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Research Article

An Evaluation of Seed Spacing Accuracy of a Multi-Row Pneumatic Plate for Precision Rapeseed

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Abstract: The main objective of this study was to investigate the performance of a single pneumatic plate with four-rows for rapeseed precision using an adjustable plastic slice for changing vacuum around the metering nozzle entrance. The slice was located near plate surface at seed pick-up area of rows holes closer to the rotation center of the plate (row 1and 2) owing to their multiple seed pick-up. Five clearances between the slice and plate surface have been inspected at 15 and 20 r/min combined with their optimum vacuum amount to detect the best clearance for same rows seed pick-up. Laboratory test demonstrated that 1 mm was the best clearance, which in turns used for verifying seed distribution regularity among the rows. Results disclosed that the optimum negative pressure associated with 15 r/min and 20 r/min were 1.15 kPa and 1.25 kPa, respectively. 15 r/min resulted in quality index of 91.34%, 92.83%, 91.7% and 90.65%, while 20 r/min attained 89.81%, 92.23%, 89.86% and 92.05% for rows 1, 2, 3 and 4, respectively. The highest seed feed index was obtained by row 2 at both speeds, while the lowest value (89.81%) was achieved by row1 at 20 r/min. Both the separate rows stability and rows consistency resulted in less than 2%, with some tendency of 15r/min to be more consistent than 20r/min. Results concluded that the multi-rows pneumatic plate coupled with plastic slice technique is able to satisfy the required seed precision without damage which could be employed for further advanced investigations.

Keywords: Multi-row plate, pneumatic metering device, rapeseed, seed precision

INTRODUCTION

Precision planting principle was established by Datta since 1940s (Yasir *et al*., 2012). It's known as a locating of individual seeds in an appropriate and desired spacing (Liao *et al*., 2009). The more accurate seed precision, the better value of the produced crop. Precision planting decreases unnecessary use of seeds by reason of regular distribution, prevent seed rolling which result in specific seed number along with a unit length and make easier to perform subsequent field processes, like weed-suppressing and harvesting with lower cost (Domier, 1991). Furthermore, the operation reduces plants competition by providing an optimum gap for each growing plant which increases productivity (Heege, 1993).

Seed metering process relies mainly on the metering device, which is considered an essential constituent in the planter (Yang *et al*., 2016). Numerous types of metering units are recently employed in precision seeding, among them are belt type, slant plate, vertical rotor, fluted roller and pressurized plate types (Guler, 2005; Boydas and Turgut, 2007). The device working is either of mechanical or pneumatic principle. The first depends on mechanical forces, such as gravity, centrifugal and the like, while the other utilizes the pneumatic system as an extra appliance to generate airflow pressure. The pneumatic type devices are superior compared with mechanical ones due to their accurate seed rate, lower broken seed ratio, better seed sucking, maintaining and dropping (Searle *et al*., 2008; Guozhong *et al*., 2015; Liu *et al*., 2016).

Rapeseed described as round, light in weight, thinly coated and easily be damaged by a little shear force (Li *et al*., 2012). By reason of these characteristics, it's tricky to achieve sowing requirements with mechanical types, whereas some seeds may expose to damage and close metering nozzles (Jiajia *et al*., 2014). Accordingly, researchers adopted three manners of pressure during optimization of rapeseed precision included utilizing of positive air for seed dropping, singling or combination of the two

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methods (Li *et al*., 2015). Some of them used positive gas pressure for seeds conveying coupled with mechanical seed feeding process (Lei *et al*., 2016). Others used vacuum pressure for seed sucking and positive pressure for dropping and blowing off any particles adhering to the nozzles (Liao *et al*., 2009; Cong *et al*., 2014a; Li *et al*., 2014).

One of the shortcomings of recently applied pneumatic plate types for metering rapeseed is their incapability to meter more than single row simultaneously (Liao *et al*., 2009; Cong *et al*., 2014b). These conventional disk-type metering devices are usually using a single plate with one row of holes on its periphery and fit a separate sowing unit of the planter. In other meaning, a separate metering system of the planter requires a separate metering plate for seed metering operation. This definitely makes the planter quite heavy, brings some complications of planter transmission and pneumatic systems, consumes more power and necessitates using of several planting units which they decidedly result in a further cost. The recently invented seed planting unit has been formerly investigated at several angular velocities combined with vacuum pressure; unfortunately, the rows of holes closer to plate center (row1 and 2) resulted in some multiple seeds in comparison with the other two rows. This situation necessitated using a method that is able to achieve equal seed pick-up of the rows. Therefore, a rigid plastic slice was employed as an endeavor for changing vacuum amount around the holes with multiple seeds as to attain same rows seed sucking. The prototype assured it's capability to suck and meter seeds through the four rows with a little variation, but the performance was remarkably improved by utilizing plastic slice technique for vacuum reducing through mentioned hole rows.

