Gezira J. of Agricultural Science
ISSN Linking: 1858-8735
http://journals.uofg.edu.sd/index.php/gjas/

Performance evaluation of a four-row pneumatic seed plate with and without additional two components for metering sesame seed

*Elebaid J. Ibrahim*1 Lei X. Long2, Anas D. Abdallah3,*

1,3. Department of Agricultural Engineering, Faculty of Agricultural Sciences, University of Gezira P. O. Box 20, Wad Medani, Sudan.
2. College of Engineering, Huazhong Agricultural University, Wuhan, Hubei 430070, China.
*Corresponding Author: Elebaid Jabir Ibrahim: Assistant professor, research interest: Modern Agricultural Equipment Technology, College of Engineering, Huazhong Agricultural University (HZAU), Wuhan, Hubei 430070, China. E-mail: ebaidjabir@gmail.com; ebaidjabir@uofg.edu.sd

INFORMATION:

Submission:
Accepted:
Publication:

ABSTRACT

This study try to solve the problem of multiple seed picked-up by rows 1 and 2 of a prototype of four-row pneumatic seed plate that previously developed to meter small seed. This prototype can diminish unnecessary multiple seeding units, components and associated complications. The objective of this study was to compare the performance of a four-row pneumatic seed plate (prototype) with two additional components, namely; curved-edges seed ejecting and vacuum controlling devices on sesame seed. The study was conducted in the College of Engineering Huazhong Agricultural University, China in 2022. The vacuum pressure controlling and curved-edge seed ejecting devices were fabricated from plastic materials using a three dimensions printing machine. These two devices were assembled independently into the prototype. The test included three methods; prototype alone, the vacuum pressure controlling device assembled to the prototype and curved-edge seed ejector device assembled to the prototype. For the three methods, the test was executed at a constant pressure (1 kPa) and at five rotating speeds, namely; 5, 10, 15, 20, and 25 rpm. However, the vacuum controlling device was positioned at five clearances from seed plate surface (zero, 0.5, 1.0, 1.5 and 2.0 mm). The results showed that row 1 still picked-up the highest seed mass across all rotating speeds and the three methods. The prototype gave the highest seed mass at all rotating speeds compared to the other two methods. The picked-up seed mass per rows increased consistency as rotating speed increased. The clearance of 1 mm of vacuum controlling device obtained relatively better results compared with the other studied clearances. The curved-edge device obtained lower picked-up seed mass and semi-uniform output per rows compared to the vacuum controlling device. The study concluded that further studies are needed on adjusting the position of vacuum controlling device and curved-edge clearance.

Multi-rows seed plate, vacuum controller device, curved-edge seed ejecting device, sesame seed.

KEYWORDS: ***pneumatic seed; sesame seed ; Performance evaluation***

1. Introduction

Sesame is one of the most important oil crops and an essential source for edible oil. Sudan is considered as an important country of sesame producers worldwide (Banerjee and Kole, 2009). Sesame is also one of the most cash crop and hard currency earning in the Sudan (Ahmed and Ahmed, 2013). It is mainly cultivated in rain-fed areas and under both traditional and mechanized farming systems. Sesame cultivation in the Sudan constitutes an essential source of subsistence and income generation for a considerable number of poor and small holder farmers (Sabiel *et al.*, 2015). Nevertheless, Sudan sesame production for export confronts with several problems resulting in low productivity compared to other oilseed crops. Among these problems , the use of poor yielding cultivars, traditional cultivation method, seed losses during threshing and inadequate use of agricultural inputs (Baydar, 2005; Iman *et al*., 2011; Ogbonna and Ukaa, 2012). There is an annual variation in sesame areas under cultivation, which may be due to rain fluctuations, lack in suitable drilling machines and economical situations of the farmers' (Ibrahim *et al*., 2018). Most of sesame fields are cultivated under conventional farming system with little or no use of machinery or modern inputs (Osman *et al.*, 2023).

Seed sowing practice relies primarily on the metering mechanism which is essential component in sowing equipment (Yang *et al*., 2016). Several metering systems and devices are implemented in precision seeding, among them are belt-type, slant plate, vertical rotor, and pressurized plate (Guler, 2005; Boydas and Turgut, 2007). The operating principle of these systems is either mechanical or pneumatic system. Pneumatic systems are more preferable compared to mechanical systems , due to their accurate seed rate calibration, lower broken seed ratio, better seed adhering, better holding and dropping of metered seed (Searle *et al*., 2008; Guozhong *et al*., 2015; Liu *et al*., 2016). For optimizing and development of precision seeding, researchers have implemented three pneumatic systems. Li *et al*., (2015) used positive pressure for seed hill dropping and singling, or for both. Others used positive pressure for seed conveying accompanied with mechanical feeding means (Lei *et al*., 2016). While some others employed vacuum for seed picking and positive pressure for dropping and blowing off undesired particles (Cong *et al*., 2014a; Li *et al*., 2014; Wang *et al*., 2018).

Several studies have been executed to study the performance of planting equipment, which provide information about precision systems. Karaye *et al*. (2004) set up a mathematical model relying on seed physical properties to identify the optimal vacuum amount of a planting machine. Deng *et al*. (2010) and Ibrahim *et al.*(2018) have studied seed suction capability by a pressurized metering system to verify seed plate velocity, hole number, diameter of seed cell . Singh *et al*. (2005) checked the effect of disk rotational speed, negative pressure and shape of seed cell on cottonseed distribution. Asset of endeavors

have been previously exploited for assuring and measuring the performance of seed precision. Response surface methodology (RSM) to look for seed spacing regularity of a planter (Yazgi and Degirmencioglu, 2007). An application of optoelectronic sensor system was engaged in seed preciseness to study seed locations. Thus, seed spacing stability was portrayed by means of the coefficient of precision (Panning *et al*., 2000). The technique was also implemented to find out time intervals between successive dropped seeds, to view metered seeds accuracy (Lan *et al*., 1999; Kocher *et al*., 1998). High-speed camera technique was also used to detect seed fall velocity and preciseness (Karaye *et al*., 2006). Bench test stand incorporated with a computerized camera technique for seed monitoring had been attempted to validate precision performance. Results showed that no damaged seed was occurred, while precision was plainly affected by angular velocity and vacuum level (Qingxi *et al*., 2009; Onal and Onal, 2009). Zhan *et al*. (2010) applied the computational fluid dynamics (CFD) to compute forces affecting on dropped seeds, by employing a set of numerical formulas.

