الموصى بها بمصر. ومن ثم يعتبر التصميم الجديد لجهاز التلقيم والذي يعمل بشفط الهواء هو الحل الفعال للتحكم في كمية التقاوي للفدان مع الاحتفاظ بتساوى مسافات الزراعة داخل وبين الصفوف للمساحة المنزرعة قمح في مصر.