LITERATURE REVIEW

Various studies were formerly executed to explore the precision planters' performance. They provided a valuable information about the output of precision metering units either they were laboratory or field tests. Karaye *et al*. (2004) established a mathematical model depending on seed physical properties to recognize the optimum vacuum value of a seed planter. Rapeseed pick-up capability by a pneumatic metering device was tested to obtain some findings of plate peripheral speed, hole number, nozzle diameter and radius of the orifice (Deng *et al*., 2010). Singh and others made a survey about the influence of rotating speed, negative pressure and hole entrance shape of a vacuum disk on cottonseed precision and they assessed the precision indices (skip, multiple and seed quality index). In addition, they proposed that the proper diameter of the nozzle was 2.5 mm. They also pointed out that 0.42 m/s and 2 kPa negative pressure provided 94.7% and 8.6% as a quality index and coefficient of variance, respectively (Singh *et al*., 2005). The working parameters, namely; applied vacuum, hole diameter and the plate velocity of planter were evaluated. Through these trials, the authors applied Response Surface Methodology (RSM) to search the seed distribution regularity. They concluded that 5.5 kPa vacuum amount and 3 mm puncture diameter were the best values to precise cotton seeds (Yazgi and Degirmencioglu, 2007). Five planter arrangements were studied for seed preciseness at three machine speeds. In this trial, an optoelectronic sensor system had been involved to detect seed location. They portrayed the seed distance stability by means of the coefficient of precision (Panning *et al*., 2000). Furthermore, the optoelectronic system was used to establish a laboratory measuring means for determining time intervals between successive dropping seeds and front and back position incidents as to reveal the accuracy of distributed seeds (Lan *et al*., 1999; Kocher *et al*., 1998)· Using cotton and maize cereals, Moody and others appraised a pressurized-type row planter under field test at three peripheral speeds (0.16, 0.23 and 0.31 m/s) coupled with planter forward speeds (1.33, 2.0 and 2.7 m/s). Their investigations confirmed that the variance in seed spacing was proportionally increased with the linear velocity (Moody *et al*., 2003). The method of the high-speed camera was also involved to examine seed distribution accuracy and velocity of seed dropping. Seed preciseness resulted from camera system was compared with that of greased -belt stand which regarded as a reference. Under all tests with the camera system, no missing seed has been existed (Karaye *et al*., 2006). An estimation of pressure variation around metering nozzles was verified using a mathematical model. Some endeavors have been exerted for confirming the theoretical outcomes. Bench test stand incorporated with a computerized camera technique for seed observation was tried to verify the pneumatic disk performance for rapeseed precision. Results appeared that no seed damage was existed, while the precision operation was evidently influenced by disk speed and vacuum amount (Qingxi *et al*., 2009). Zhan and others studied a pressurized type cylindrical planter for rapeseed distribution. They applied the Computational Fluid Dynamics (CFD) method for computing the affecting forces on fallen seeds, accordingly, they clarified seed movement and dropping trajectories via a number of numerical equations (Zhan *et al*., 2010). Their trials integrated with greased-belt test resulted in sensible findings. Rapeseed pick-up capability by a pneumatic metering device was tested and some findings of plate peripheral speed, hole numbers, nozzle diameter and radius of the orifice were obtained (Deng *et al*., 2010).

The main target of the study was to build up and examine the performance of a single pneumatic plate with four-rows for rapeseed precision aiming at reducing the number of metering units in the planter and remove inessential parts and then avoid unnecessary costs. The study was executed as to:

- Examine the effect of plastic slice clearance on rows seeds pick-up similarity.
- Detect the regularity of rows seed pick-up and appropriate vacuum amount for same seed sucking through four rows levels.
- Investigate the similarity in seed distribution of the rows relying on the Quality of Feed Index (QFI), Multiple Indexes (MULI) and Miss Index (MISI) accompanied by the rows quality index consistency.

MATERIALS AND METHODS

Structure and working principle of the multi-rows metering plate: The prototype metering unit using a vertical plate with four-rows was developed for sowing rapeseed. One face of the plate was connected to vacuum pressure at seed sucking stage and positive air at release points, while the other side was attached to seed supply source and seed dropping tubes. Figure 1a showing the main components of the seed metering device, while Fig. 1b presents the metering plate with four rows of metering holes mounted to the pressure chamber.

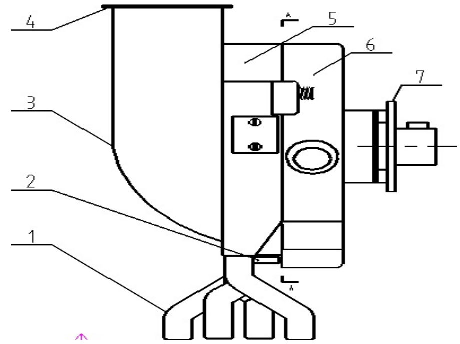
The air chamber of the device was made with two cavities; one was connected to the vacuum pump, while the other receives positive pressure. The top edge of positive pressure cavity was machined to be at a horizontal level to allow positive pressure connects to the four nozzles of rows simultaneously when aligning at release points as to secure same dropping time.