Sesame seed have irregular shape, small and soft (thin coat), that could be easily injured by metering system elements. However, hand seeding or machine broadcasting are the most traditional practices employed for crop seed distribution in the Sudan. One of their limitations is in performing subsequent mechanical operations such as weeding and harvesting, particularly, in large-scale areas. Manual practice is inaccurate in seed rate, lack homogenous distribution, consumes considerable time, results in higher cost and limits the cultivated area due to the scarcity of labor. Owing to the nature of such seeds, metering process could not be realized by mechanical devices. Such metering devices are repeatedly produce some damaged seeds which in turns plug metering seed cells due to their oily nature (Jiajia *et al*., 2014; Li *et al*., 2012). Additionally, they affect the accuracy of seed rate and plant density which have direct impact on crop yield. Accordingly, pneumatic patterns remain the most convenient systems for metering such seed with a suitable seed rate and without injury. However, the pneumatic disk metering devices are incapable to execute multi-rows simultaneously (Cong *et al.*, 2014b). They commonly utilize a single plate to perform individual row planting and fit to a separate metering unit of seeding equipment. This configuration produces quite heavier planter, complex transmission and pneumatic systems, and relatively higher power will be needed; thus result in unnecessary costs.

In a recent study, a pneumatic multiple rows seed plate (a prototype) was designed for metering small seed types (Ibrahim *et al*., 2018). It was used to sow sesame seeds by implementing pneumatic pressure for holding and releasing to avoid seed damage. Two devices were assembled independently into the prototype. These devices were vacuum controller device and seed release mechanism. The first was used to control the quantity of the negative pressure flow, especially through seed holes of row 1 and row 2, for diminishing multiple seed picked-up by each hole. The second device, is seed ejector, which was used to release excessive seed adhere around holes.

The main objective of this study was to compare the performance of a four-row pneumatic seed plate (prototype) with two additional devices for performance improving under a set of angular velocities. The specific objectives were to:

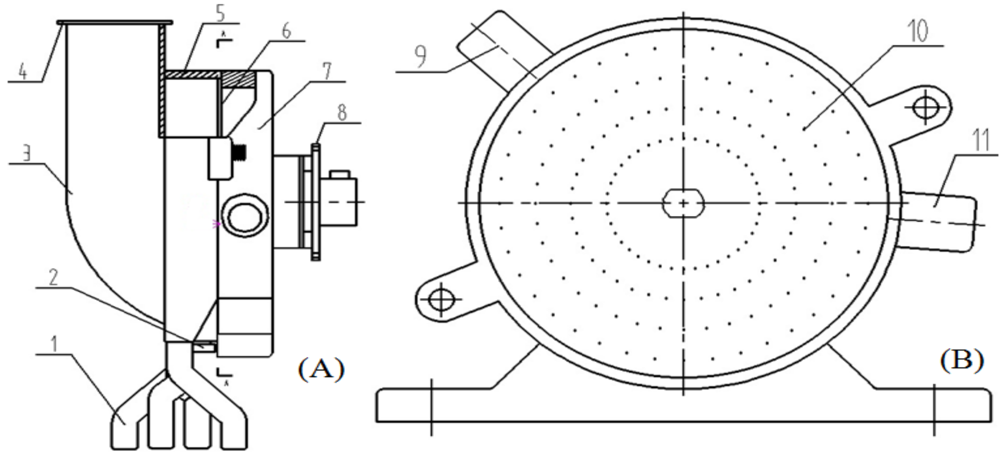
1. Study the effect of the two improving methods on rows output.
2. Inspect the influence of vacuum controlling device on vacuum pressure and rows pick-up regularity.
3. Investigate rows performance under the three methods.

2. Materials and Methods

This study has been carried out at College of Engineering, Huazhong Agricultural University, China, in 2022.

2.1 Structure of the prototype

A prototype of small-seed (sesame) metering device employing a pressurized vertical seed plate with four-rows was developed. Figure 1(A) presents the constructional elements of the prototype. Figure 1(B) shows the metering seed plate mounted to pressure chamber. The air chamber was made up with two cavities, one receives vacuum for seed picking and holding and the other cavity conveys positive pressure for dropping. One side of the seed plate faces negative pressure source at seed picking chamber and positive pressure at dropping area. The other side faces seed supply area and seed discharge tubes.



1. Seed tube | 2. Seed discharge nut | 3. Seed box | 4. Seed box cover | 5. Plate cover
6. Seed metering plate | 7. Pressure chamber | 8. Driving sprocket | 9. Vacuum inlet
10. Seed cell in the seed plate | 11. Positive pressure inlet.

Figure 1. (A). A schematic diagram of the multi-rows pneumatic seed plate metering device, **(B).** Seed plate on its groove in pressure cavity

The metering seed plate is prepared with four rows of small cells around its center of rotation (Fig. 1B). Row one was the nearest to the center of rotation, while row 4 was the farthest. Each row contains 40 seed cells around its center of rotation with a diameter of 1.2 mm. Previous test showed that this cell diameter was appropriate for smooth picking without causing any damage to the tested sesame seed (Ibrahim *et al*., 2018). Row 1 was 30 mm apart from the center of rotation, while the space between each two adjacent rows was 14 mm, the total diameter of the seed plate was 160 mm. The spacing between each two cells, across all rows, was 9°. The angular speed of all seed cells was constant, whereas linear speed increased when moving from row one towards row four.

2.2Vacuum controlling device

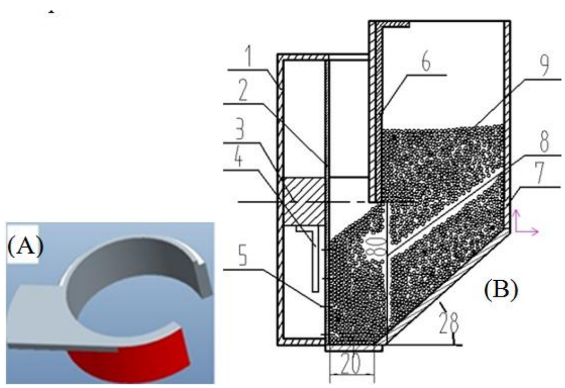
The vacuum controller device was used to create a clearance at the seed plate surface to control pressure amount pass through seed cells aiming at improving rows seed picking. The vacuum controller device (Fig. 2 A) was composed of two parts fixed together, a circular shape and a flat shape (Fig. 2 A). The circular part was tightened to the center of rotation; its diameter was 25 mm and thickness was 3 mm. The flat shape dimensions was 20 mm length, 15 mm width and 3 mm thickness. The flat shape (slice) was positioned near the metering seed plate surface and opposite to the entrance of vacuum pressure of row 1 and 2. The three dimensions printing machine was used to prepare this device. The clearance of the slice from the seed plate surface can affect pressure amount run through the seed cells. Figure (2 B) shows a sectional view of seed flow from seed hopper to seed plate. Seeds pass through a seed flow opening, which is adjustable by using a seed flow controller to the gathering area.

