Fabrication and evaluation of vacuumed metering drum performance for row planting of soybean with grease belt

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Abstract: In this study, a vacuumed metering drum was fabricated under special vacuum pressure for the cultivation of soybean seeds DPX and it was evaluated by grease belt machine. In order to evaluate this metering drum, the speed of planter was assessed with three levels of 0.5, 1 and 1.5 m s^{-1} and three levels of metering drum vacuum pressures of 980, 1180 and 1380 Pa with two seed-separating methods (mechanical and pneumatic) in three replications. In this study, the effects of in-cylinder vacuum pressure and speed of planter's forward movement on the filling percentage, multi-seed, non-planting, deviation from planting line, and uniform distribution of seed were assessed. The results of the test were examined in the form of a factorial experiment with a completely random design and comparison of means was performed by LSD test in SAS software. The results indicated that when the vacuum pressure was increased or the speed of planter was reduced, the filling percentage was increased. The filling percentage and multi- planting were increased with the increase of pressure and multi- planting was reduced with reduction of speed. The in-cylinder pressure and speed of planter have no effect on the rate of deviation from the planting line, and uniform distribution of seeds was done better in the lower pressure and speed. Moreover, the performance of this metering drum equipped with the pneumatic separator was better than mechanical separator in all parameters.

Keywords: seed separator, filling percentage, planting line, metering of seeds

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1 Introduction

Farmers often use grain drill to plant soybean. This planter pours the seeds in strip lines on land while it does not arrange distance of seed from each other. As a result, when the grain drill is used, use of seeds is increased per unit area. Of course, use of grain drill, in addition to extra seeds' consumption, increases the cost of production regarding the de-blossoming operation to remove additional bushes.

Nourgholipour et al. (2013) conducted some researches on the pneumatic planters and reported that in the pneumatic planter, the different pressures between two sides of the metering drum are the only factor to choose the seeds. The seed damage was very low moreover, it was possible to arrange the accurate distance of seeds on the cultivation line in this planter. Yasir et al. (2012) made a new pneumatic metering device for wheat seeds. The fabricated metering device was tested under laboratory conditions using a test chassis equipped with a camera system. They showed that rotational speed, the negative pressure of the metering device, and their counter-effect have some effect on the metering drum. Singh et al. (2007) indicated that optimization of design and operation parameters of the pneumatic metering device was assessed for the planting of cotton seeds. In this research, they examined the effect of linear speed of metering plate in four levels (0.29, 0.42, 0.58, and 0.69 m s^{-1}), vacuum pressure in four levels (1, 1.5, 2 and 2.5 kPa), three angles of seed entry into aperture (90°, 120°, and 150°) on the average distance of seeds, metering drum's filling percentage index, multi-planting index, and highest quality of metering drum's feed. Karayel et al. (2006) examine (a) distance of seeds separated from metering drum and (b) speed of seed hit to