The metering plate was 160 mm in diameter, perforated with 40 round holes around its center of rotation. Four circles of holes were punched and hence four rows for an evaluation of the device performance (Fig. 1b). Each hole was drilled to 1.2 mm as a diameter. 30 mm was the distance of the first holes row from the disk center, while 14 mm was the clearance between each adjacent hole rows. Zhang (2007) stated that the diameter of the metering hole for metering small seed size was selected due to formula1:

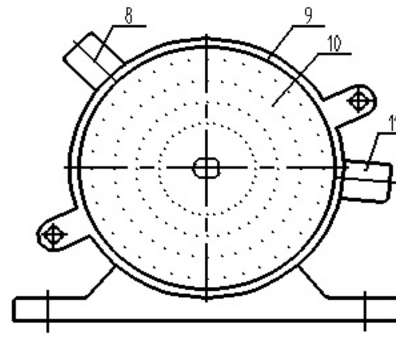
$$dx = (0.64\ to\ 0.66)b \quad (1)$$

where,
dx = Hole diameter (mm)
b = Mean width of the seeds (mm)

Regarding seed physical properties of rapeseed, 1.5 mm and 2.4 mm were the lowest and highest means of seed width, respectively (Li *et al*., 2015). By applying the two means in the equation, the diameter of the holes ranged from 0.96-1.58 mm. The tests demonstrated that 1.2 mm was the most effective diameter size of the hole for seed capture (Cong *et al*., 2014a).



(a)



(b)

Fig. 1: (a): a schematic diagram of the multi-rows pneumatic plate metering device; (b): showing the metering plate in its groove on pressure chamber;
1. Seed tubes; 2. Seed discharge nut; 3. Seedbox; 4. Seedbox cover; 5. Plate cover; 6. Pressure chamber; 7. Driving gear; 8. Vacuum inlet; 9. Metering plate; 10. Metering hole; 11. Positive pressure inlet

According to rapeseed' angle of repose, a special seed box was equipped with an angle of 28° at the bottom and seed flow opening to provide and keep seed level accessible for the four rows levels under seed sucking stage (Fig. 2). The opening was cut in the box inner wall with an oblong shape starting from the bottom upwards which labeled as No. 4 as in Fig. 3. The height and width of the cut were 80 mm and 25 mm, respectively. The height was found to be enough for keeping seed available to the rows levels. Furthermore, a seed flow controller (as shown in Fig. 2 and labeled as No. 6) is a sliding plastic sheet mounted on seed flow opening which can be drawn up and down to control the level of seed flow to the metering plate and consequently it determines the number of rows needs to be utilized for seed metering process.

On the other hand, a rigid plastic slice was set up around the plate center of rotation with a part of it extends to cover the area over the adjacent two hole rows, namely row1and 2 (as shown in Fig. 2 and labeled as No. 4). This slice (Fig. 4) could be easily drawn to come nearer or farther from the disk surface, therefore it can influence vacuum amount passes

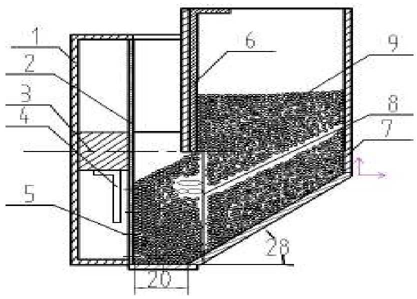


Fig. 2: Sectional side view of seed flow through seed flow opening incorporated with seed flow controller and the plastic slice for vacuum reducing;
1. Pressure chamber wall; 2. Seed metering plate; 3. Plate center of rotation; 4. Plastic slice (vacuum reducer); 5. Metering holes level; 6. Seed flow controller; 7. Seedbox; 8. Seed flow opening; 9. Seeds

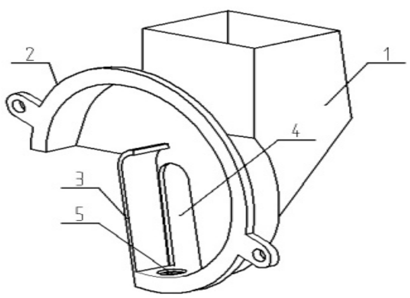


Fig. 3: A perspective view of metering plate shield showing seed flow opening, seed barrier and other parts; 1. Seedbox; 2. Plate cover or shield; 3. Seed barrier; 4. Seed flow opening; 5. Seed discharge hole

Fig. 4: Presents the plastic slice mounted around the housing of plate drive shaft and it can be drawn along this part as to come closer to the plate surface

through these nozzles. If the slice surface comes near to the plate surface, it will affect on vacuum amount passes through these holes, which in turns, will directly affect on seed pick-up process.