2.3 Excessive seed ejecting device

Figure 3A shows curved-edge device with four arc-shape edges for ejecting multiple seed from seed cells. It was made of four rigid plastic edges, following-the same arcs of the rows of seed cells, with arc diameter of 1.1 mm. The dimensions of this device were 70, 15 and 20 mm for length, width and thickness, respectively. The three dimension-printing machine prepared this device. This device was fixed to the inner side of the seed plate, in such away, to be in direct contact with the excessive seed. The degree of multiple seed removal relies on the edge clearance from cells entrance as shown in Fig. 3 B.

4.4 Working principle of the prototype

Seed metering process by utilizing the two methods is basically occurring as presented in Fig. 2 B and Fig.3 B. Figure 2 B shows side view of seed flow process and vacuum controlling slice position. The slice gap from plate surface determine vacuum magnitude and hence seed picking amount that could be metered. Figure 3B presents a transparent cut view of the metering device shield showing how metering operation take place. Seed from accumulation area are picked by vacuum pressure force; at times, multiple seeds are picked by the seed metering cells. While seed pass nearby the device, they touch the curved-edge that removes multiples according to the degree of contact. Seeds are then fall down at dropping points under the gravity and positive air force.

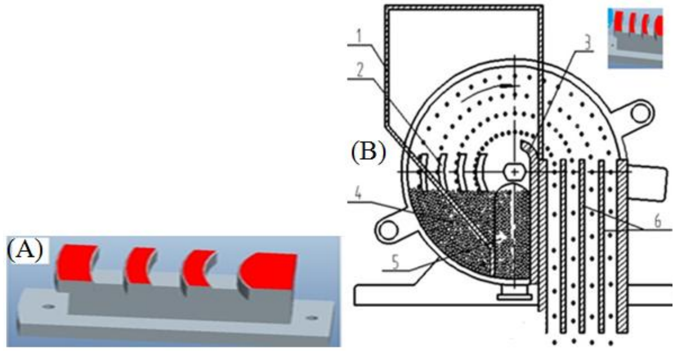


1. Pressure chamber wall | 2. Seed metering plate | 3. Plate center of rotation

4. Vacuum edrucing slice | 5. Metering holes level, | 6. Seed flow controller | 7. Seed box

8. Seed flow opening | 9. Seeds

Figure 2. (A) Vacuum reducing device, (B) Side view of seed flow operation and plastic slice location.



1. Seed box 2. Curved-edge (seed ejector) device 3. Seed barrier, 4.Seeds area, 5. Seed flow opening 6. Rows separator

Figure 3. (A) Curved-edge seed ejector, (B) Transparent view of metering plate and curved-edge device

2.5Testing procedures

The experiment was carried out at five levels of seed plate rotating speeds, namely, 5, 10, 15, 20 and 25 rpm. Moreover, due to lightweight of sesame seeds, a constant vacuum pressure of 1 kPa was used with these speeds. This vacuum pressure was found to be sufficient for seed picking through rows 3 and 4 without skipping (empty seed cells), but with some multiple seed picked in rows 1 and 2 (Ibrahim *et al.*, 2018). Furthermore, the prototype was actuated for one minute and seed mass for each row was collected and weighted (Figure 4). The vacuum controlling and seed ejecting devices were tested using this procedure as follows:

1. For the vacuum controlling device, five clearances between seed plate surface and the vacuum control device, namely, zero, 0.5, 1.0, 1.5 and 2.0 mm, were tested.
2. For the excessive seed-ejecting device, only the edges of the ejecting device were adjusted to be closer enough to the seed in the holes of metering seed plate to provide good contact with excessive seeds.

2.6 Statistical analysis

Data was subjected to analysis of variance (ANOVA) using the GenStat statistical package (14th edition (PC/windows 7). The means, standard errors of the mean, as well as coefficients of variations were calculated. The means were separated using least significant difference (LSD) at 1% significance level.

In addition to (LSD), Coefficient of variation (C. V. %) was involved for rows comparison using equation 1 as stated by (Lü *et al*., 2016)

$$\text{C.V.\%} = \frac{S}{Z_m} 100 \qquad (1)$$

Where:

S = standard deviation of the main seed mass and

Z_m = average of seed mass.

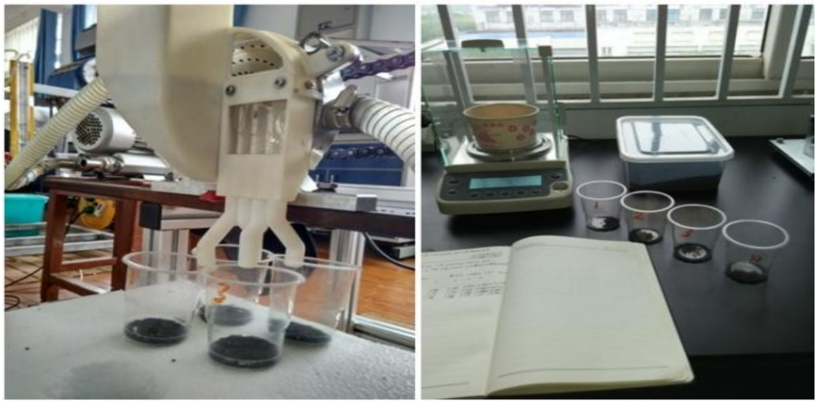


Fig. 4. Sesame seed collection and its mass measurement

3. Results and discussion

3.1 Analysis of variance:

The results showed highly significant difference ($P < 0.001$) among different speeds, rows and their interaction under the three tested methods (Table 1). The differences indicated the effect of the operating speeds on the prototype rows results under separate investigated methods.

Table 1: Analysis of variance for means sum of squares of the device prototype normal operation , Vacuum control slice and curved edge ejector device

SOV	d.f	Normal device operation	Vacuum control slice	Curved edge ejector
Rows	3	5.276***	6.264***	1.574***
Speed	4	50.347***	37.805***	32.039***
Rows*speed	12	0.358***	0.242***	0.176***
Residual	76	0.08818	0.02661	0.02123

SOV: Source of variation; Df: Degree of freedom; *** = Significant at .001.