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surface of grease belt by use of high-speed camera system in the rotational speed of metering drum's rollers of 10, 20, 30 and 40 rpm and grease belt's linear speed of 1 m s^{-1} for wheat and soybean seeds. The results of the study conducted by these researchers indicated that the high-speed camera can record the speed of seeds hit to grease belt in addition to distance of seeds from each other, whereas all seeds can be recorded by the camera. Zhan et al. (2010) examine the performance of precise cylindrical vacuum planter by numerical analysis and laboratory test. Using physical properties of seeds such as sphericity, 1000-grain weight, and fall – line analysis, they found that positive differential pressure, discharge angle and rotational speed of cylinder had a significant effect on the distribution uniformity of seed on the row. Deng et al. (2010) investigated the mathematical model, optimization of structure and important parameters of accurate pneumatic metering drum for rapeseed planting. In their model, an appropriate approximation is presented for the nozzle pressure difference in order to create the minimum force required to stick the seed to the distributor with regard to grain diameter, cone angle and nozzle diameter. Karayel et al. (2004) the purpose of study is to determine the vacuum pressure regarding some physical properties of seed such as mass of 1000 seeds, spherical coefficient and seed density in the planter. With regard to a laboratory test that was performed on seeds of corn, cotton, soybeans, watermelons, melons, cucumbers, sugar beets and onion, their results show that mathematical model with 0.99 efficiency model predicts necessary pressure for precise planter. Afify et al. (2009) study a mathematical model to predict required vacuum pressure to precise pneumatic planter for onion seeds. Their suggested model can satisfactorily predict vacuum pressure in the aperture of accurate vacuum planter with the 0.99 efficiency. Yazgi and Degrimenciogh (2007) examined the optimization of a metering device performance under vacuum on the seeds of cotton by using response level. In their research, filling index, multi- planting, and non-planting were assessed. Their results showed that the least environmental speed has the highest performance. Önal et al. (2012) estimate the accuracy of distance between seeds of corn and cotton by using accurate vacuum-kind metering based on the theoretical consideration and test on the seeds fallen on the greased conveyor belt. In this research, they considered the quality of feed index, filling rate of metering device, multi- planting, and accuracy as criteria for accurate spacing of seeds. Guarella et al. (1996) examined the laboratory and theoretical performance of vacuum pneumatic planter for seeds of vegetables. They carried out the experiment for four kinds of seeds with different shapes and properties, seven kinds of nuzzle with different diameters, and pressure difference ranged from 0 to 80 kPa. The results indicated that in the pressure difference more than 20 kPa, seed distance does not increased remarkably. Rahmati and Hajiahmad (2008) conduct a study about optimization of pneumatic row planter for tomato seeds in which ground wheel causes the machine and metering drum's system to move. In the earlier mentioned machine, blower provide the required air pressure to keep seeds behind the aperture of cylindrical metering drum by means of power takeoff (PTO) shaft of tractor. They reported the distribution uniformity coefficient of seed around the arranged distance of machine about 97.5% and around average distance about 95.2%. Nourgholipour et al. (2013) designed and fabricated cylindrical metering device under electro-pneumatic pressure for soybean seeds. They evaluated metering device with three air flow of 23, 27 and 32 m s^{-1} and different speeds of planter's movement. They intended to determine the highest speed of planter's movement with at least 95 filling percentage of metering device. Their results showed that the filling percentage was reduced with increase of planter's forward speed in the fixed speed of air flow. Mamizadeh et al. (2014) designed and fabricated a metering drum under electro-pneumatic vacuum for soybean seed. Metering drum was evaluated with three vacuum pressure levels of 1, 2 and 4 kPa and different speeds of metering drum's rotation. The results indicated that the most rotational speed (accounting for 80 filling percentage of metering drum's aperture) was equal to 1.8 m s^{-1} in the negative pressure of 4 kPa.

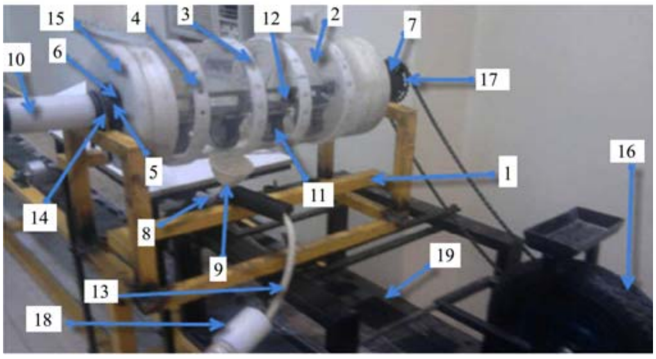
Pneumatic planters are replaced with mechanical planter due to damages incurred on seeds and un-controlled plantation. In this study, given that precise plantation of agricultural products, inhibition of seed loss, and extra cost of non-planting are important, so of pneumatic planter, cylindrical planter under vacuum draws many attentions due to use of central metering drum for all planting rows and better control of its performance for doing task. Cylinder vacuum metering device with four rows equipped with pneumatic separator was fabricated for planting of soybean and was evaluated with grease belt.

2 Material and method

2.1 Fabrication and operation the machine

Pneumatic seed metering drum with four rows was made for planting of soybean seed in manufacturing and production workshop of Bio-system Mechanical Engineering Department in Gorgan University of Agricultural Sciences and Natural Resources. Figure 1 shows the general schema of this metering device.