Seed tube (Fig. 5) is built as one unit in a rectangular box internally divided into four parts to create a separate groove for each row planting. The lower ends of these parts were turned into equal round tubes with 1.2 mm in diameter each. The same space between neighboring hole rows (14 mm) was given to the neighboring tubes. Each tube was bent at an angle of 135° from the vertical level downwards as to allow smooth seed dropping. The direction of each angle was

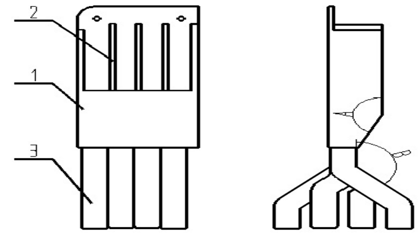


Fig. 5: Side views of seed tube unit showing the dropping tubes arrangement; 1. Seed tube body; 2. Separators; 3. Dropping tubes: Notes: A is155°; B is135°

made to be in opposite direction of the adjacent one as to make an easy connection with dropping hoses. The whole unit was connected to the prototype frame with its dropping tubes aligning with the disk metering holes during dropping stage.

The metering system relies on the vacuum and positive pressure for seed sucking and releasing, respectively. Under the stage of negative pressure, seeds are picked-up and cling to the holes of the metering plate. Further rotation of the plate results in seed releasing at positive blowing pressure, where seeds from the four rows simultaneously drop down because of the air connection to the four nozzles at the same time.

Test methods:

Using plastic slice method for vacuum reducing: Previous investigations were carried out on this device, but it resulted in some multiple seeds sucking of row1 and 2(closer to plate center of rotation) more than other two rows under the same vacuum and rotating speed, which may not allow precision seeding. An attempt through this study aiming at reducing vacuum around mentioned two rows was conducted as to reduce multiple seeds and maintain same seed pick-up of the rows and then same precision seeding. Therefore, a rigid plastic slice was fixed inside vacuum cavity at picking area with its flat surface extend opposite to disk surface over the row1 and 2 (Fig. 2 and 4). Due to the possibility of the slice to drag nearer and farther from plate surface, it will surely affect on negative pressure around these holes.

In this study, five clearances between the slice and plate surface, namely; 0, 0.5, 1, 2 and 3 mm were investigated to detect the effect on seed pick-up. The influence of each gap on seed sucking uniformity, in terms of seed mass, among the four rows was inspected at plate angular velocity of 15 and 20 r/min. The vacuum was adjusted under each speed to a value that was sufficient to suck seeds through the holes of row 3and 4 without any missing. The optimum clearance obtained from these experiments was employed for investigating seed distribution regularity on sticky belt test stands at the two mentioned speeds incorporated with their corresponding vacuum pressure values.

Fig. 6: The metering device on belt test stand for performance evaluation; 1. Greased belt; 2. Positive pressure line; 3. U-shape manometer; 4. Vacuum line; 5. Metering device; 6. Variable speed motor; 7. Air fan

Seed spacing evaluation: Seed distance regularity via the sticky or greased belt test has been formerly utilized for spacing evaluation of the seeder (Karaye *et al*., 2004). The belt test stands incorporated with a Computerized Measuring System (CMS) was used for monitoring seed spacing (Onal and Onal, 2009). The program provides the results of seed distribution in a numerical and graphical form. The prototype was located over the slimy belt (Fig. 6) and driven by belt mechanism as to provide the selected theoretical seed spacing according to the disk and belt speeds. As seeds release from the device, the oil provided on upper surface of the belt capture the seed with less rolling. In such a way, released seeds pass under the coverage area of the camera system.

The sticky belt was operated at a constant speed of 2.75 km/h. Seed spacing on the belt was calculated by computer software system due to Eq. (2):

$$theoretical\ spacing(mm) = \frac{beltspeed(km.h^{-1}) \times 10^6}{60 \times rotational\ speed(rpm) \times numberof\ hole} \quad (2)$$

Since the plate is vertical, the four rows are concurrently dropped seeds in the same line, which could not permit precision distribution. Due to this reason, each row was separately inspected for precision accuracy, while seeds in other rows were thrown off using a special ejector for this purpose. For each speed, the test was repeated five times and then the mean value of each index was obtained. Moreover, the (CV %) as explained by formula 3 was used to examine the stability and the consistency of quality index (Lü *et al*., 2016):

$$CV = \frac{S}{Z_m} 100 \quad (3)$$

where S is the standard deviation of the main distributed seeds and Z_m is the mean of seed spacings.

As reported by Singh *et al*. (2005), the precision indices could be calculated for the Pressurized planter as follows:

Miss Index (MISI): Miss index (I_{Miss}) as in Eq. (4) is the proportion of spacing bigger than 1.5 times theoretical planting distance (S) in mm:

$$I_{Miss} = {}^{n_1}/_{N} \times 100 \quad (4)$$

where, $n_1$is the spacing number> 1.5 *S* and *N* is the total number of measured spacings.

Multiple Index (MULI): The multiple index (I_{Mult}) as explained in Eq. (5) is the percentage of spacing that is lesser than or equal to half of the set seed distance (*S*) in mm:

$$I_{Mult} = {}^{n_2}/_{N} \times 100 \quad (5)$$

where, *n2* is the number of spacing ≤ 0.5 *S*.