3.2 Performance of the prototype alone

Table 2 display the results of the prototype alone (without using any additional device) that previously designed for multiple rows seed metering (Ibrahim *et al*, 2018)**.** The results were presented for comparison and to discover, later, the progress made by either of the two devices. The results showed that, irrespective to the row number, the amount of picked-up seed (g/row) increased as rotational speed increased, which is a logical result. On the other hand, it is obviously observed that the amount of picked-up seed decreased from row one through rows two and three toward row four. This variation makes it necessary to intervene for equalizing the seed picked-up by each row.

Table 2. Effect of rotational speed on the performance of the multi-rows seed metering proto type

Speed, rpm	picked-up seed, g/row				Mean, g	SD	C. V. %	L.S.D
	R1	R2	R3	R4				
5	1.417	1.273	1.165	1.112	1.241	0.134	10.845	0.347
10	3.132	2.443	2.398	2.37	2.585	0.365	14.13	
15	3.616	2.916	2.932	2.667	3.032	0.407	13.432	
20	4.981	4.003	3.866	3.722	4.143	0.570	13.765	
25	6.632	5.335	5.008	4.749	5.431	0.836	15.390	

SD = Standard Deviation; C. V. (%) = Coefficient of variation, R1 = Row 1, R2 = Row 2, R3 = Row 3, R4 = Row 4

L.S.D = Least Significant Difference.

3.3 Performance of vacuum controller device on seed picked-up per row

The performance of vacuum controlling device on the amount of picked-up seeds per row is shown in Table 3. The results discovered that the vacuum controller device at zero mm clearance followed by 0.5 mm clearance gave the lowest seed mass for rows 1 and 2 across all rotational speeds. This could be attributed to insufficient vacuum resulted from effect reduced clearance between seed cell and vacuum controller device at the seed cells of rows 1 and 2. The results of insufficient vacuum for seed picking were corresponding with that acquired by single-row of vertical seed plate (Qingxi *et al.*, 2009; Liao *et al.*, 2017). The effect of narrow clearance may result in vacuum reduction around the area of multiple picked-up or an increase of vacuum through the other two rows' seed cells. Zero mm clearance showed that rows 1 and 2 picked up some seeds, which could be due to the influence of seed plate rotation that may give some narrow clearance for the vacuum to penetrate through the seed cells. It was observed that, row 1 picked-up larger amount of seed than row 2 across all rotational speeds; this may be due to the friction between the seed plate and vacuum controlling device that created unleveled surface, which either cut vacuum from row 2 or guide the pressure towards row1. Another interpretation is that the inclined surface of the vacuum controller device existed around row 2 provided more skipped seeds than row 1.
On the other hand, referring to 1.5 and 2 mm clearances (apart from Zero and 0.5 mm) multiple seed picked-up might be occurred through the rows. These two clearances created inconsistent and worse rows results based on the C. V. (%) values compared with 1mm clearance; especially at higher speed levels. Multiple seed picked-up around seed plate center may related to the variation in linear velocity of rows and/or to the vacuum magnitude, which is higher than at the circumference of the seed plate due to the lack of air escape at the center.

Table 3. Effect of vacuum slice clearance on picked-up seed mass per row

Speed, rpm	Clearance, mm	~~Rows~~ picked-up seed, g/row				Mean, g	SD	C. V. (%)	**L.S.D**
		R1	R2	R3	R4				
	2.0	1.655	1.326	1.354	1.377	1.42	0.152	10.69	
	1.5	1.411	1.115	1.063	0.914	1.12	0.208	18.50	
5	1.0	1.497	1.168	1.112	1.105	1.17	0.103	8.75	0.205
	0.5	1.151	0.519	1.185	1.201	1.01	0.331	32.66	
	Zero	0.898	0.541	1.147	1.163	0.93	0.292	31.01	
	2.0	2.739	2.403	2.367	2.317	2.43	0.204	8.38	
	1.5	2.739	2.403	2.514	2.266	2.48	0.199	8.06	
10	1.0	2.636	2.371	2.308	2.203	2.37	0.184	7.76	0.205
	0.5	2.203	0.788	2.146	2.196	1.83	0.697	38.03	
	Zero	1.499	0.793	2.047	2.001	1.58	0.583	36.80	
	2.0	4.037	3.322	3.176	3.108	3.41	0.426	12.51	
	1.5	4.107	3.243	3.014	2.923	3.32	0.540	16.27	
15	1.0	3.439	3.304	3.114	2.978	3.43	0.243	7. 52	0.205
	0.5	3.142	0.862	2.840	2.849	2.42	1.050	43.34	
	Zero	2.064	1.028	2.710	2.432	2.05	0.736	35.76	
	2.0	4.973	3.976	3.925	3.493	4.09	0.626	15.30	
	1.5	5.081	3.999	3.736	3.438	4.06	0.716	17.62	
20	1.0	4.967	4.019	4.044	3.67	4.2	0.526	12.52	0.205
	0.5	3.875	1.008	3.474	3.432	2.94	1.308	44.38	
	Zero	2.470	1.002	3.541	3.165	2.54	1.119	44.01	
	2.0	6.085	4.902	4.598	4.135	4.93	0.823	16.87	
	1.5	6.152	4.609	4.203	3.618	4.64	1.083	23.32	
25	1.0	5.756	4.374	4.388	4.123	4.66	0.740	15.89	0.205
	0.5	4.294	0.904	3.799	3.910	3.22	1.563	48.45	
	Zero	2.617	0.924	3.862	3.221	2.65	1.262	47.52	

SD~~:~~ = Standard Deviation; C. V. (%) = Coefficient of variation~~,~~ R1 = Row 1, R2 = Row 2, R3 = Row 3, R4 = Row 4, L.s.d = Least Significant Difference.

With regard to coefficient of variation (C. V. %) measure, the table is obviously viewing that 1 mm clearance achieved the most convenient results compared to other clearances. Generally, rows pick-up with this gap provided closer performance and created consistent results in relation to other clearances. The gap accomplished the consistency C. V. % of 7.76% and 15.89% as the lowest and highest values under the tested velocities, respectively. The C. V. % measure was formerly used in research studies for results comparison as stated by Lü *et al*. (2016). It is clear from Table 3 that variations existed in rows pick-up under same speed with different clearances, where it increased as the rotating speed increase. This is due to the level of the negative pressure, which may need an altering in the vacuum controlling device clearance to meet the applied pressure. Table 3 also illustrated that as the clearance between the vacuum controlling device and seed plate increase, seed pick-up by row 1 and 2 increased too, but with unequal amount. However, the variation between the two rows and even with the other rows (3 and 4) became to decrease up to 1 mm clearance, wherein the most regular seed pick-up was obtained by the rows. Therefore, the better results of 1mm clearance provide a preference for comparison with seed ejector method and the prototype results.