Pneumatic seed metering drum under vacuum was formed from the different following parts:



1. Chassis 2. Metering drum under vacuum 3. Compressed plastic ring 4. Apertures 5. Ball bearing 6. Felt bowl 7. Bearing 8. Seed drop tubes 9. Funnel 10. Vacuum tubes 11. Dispensers 12. Springs 13. Air intake pipe 14. U-bolt 15. Compressed plastic cap 16. Moving wheel 17. Gear 18. Divider 19. Grease-belt machine

Figure 1 Different components of the fabricated pneumatic metering drum

This machine works as follows: when the grease belt machine is turned on and the belt is moved, moving wheel of the planter that is in contact with belt began to rotate. Rotation of wheel is transformed to machine through chain and gear and then cylinder begins to rotate. The ratio of linear speed of conveyor belt and linear speed of metering drum are determined by arranging the ratio of moving gear wheel and cylindrical gear of metering drum and then specifying the radius of cylinder. Five-centimeter distance of two seeds next to each other on the planting row is based on arranging ratio of gear attached to metering drum cylinder to exerting force to gear attached to moving wheel of planter. According to arrangement, the metering drum is rotated per linear speed (1 m s^{-1}) of grease belt gear. Since there are 20 apertures in each row, so that the distance between two seeds poured next each other on the grease belt is five centimeters. The movement of grease belt strap is supplied by three-phase electric motor (3.5 KW) and change of grease belt speed is provided by changer's frequency that changes electromotor cycles. Rotational speed of moving cylinder of grease belt strap is measured by tachometer. Then, linear speed of grease belt is calculated. Moreover, vacuum pressure required by electro-pump (model: BVC-2.8) made by MAHAK Electric Blower Company is provided. Electro- pump was equipped with possibility to select different rotational speeds, so it is able to supply different vacuum pressure. Moreover, vacuum pressure in the metering drum was measured by manometer. Due to the force created by the difference in pressure created on both sides of the cylinder wall, when cylinder is rotating, seeds stuck behind the aperture rotate with cylinder, when seed reaches to the funnel attached to both walls of cylinder. When the cylinder rotates, the seeds stuck behind the apertures rotate along with cylinder. When the seed reaches the site of funnel attached to outlet pipe, the pressure is removed by means of separating rubber wheels (in the type equipped with a mechanical separator of seeds) and pneumatic ejector (in the type equipped with a pneumatic separator of seeds) and seed is separated from the aperture due to its weight and is dropped into the funnel attached to the inlet tube, as soon as it leaves the funnel and exposed to the fall, it moves just few centimeter distance of grease belt with air flow passing the tube, it stops where it hits the layer of grease on the strap (see Figure 2).

Figure 2 The condition of seeds stuck on the grease belt

2.2 Physical properties of seeds

In this study, soybean seed DPX was provided from oily seeds factory located in Gorgan City. The sample was separated from external materials such as seeds of weed, broken grains, large and small seeds. Approximately 20 grams of sample were weighted with a Japanese scale of A & DEK-600i model with a precision of 0.01 grams. The initial moisture in the seeds according to Equation (1) and (2) was measured by oven drying (German T-Power model) at 130°C until it reaches fixed weight and then it is measured (Martynenko and Zheng, 2016). This task was done at three replications and average numbers were recorded. The moisture of seeds is 7.8% based on dry weight and 7.3% based on the wet weight.

$$MC_{w.b.} = \frac{m_1 - m_2}{m_1} \times 100 \quad (1)$$

$$MC_{d.b.} = \frac{MC_{w.b.}}{100 - MC_{w.b.}} \times 100 \quad (2)$$

In order to measure dimensions, 30 soybean seeds were selected randomly and then three dimensions of soybeans i.e. length (l), width (w) and thickness (t), were measured by using digital caliper (Chines INSIZE model). The geometrical inner diameter (d_s), average mathematical diameter (d_a), sphericity (φ), and lateral surface of seeds (S) were calculated by the following Equations (Mohsenin, 1986).

$$d_s = (lwt)^{1/3} \quad (3)$$

$$d_a = \frac{l + w + t}{3} \quad (4)$$

$$\varphi = \frac{(lwt)^{1/3}}{l} \times 100 \quad (5)$$

$$S = \pi d_s^2 \quad (6)$$

In rotating the metering drum, the force created from the pressure difference between inside and outside of metering drum is exerted on the seeds stuck to metering drum according to Equation (7), and among of pressure force that was exerted on the seeds from the walls, are according to Figure 3 and Equation (8):