Quality of feed index (QFI): This index (I_{QF}) is the percentage of spacing more than half but not more than 1.5 times the theoretical distance *S* in mm. The quality index is an alternate manner of declaring the performance of misses and multiples Eq. (6):

$$I_{QF} = 100 - (I_{miss} + I_{mult}) \quad (6)$$

RESULTS AND DISCUSSION

Effects of clearance between plastic slice and plate surface on seed pick-up: The influence of rotating speed and vacuum pressure amount on seed pick-up performance were previously demonstrated through some investigations of this device. The results of the two factors were found to be similar to that obtained by the advanced pneumatic seed-metering device (Liao *et al*., 2009; Yazgi and Degirmencioglu, 2014). However, it was found that seed pick-up through the hole rows nearer to the disk center (row 1 and 2) produced more multiple seeds than the other two rows (3 and 4) under same speed and vacuum pressure. That may attribute mainly to the variation in peripheral speeds of holes rows and/or to the vacuum level which is comparatively higher around the center because of no air leakage. Due to this fact, an attempt was tried for

Table 1: Influence of five clearances combined with plate rotating speed and vacuum on rows seed pick-up performance

Clearance (mm)	Speed (r/min)	Vacuum (kPa)		Rows seed mass (g)				Consistency CV (%)
				Row1	Row2	Row3	Row4	
Zero*	15	1.15	Stability *CV*	0.96	0.02	2.61	2.57	85.43
				8.66	65.18	3.41	5.66	
	20	1.25		1.37	0.06	3.72	3.70	84.76
			Stability *CV*	3.23	51.40	1.61	2.29	
0.5	15	1.15		2.09	1.21	2.87	2.93	40.64
			Stability *CV*	10.80	5.42	2.58	4.21	
	20	1.25		2.550	1.766	3.385	3.417	33.01
			Stability	4.36	7.48	7.04	9.67	
1	15	1.15		3.10	3.04	3.01	3.07	1.74
			Stability	1.46	2.54	1.59	1.05	
	20	1.25		4.00	3.94	3.92	3.94	1.18
			Stability	1.49	0.92	1.09	0.99	
2	15	1.15		3.10	2.92	2.93	3.03	3.65
			Stability	1.26	2.5	0.95	1.8	
	20	1.25		4.03	3.94	3.84	3.97	2.60
			Stability	1.03	0.48	0.68	1.86	
3	15	1.15		3.11	2.94	2.89	2.98	4.10
			Stability	0.91	2.66	2.18	1.14	
	20	1.25		4.09	3.86	3.78	3.88	4.28
			Stability	2.02	1.37	3.02	2.13	

Note: Stability *CV* is coefficient of variance for each row replicates (five replicates); Consistency CV is coefficient of variance for the four rows; Zero* means no gap between the plastic slice and plate surface.

equalizing seed sucking by reducing vacuum passes through nozzles of row 1 and 2 using a flat plastic slice -as previously illustrated in the method section- as to create a narrow distance between the slice and plate surface. Test results for five clearances under 15 and 20 r/min are shown in Table 1. Through gradual adjustment of the vacuum, it was found that 1.15 kP and 1.25 kPa were the appropriate vacuum values needed for seed pick-up with less seed missing at 15 and 20 r/min, respectively. The Table disclosed that zero and 0.5 mm clearances resulted in immoderate miss seeds with different levels in row1and 2 compared with row 3 and 4 at both speeds, that could mainly be returned to insufficient vacuum for seed sucking through the nozzles of row1 and 2. The result of insufficient vacuum for seed sucking was agreed with that obtained by single-row vertical disk unit and inside-filling seed-metering cylinder (Liao *et al*., 2009; Liao *et al*., 2017). Although there was no space between the plate and slice surface (zero mm), row 1and 2 sucked up some seeds, that could be attributed to the effect of plate rotation which may provide some narrow gaps for the vacuum to penetrate -particularly if an unleveled surface has existed- and resulted in frequent seed pick-up. However, it could be noticed that miss seed was higher with row2 than row1 that may refer to any unleveled slice surface result in direct contact with plate surface which may cut vacuum passage through row2 or create a gap for vacuum towards row1. It seems there was an inclined surface of the slice towards row2 which provided more missing seed than row1. It could also be observed from the table that zero clearance produced the worst results under both speeds as a result of large variation between rows with a consistency CV of 85.43% and 84.76 for speed 15 and 20 r/min, respectively. Moreover, row2 resulted in lowest seed pick-up compared with row1 with replicates stability CV of 65.18% at 15 r/min and 51.40 % at 20 r/min.