Least significant difference (Ls.d) measure was used for rows results comparison of 1 mm clearance only at different speeds, where some rows were significantly differed while others were not. According to this measure, it could be noticed from the table that row1 was significantly different in comparison with the other rows.

The results showed that multiple seed drop occurred at any speed or vacuum pressure through each rows. These results are in line with that reported by Barut (1996) who found that seed suction is largely varied at high or low negative pressures as well as speed of metering element. Generally, an increase in the clearance produced more picked-up seeds, while smaller clearance resulted in more empty cells.

3.4 Performance of curved-edge ejector on seed picked-up per rows

Results obtained by curved-edge seed ejecting device at the five rotating speed were presented in Table 4. The results showed that seed picked-up consistency in term of the C. V. % was increased as the rotating speed increased, where its value was ranged between 3.246 and 12.115%. It also showed that seed picking under all rotating speed resulted in little difference between the rows. According to LSD value (0.183), rows were not significantly different at 5 rpm speed, but there were significant differences at other speed levels, particularly, with row1 compared to the other rows. The results also revealed that seed picking across all rotating speeds resulted in little differences between the rows. The results showed that row 1 still gave higher seed weight across all speeds compared to the other rows; this may be due to the concentration of vacuum around seed plate center generate relatively higher vacuum pressure at row 1, thus picking more multiple seed. This result suggest readjusting the position of curved-edge device to be closer enough to row 1 than to the other rows. Regarding the other rows, there were little dissimilarity with a propensity of row 4 to have the minimum seed mass, but the variation was not as much as in row 1. The results showed that the amount of picked-up seed increased as rotational speed increased as that happened with the use of vacuum controller device. These are inline with the results reported by Qingxi *et al*. (2009), who pointed out that the metering device rotating speed and vacuum amount affect metering system output. This result confirmed that the use of the curved-edge ejector device achieved improvement and realized better results compared to vacuum controlling device.

Table 4. Effect of curved-edge device on picked-up seed mass per row

Speed, rpm	**Picked-up seed ~~mass~~, g/row**				**Mean, g**	**SD**	**CV, %**	**LS.D**
	R1	**R2**	**R3**	**R4**				
5	1.173	1.073	1.071	1.065	1.095	0.036	3.264	
10	2.595	2.16	2.425	2.202	2.345	0.203	8.652	
15	3.212	2.862	2.846	2.755	2.918	0.201	6.889	0.183
20	4.204	3.794	3.755	3.442	3.798	0.312	8.232	
25	4.918	4.344	4.283	3.734	4.344	0.526	12.115	

SD = Standard Deviation, C. V. (%) = Coefficient of variation, R1 = Row 1, R2 = Row 2, R3 = Row 3, R4 = Row 4, L.s.d = Least Significant Difference.

3.5 Comparison of rows picked-up seed under the tested methods

Figures 5 (a - e) exhibit the performance of the two tested techniques compared to the prototype, for each row and at specific rotating speeds. Results obtained by 1 mm clearance of the vacuum controlling device were only used for comparison, while the results obtained by other clearances were excluded because they merely studied to determine the convenient clearance.

Figure 5 (a) presents the picked-up seed per row for the three methods at 5 rpm rotating speed. The figure showed that the picked-up seed per row of the three methods were very similar to each other at row 4. The result also revealed that the curved-edge device picked-up the lowest seed across all rows and seemed to be more stable compared to the other two methods. This point out advantage of using the curved-edge ejector device over the other two methods. The proto type device produced higher seed mass than vacuum controlling device. Figure 5 (a) also displays that seed mass per row for the three tested methods was oscillating between 1.07 and 1.4 g.

Figure 5(b) shows the picked-up seed per row at 10 rpm rotating speed for the three methods, where some variations between these methods were found. The mean seed mass of the methods among the four rows fluctuated between 2.16 and 3.13g, where, for the three methods, row 1 picked-up highest seed mass. Like that occurred at 5 rpm speed, the prototype gave the highest seed mass than the other two methods, while vacuum controller and curved-edge devices were changeable through the rows, with little advantage to curved-edge ejector, specifically at rows 1 and 2.

Figure 5 (c) presents the picked-up seed per row at 15 rpm rotating speed for the three methods. At this rotating speed, interaction between the three methods and among the rows was occurred. Row1 still gave the highest seed mass picked-up across the three methods. The maximum and minimum seed mass obtained by these rows and at this rotating speed was 3.61g and 2.66g, respectively. The results showed that seed mass picked-up by the vacuum controller device was higher than the proto type, for all rows except for row1. This indicated the influence of the vacuum controlling device on row 1 and direct vacuum pressure for seed picking to other rows.

Figure 5 (d) shows the picked-up seed per row at 20 rpm rotating speed for the three methods. The obtained seed mass by the vacuum controlling device and the proto type appeared to be similar or very close across the four rows. The curved-edge device resulted in the lowest seed weight through all rows compared to the other two methods. This result confirm the advantage of curved-edge device over the other two methods.

Figure 5 (e) views the effects of 25 rpm rotating speed on the seed mass picked-up by the three methods. The proto type gave extremely the highest seed mass through all rows than the other two methods. The two other methods obtained relatively close seed mass, specifically at rows 2 and 3. The high difference of the proto type from the other two methods may be attributed to the combined effect of rotating speed, vacuum controlling device and the curved-edge device. Row1 picked-up seed mass ranged between 4.74g and 6.63g, while for the other rows fluctuated between 3.73g and 5.75g in an irregular pattern.

These comparisons revealed that row 1 picked-up the highest seed mass across all rotating speeds and the three methods. Generally, the prototype of multi-rows seed plate gave the highest seed mass at all rotating speeds compared to the other two methods. The curved-edge device resulted in lower picked-up seed mass and semi-uniform output per rows compared to the vacuum controller device. A uniform rows performance by using curved-edge device could be achieved by resetting up the edges of contact for rows 1 and 2 to be closer enough to the metering seed cells than in other two rows. However, further adjustment in vacuum controller with narrower clearance than 1 mm (e.g. 0.7 or 0.8 mm) may give better results. Finally, the results showed that the picked-up seed mass per rows consistency increased as rotating speed increase.