$$F = \frac{1}{8} \pi P \circ d_s^2 (1 + \cos\alpha) \quad (7)$$

$$N = F - mg\cos\beta - mr\omega^2 \quad (8)$$

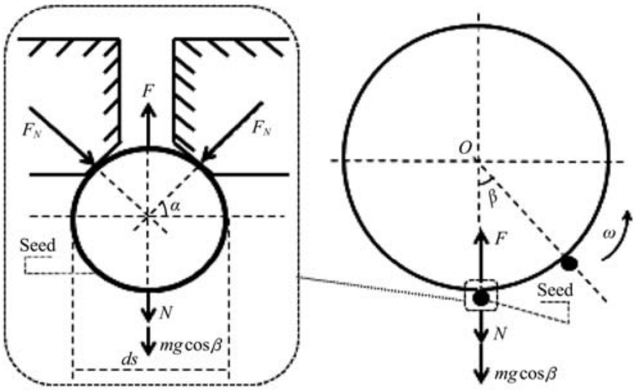


Figure 3 The force that is exerted on the seeds stuck to the external wall of cylinder vacuum metering drum when rotating

2.3 Distribution filling percentage

In order to determine the metering drum filling percentage, the seeds that left the drop tube are collected in the container. Per specified rotation of metering drum, the number of seeds leaving the drop tube was counted. When the number of seeds that should leave the drop tube was calculated, the filling percentage of the metering drum was determined (Equation (9)), this test was performed in three replications for all different states when evaluating the machine.

$$D = {}^{n}\!/\!_{n'} \times 100 \quad (9)$$

In order to determine the filling percentage, the number of seeds stuck behind the metering drum aperture and the number of seeds leaving the drop tube was assessed. Furthermore, the mechanical damages inflicted on the seeds that leave the drop tube was assessed in terms of fracture, crushing, etc.

In order to determine multi-planting and non-planting, seeds poured on the grease belt with 4m length were assessed. In order to find out the cause of multi-planting, the rotation of metering drum was stopped in the sequent times and the number of seeds stuck behind aperture of the metering drum was examined with eyes carefully.

In order to determine the deviation from cultivation line, the distance between 20 seeds from cultivation line is measured and deviation rate was calculated from cultivation line by use of Equations (10) and (11) (Rahmati and Hajiahmad, 2008).

$$\bar{x} = \frac{\sum x_i}{n} \quad (10)$$

$$SD = \sqrt{\sum \frac{(x_i - \bar{x})^2}{n - 1}} \quad (11)$$

2.4 Distribution uniformity coefficient of seed

In order to determine the distribution uniformity coefficient of seed of metering drum around average distance as well as around arranged distance (5 cm) in different speeds of machine's forward movement at every time of test, the distance between 20 seeds were measured and distribution uniformity coefficient of seed was gotten using Equation (12) (Rahmati and Hajiahmad, 2008).

$$Se = (1 - Y/D) \times 100 \qquad (12)$$

Metering drum test was performed at three levels of vacuum pressure inside the cylinder of 980, 1180, and 1380 kPa and three forward movement speeds of 0.5, 1 and 1.5 m s^{-1} and in separating pneumatic and mechanical method. Indexes assessed in this study were the effect of pressure inside the pneumatic cylinder, planter's forward movement speed, and pressure counter-effect inside the cylinder, and forward movement speed on the filling percentage of metering drum, multi-planting percentage, non-planting percentage, deviation rate from cultivation line and uniformity of seed distribution. Data analysis in the form of factorial test with completely random basic design and comparison of average data was performed using Least Significant Difference (LSD) test in SAS software.

3 Result and discussion

3.1 Effect of in-cylinder vacuum pressure and forward movement speed on the filling percentage

The results of data variance analysis show that the difference between pressure levels inside the cylinder and forward movement speed and their counter effect in terms of filling percentage of metering drum's aperture was significant in the levels of 1 and 5 (Table 1).