The clearance of 1 mm and 2 mm attained the different success of seed sucking performance under both speeds. It could be observed from the table that 1mm clearance achieved the best result with rows pick-up consistency of 1.74% and 1.18% at 15 r/min and 20 r/min, respectively. The values of 3.10 g, 3.04 g, 3.01 g and 3.07 g were rows means weight attained at 15 r/min, whilst 4.00 g, 3.94 g, 3.92 g and 3.94 g were accomplished at 20 r/min by row 1, 2, 3 and 4, respectively. Although 2 mm clearance provided an acceptable performance, it resulted in quite more variation between the rows with the consistency of 3.65% and 2.60% at 15 r/min and 20 r/min, respectively. Moreover, the clearance of 3 mm provided lower performance in seed sucking consistency compared with 2mm clearance. It resulted in 4.10% and 4.28% as rows pick-up consistency at 15 and 20 r/min compared with 3.65% and 2.60% under 2 mm clearance. Due to these results, 1 mm gap realized the most convenient clearance among the five investigated clearances for seed pick-up through rows levels; accordingly, it has been used to inspect seed distribution regularity of the metering unit.

It could be noticed from the table that as the opening between the slice and plate surface increases, seed pick-up of row 1and 2 also increases but with different levels. However, the variation between the two rows and even with the other rows (row 3 and 4) became to decrease up to 1 mm clearance, wherein the most regular seed pick-up was obtained by the rows. Little different values (such as 1.5 mm or 0.75 mm) may have better results, but they were not considered in

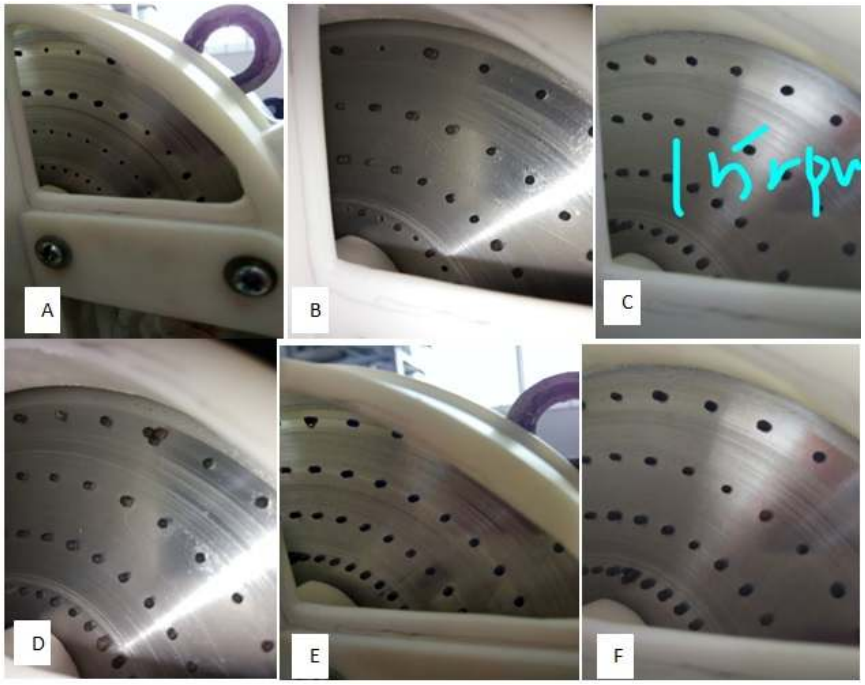


Fig. 7: Showing some results of seed pick-up under the effect of plastic slice clearance

this study. Under 2 mm clearance, rows variation began to increase again due to the decrease in row 3 and 4 seed suction, but it was not much as with 3 mm. It could be anticipated that if the clearance is more than 3 mm, it may result in more rows variation or provide pick-up performance similar to the normal situation (without the slice) which may insignificantly influence rows seed picking regularity.

Skip seeds or multiple drops sometimes occur at any disk speed or vacuum pressure through separate rows. These results are similar to that reported by Barut (1996) who stated that the vacuum disk seed sucking is largely varied at high or low negative pressures and plate speed. The results interpret the variation of seed pick-up between rows and within separate rows. Under mentioned clearances, when vacuum pressure increased to more than the level that fits well with a specific speed, the multiple seeds also increased and vice versa. Generally, an increase in the clearance provided more sucking seeds or multiple seeds while decrease resulted in more empty holes.

Figure 7 showing some results of the plastic slice clearance influence on seed pick-up of the four rows. Figure 7A and 7B showing the impact of zero and 0.5 mm clearance, where some empty nozzles of row 1 and 2 were existed, particularly with zero clearance. Figure 7C and 7D reflect the effect of 1 mm on seed pick-up regularity at 15 and 20 r/min, respectively, wherein consistent pick-up has occurred. Regarding Fig. 7E and 7F), multiple seeds could be observed in row 1 and sometimes occurred in row2 more than row 3 and 4.