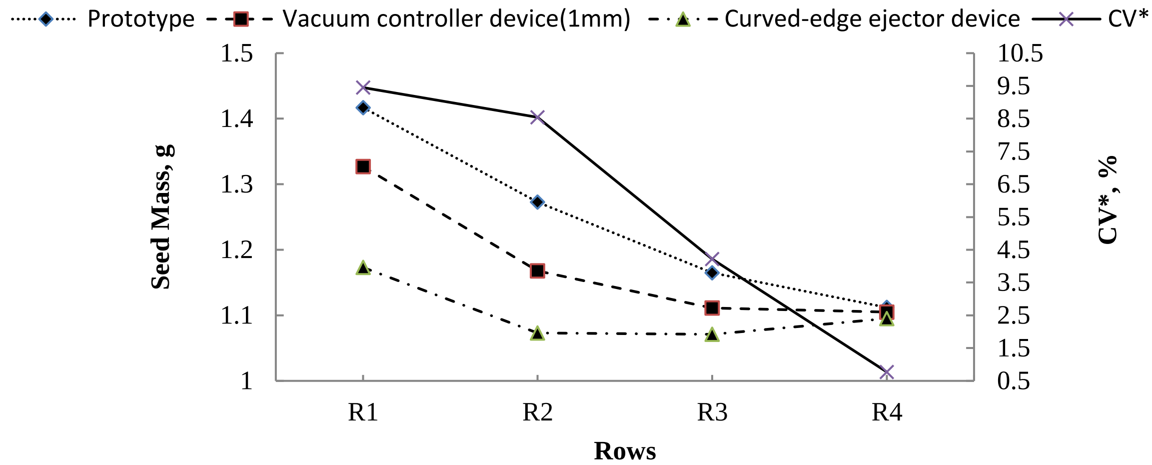


Fig. 5 (a). Comparison of the picked-up seed mass per row of the tested methods at 5 rpm rotating speed.

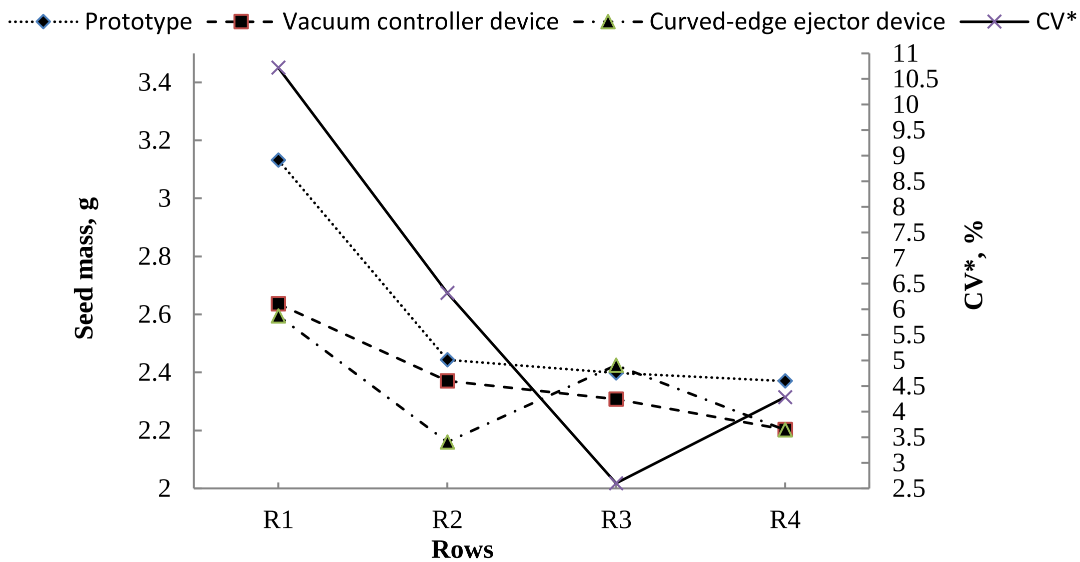


Fig. 5 (b): Comparison of the picked-up seed mass per row of the tested methods at 10 rpm rotating speed

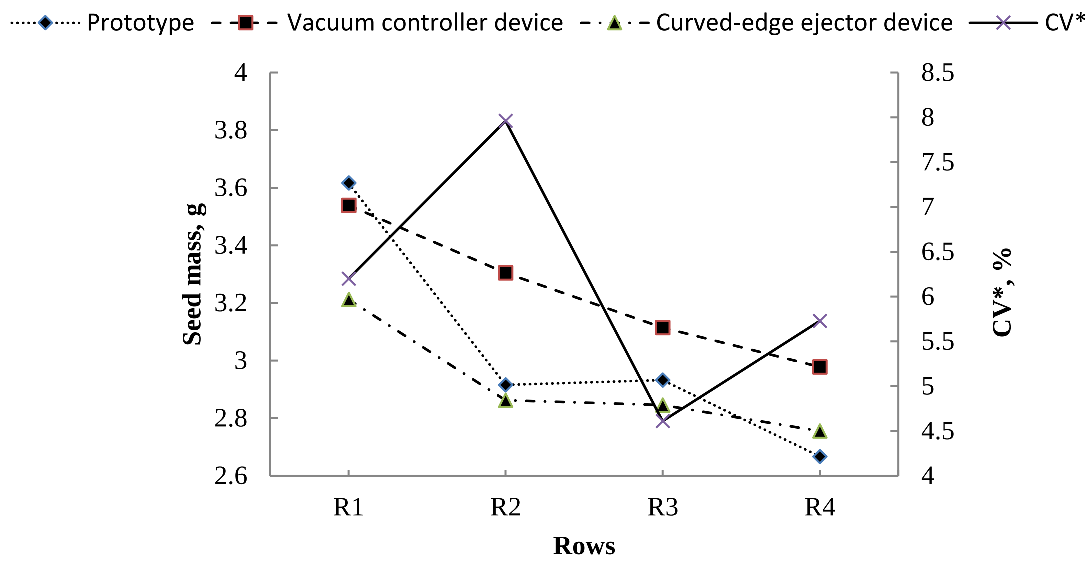


Fig. 5 (c)~~:~~ Comparison of the picked-up seed mass per row of the tested methods at 15~~.~~ rpm rotating speed