Effect of 1mm clearance on rows seed distribution uniformity: The influence of the clearance combined with the mentioned two speeds and vacuum pressure on seed sucking and distribution homogeny was verified relating to the seed quality index (I_{QF}), multiple index (I_{MULT}) and miss index (I_{MISS}). Due to the light weight of rapeseed, a little positive pressure of 100 Pa was found to be sufficient for smooth seed releasing with little deviations. Results procured by the greased-belt have been displayed in Table 2 to explain the variability among the rows. The table illustrated the effect of 1 mm clearance on seed distribution accuracy through the four rows and the (CV, %) for separate rows stability and consistency between the rows. It was found that 15 r/min combined with vacuum of 1.15 kPa resulted in quality index of 91.34%, 92.83%, 91.7% and 90.65%, while 20 r/min coupled with 1.25 kPa vacuum amount attained 89.81%, 92.23%, 89.86% and 92.05% for row 1, 2, 3 and 4, respectively. Results showed that the highest seed quality index (92.83%) and the lowest miss index value (1.92%) were achieved through row 2 at 15 r/min. Moreover, row2 attained the highest seeding quality of 92.83% and 92.23% among the rows at both speeds. In the same context, the I_{QF} of row1 at 20 r/min resulted in the lowest value (89.81%), which may attribute to the fact that the successive holes' distance is closer than other rows which may sometimes drop seeds in a closer time which in turns provided more multiples. Regarding rows consistency, the values of 0.99% and 1.46% were accomplished at 15 r/min and 20 r/min, respectively, which indicated that seed precision operation was steady. As it could be seen

Table 2: Effect of 1 mm clearance combined with plate rotating speed and vacuum on the seed feed quality index of the rows

Plastic slice clearance (mm)	Speed*vacuum (r/min* kPa)	Quality Index (%)	Rows quality index (%)				Consistency C.V (%)
			Row1	Row2	Row3	Row4	
1	15*1.15	I_{QF}	91.34	92.83	91.71	90.65	0.994
		Stability *CV*	1.49	1.69	0.97	1.07	
1	20*1.25	I_{QF}	89.81	92.23	89.86	92.05	1.465
		Stability *CV*	1.09	1.29	0.81	1.03	

Note: I_{QF} is quality of feed index (%); Stability *CV* is coefficient of variance for each row replicates (five replicates); Consistency CV is coefficient of variance for the four rows (%); * means combined rotating speed and vacuum pressure

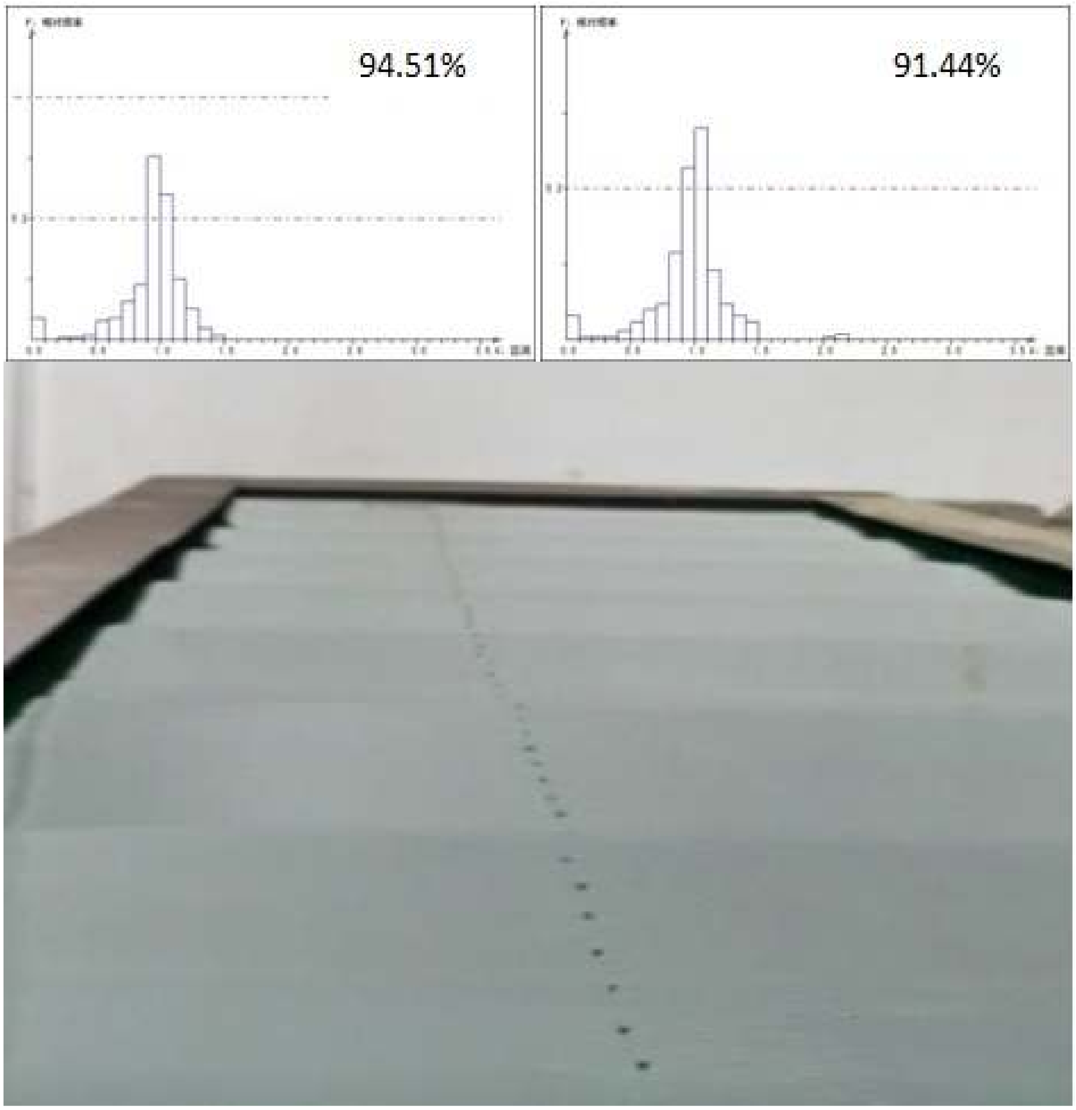


Fig. 8: showing a model of graphs obtained for seed quality index and photo explaining seed distribution on belt test stand

from the table both the stability and consistency CV of the rows were less than 2%. By comparing rows consistency with their stability CV, 15 r/min provided better results than 20 r/min. Figure 8 showing some results photos obtained through the investigation via belt test stand.

Stability of rows quality index, miss index and multiple index: The seed feed quality index, stability (*CV*) of each row, miss and multiple indexes of the rows are shown in Figure 9 and 10 at the two speeds. Their results expound that seed allocation regularity could be successfully performed by using plastic slice method with rather stable quality index. Through all rows, the quality index of each row was above 89% as presented in Table 2, while miss index was below 5% as in Fig. 9 and 10. The quality index of the rows has been fluctuated within little values not exceeded 2.5%

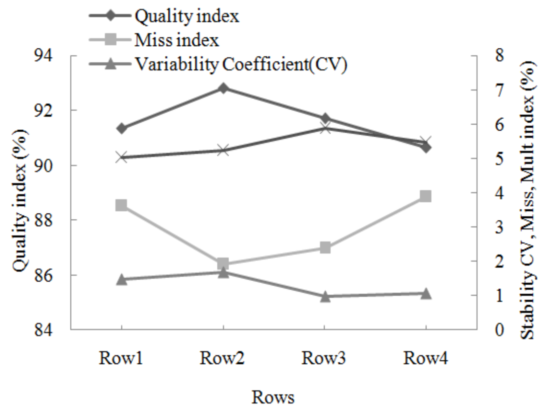


Fig. 9: Influence of 15 r/min. on seed quality index, stability (CV), miss and multiple indices of the four rows

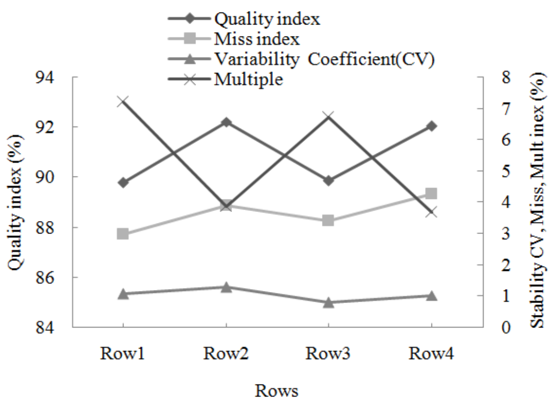


Fig. 10: Influence of 20 r/min. on seed quality index, stability (*CV*), miss and multiple indices of the four rows

at both speeds, but the speed of 15 r/min was more consistent than 20 r/min. Figure 9 and 10 are obviously showing that multiple index and miss index occurred at acceptable levels. However, multiple indexes were more frequent than miss index under presumed speeds which indicated that vacuum pressure was appropriate for seed sucking with a few missing. As a fact, multiple index increased with high vacuum pressure and low speed, while miss index was inversely affected by the two factors. These results are corresponding to that stated by Liao *et al*. (2017). The highest multiple and miss indices attained at 15 r/min were 5.89% and 3.88%, while at 20 r/min were 7.2% and 4.26%, respectively. The stability CV for each row replicates under the two speeds indicates a steady performance of rows seed pick-up.

CONCLUSION

The research findings concluded the following points:

- The device was capable to meter seeds successfully through the four rows by employing the plastic slice technique for vacuum reducing around the nozzles of row 1and 2
- It was found that 1mm was the best clearance among the five investigated clearances for rows pick-up similarity
- The values of 1.15 kPa and 1.25 kPa vacuum pressure were found to be appropriate for regular seed distribution at 15 r/min and 20 r/min, respectively
- Seed quality index of each row was above 89% with a little variation within and between rows. The highest and lowest quality indexes have been realized by row 2 at 15r/min and row1 at 20 r/min, respectively
- An innovative method that is more precise to distribute vacuum with right amount through separate rows is strongly recommended for further investigations

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