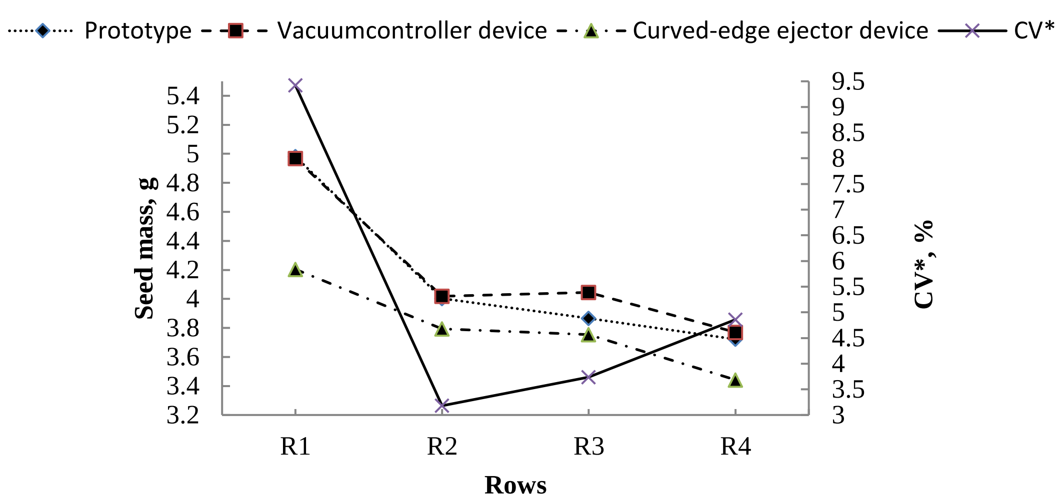


Fig. 5 (d): Comparison of the picked-up seed mass per row of the tested methods at 20 rpm rotating speed

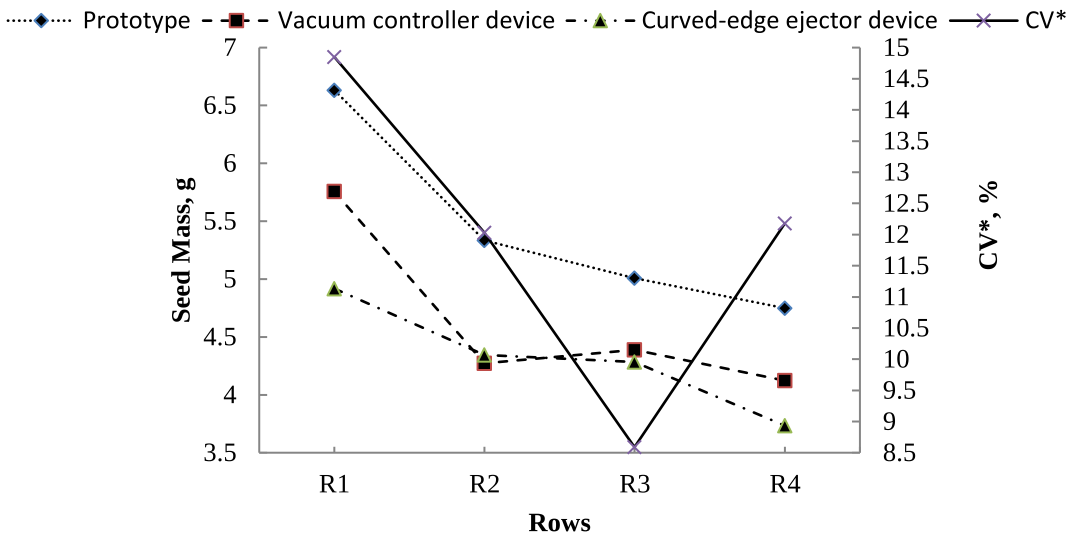


Fig. 5 (e): Comparison of the picked-up seed mass per row of the tested methods at 25 rpm rotating speed

4. Conclusion:

The study concluded with the following points

1. Quantity of seed picked-up under the tested methods was affected by operating speeds. The prototype of multi-rows seed plate obtained the highest amount of picked-up seed compared to the other methods. The curved-edge ejecting device obtained the lowest and consistent rows results of picked-up seed compared to the prototype and vacuum controlling device.
2. Under the three methods, row 1 resulted in the worst performance at all operating speeds followed by row 2.
3. It is recommended that curved-edge device could be used to improve seed picking uniformity of the multi-rows seed plate.

5. Refferences:

Ahmed, B.M.S and F.A. Ahmed. 2013. Variability of yield and some morphological traits in some sesame (Sesamum indicum L.) genotypes under rain-fed conditions. International Journal of Agricultural Science Research 2: 054–059.

Banerjee, P.P. and P.C. Kole. 2009. Analysis of genetic architecture for some physiological characters in sesame (Sesamum indicum L.). Euphytica. 168: 11–22. doi:10.1007/s10681-008-9871-6

Baydar, H. 2005. Breeding for the improvement of the ideal plant type of sesame. Plant Breeding. 124: 263–267.

Barut, Z.B. 1996. Farkli tohumlarin ekiminde kullanilan d.usey plakali, hava emisli hassas ekici du.zenin uygun c-alisma kosullarinin saptanmasi. [Determination of the optimum working parameters of a precision vacuum seeder.], Ph.D Thesis, University of Cukurova, Adana, Turkey.

Boydas, M.G. and Turgut, N. 2007. Effect of vibration, roller design and seed rates on the seed flow evenness of a studded feed roller. Journal of Appllied Engngineering in Agriculture, 23: 413-418.

Cong, J. J., Yu, J. J., Cao, X. Y., Liao, Y. and Q. X. Liao. 2014a. Design of dual-purpose pneumatic precision metering device for rape and wheat. Transactions of the Chinese Sosiety of Agricultural Mechanization 45(1): 46–52.
Cong, J., Q. Liao, X. Cao, Y. Liao, J. Yu and L. Wang. 2014b. Seed filling performance of dual-purposeseed plate in metering device for both rapeseed &wheat seed. Transactions of Chinese Society of Agricultural Engeers 30(8):30-39.
Deng, X., Li, X., Shu, C., Hang, H. D., and Q. X Liao. 2010. Mathematical model and optimization of structure and operating parameters of pneumatic precision metering device for rapeseed. International Journal of Food, Agriculture and Environment, 8(1): 318–322.
Guler, I. E. 2005. Effects of flute diameter, fluted roll length and speed on alfalfa seed flow. Appllied Engngineering in Agriculture. 21:5-7.
Guozhong, Z. Z. Ying, L. Xiwen, W. Zaiman, Z. Qiang and Shasha, Z. 2015. Design and indoor simulated experiment of pneumatic rice seed metering device. International Journal of Agricultural and Biological Engineering 8(4): 10-18.
Jiajia, Y., Yitao, L., Jinling, C., Song, Y., and L. Qingxi. 2014. Simulation analysis and match experiment on negative and positive pressures of pneumatic precision metering device for rapeseed. International Journal of Agricultural and Biological Engineering **7**(3): 1-12. http://doi.org/10.3965/j.ijabe.20140703.001
Ibrahim, J. E., Liao, Q., Wang, L., Liao, Y. and L. Yao .2018. Design and experiment of multi-row pneumatic precision metering device for rapeseed. Int J Agric & Biol Eng 11(5): 116–123.
Osman, I. M., Acar, R. Babiker, E. S. N., and Direk, M. 2023. Agricultural Production Systems in Sudan. Eurasian Journal of Agricultural Economics. 3(1): 46 -56. http://doi.org/10.25165/j.ijabe.20181105.3544
Iman, T., Leila, P., Mohammad, R,B., Sadolla, M. and J.J. Mokhtar. 2011. Genetic variation among Iranian sesame (Sesamum indicum L.) accessions vis-à-vis exotic genotypes on the basis of morpho-physiological traits and RAPD markers. Agricultural Journal of Crop Science 5 11: 1396 –1407.
Karayel**,** D., Barut, Z. B. and A.Özmerzi .2004. Mathematical modeling of vacuum pressure on a precision seeder. Biosystems Engineering 87(4): 437–444. http://doi.org/10.1016/j.biosystemseng.2004.01.011
Karayel, D., M.Wiesehoff, A. Özmerzi and J.Müller .2006. Laboratory measurement of seed drill seed spacing and velocity of fall of seeds using high-speed camera system. Computers and Electronics in Agriculture 50(2): 89–96.
Kocher, M., Lan, Y., Chen, C. and J. Smith. 1998. Opto-electronic sensor system for rapid evaluation of planter seed spacing uniformity. Transactions of the ASAE 41(1): 237–245.
Lan, Y., M. Kocher, anf J. Smith. 1999. Opto-electronic sensor system for laboratory measurement of planter seed spacing with small seeds. Journal of Agricultural Engineering Research 72(1): 119–127.
Lei, X., Y. Liao and Q. Liao. 2016. Simulation of seed motion in seed feeding device with DEM-CFD coupling approach for rapeseed and wheat. Computers and Electronics in Agriculture 131: 29-39.
Li, M., L. Qingxi, L. Yitao, S. Caixia, and L. Lei. 2014. Analysis on seeding process of pneumatic cylinder-type centralized rapeseed precision metering device. Transaction of The Chinese Society of Agricultural Engineering 30(23): 17–27. http://doi.org/10.3969/j.issn.1002-6819.2014.23.003
Li, X., Q. Liao, J. Yu, C. Shu, and Y. Liao. 2012. Dynamic analysis and simulation on sucking process of pneumatic precision metering device for rapeseed. Journal of Food, Agriculture and

Environment 10 (1): 450–454.
Li, Z.D., S.S. Li, X.Y. Cao, X.L. Lei, Y.T. Liao and Y.P. Wei. 2015. Seeding performance experiment of pneumatic-typed precision centralized metering device. Transaction of The Chinese Society of Agricultural Engineering 31(18):17-25.
Liao Y.T., L. Wang, Q. X. Liao. 2017. Design and test of an inside-filling pneumatic precision centralized seed-metering device for rapeseed. Int J Agric Biol Eng 10(2): 56-62.
Liu, L.J., H. Yang and S.C. Ma. 2016. Experimental study on the performance of pneumatic seeding system. International Journal of Agricultural and Biological Engineering 9(6): 84-90.
Lü JQ, Y .Yang, Z. H. Li, S. Q. Qin, J. C. Li, Z. Y. Liu. 2016. Design and experiment of an air-suction potato seed metering device. Int J Agric Biol Eng 9(5): 33-42.
Ogbonna, P.E.and S.I. Ukaa. 2012. Yield evaluation of 13 sesame (Sesamum indicum L.) accessions in the derived savannah agro-ecology of southeastern Nigeria. African Journal of Agricultural Research 7: 5772–5778.
Panning, J., M., Kocher, J. Smith, and , S. Kachman. 2000. Laboratory and field testing of seed spacing uniformity for sugarbeet planters. Applied Engineering in Agriculture 16(1): 7–13.
Qingxi, L., L. Jibo and Q Guoliang. 2009. Experiment of pneumatic precision metering device for rapeseed. Transaction of Chinese Society of Agricultural Mechanization 40(8): 44–48 (in Chinese).
Onal, O. and İ. Onal. 2009. Development of a computerized measurement system for in-row seed spacing accuracy. Turkish Journal of Agriculture and Forestry 33(02): 99-109.
Sabiel, S.A.I., M.I. Ismail, E.A.Abdalla and A.A. Osman. 2015. Genetic variation in sesame genotypes (Sesamum indicum L.) grown in the semi-arid zone of the Sudan. Sabrao Journal of Breeding and Genetics 47: 214–220.
Searle, C. L., M. F. Kocher, J. A. Smith and Blankenship. 2008. Field slope effects on uniformity of corn seed spacing for three precision planter metering systems. Applied Engineering in Agriculture 24(5): 581–58.
Singh, R., G. Singh, and D. Saraswat. 2005. Optimisation of design and operational parameters of a pneumatic seed metering device for planting cotton seeds. Biosystems Engineering 92(4): 429–438.
Wang, L., Y., Liao, and Q. Liao. 2018. Design and experiment of remote control precision planter for Chine cabbage. International Journal of Robotics and Automation 33(2): 208-214. http://doi.org/10.2316/Journal.206.2018.2.206-5536
Yang, L., B.X. T.Yan, Y.u. Cui, X.T. He and Q.W. Liu. 2016. Global overview of research progress and development of precision maize planters. International Journal of Agricultural and Biological Engineering 9(1): 9-26.
Yazgi, A., and A. Degirmencioglu. 2007. Optimisation of the seed spacing uniformity performance of a vacuum-type precision seeder using response surface methodology. Biosystems Engineering 97(3): 347–356. http://doi.org/10.1016/j.biosystemseng.2007.03.013
Zhan, Z., L. Yaoming, C. Jin, and X. Lizhang. 2010. Numerical analysis and laboratory testing of seed spacing uniformity performance for vacuum-cylinder precision seeder. Biosystems Engineering 106(4): 344–351. http://doi.org/10.1016/j.biosystemseng.2010.02.012