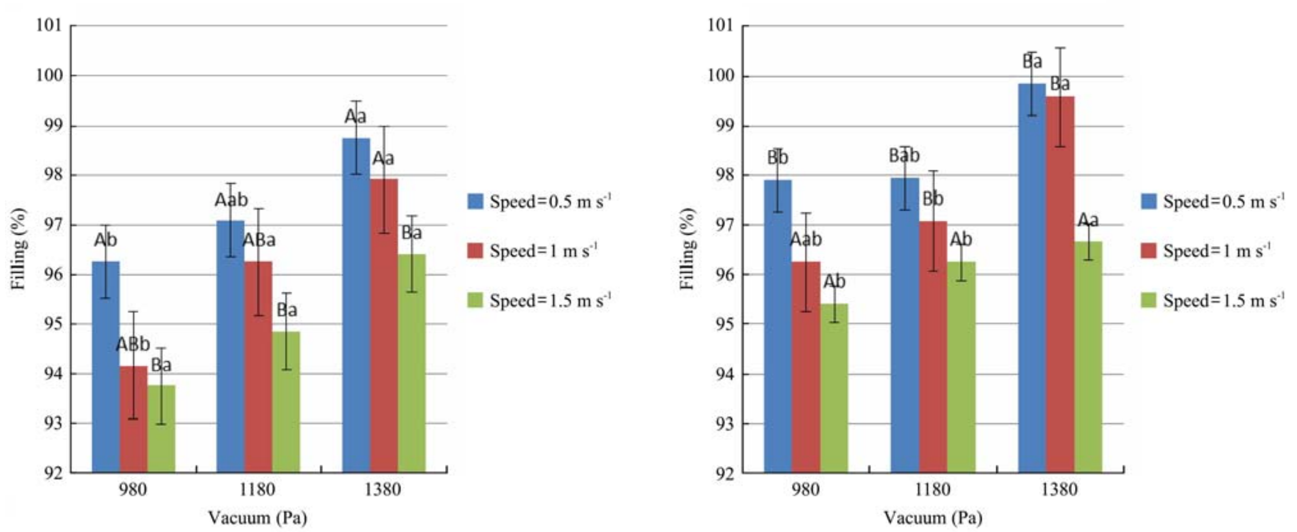
Table 1 The results of variance analysis of vacuum pressure and progress speed on the filling percentage

Variables	Mechanical method, cv=1.03		Pneumatic method, cv=0.60	
	DF	Mean Square	DF	Mean Square
Pressure inside pneumatic cylinder	2	7.69**	2	12.02**
Forward movement speed	2	30.26**	2	14.29**
Pressure inside pneumatic cylinder × forward movement speed	4	4.91**	4	1.27*
Error	8	1.56	8	1.2

Note: * and ** are significant difference at level of 1% and level of 5% respectively (LSD).

Comparing average treatments in terms of filling percentage of metering drum's aperture in metering drum equipped with mechanical separator, Figure 4(a) showed that there was a significant difference in vacuum pressure inside cylinders of 980 and 1180 kPa between the speed of 0.5 m s^{-1} and speed of 1.5 m s^{-1} and there was no significant difference between speed of 1 m s^{-1} and speeds of 0.5 and 1.5 m s^{-1}. Furthermore, no significant difference was observed between the speed of 0.5 m s^{-1} and speed of 1 m s^{-1} in vacuum pressure of 1380 kPa, while there was a significant difference between speeds of 0.5 m s^{-1} and 1 m s^{-1} and speed of 1.5 m s^{-1} (Figure 4(a) capital letters). Generally, the more speed increases in the vacuum pressure, the less the seed stuck behind aperture due to an increase of centrifuge force exerted on the seed. Therefore, filling percentage was decreased. A significant difference was observed in the speed of 0.5 m s^{-1} between vacuum pressure of 980 Pa and a vacuum pressure of 1380 Pa. While the significant difference was not observed between the pressure of 1180 Pa and pressures of 980 and 1380 (Figure 4(a) small letters). A significant difference was not observed in the speed of 1 m s^{-1} between vacuum pressure of 1180 and 1380 Pa, while a significant difference was observed between vacuum pressure of 980 and pressures of 1180 and 1380 Pa. But the significant difference was not observed in the speed of 1.5 m s^{-1} between different pressures.

Comparing average treatment in the metering drum equipped with pneumatic seed separator, the Figure 4(b) showed that there was a significant difference between the speed of 0.5 m s^{-1} and speeds of 1 and 1.5 m s^{-1} in the vacuum pressure of 980 Pa inside the cylinder. Moreover, a significant difference was not observed in the vacuum pressure of 1180 and 1380 Pa between the speed of 0.5 m s^{-1} and speed of 1 m s^{-1}, whereas a significant difference was observed between speeds of 0.5 and 1 m s^{-1} with speed of 1.5 m s^{-1} (Figure 4(b)-capital letters). According to Figure 4(b), the more rotational speed was increased in the fixed vacuum pressure, the less the seed stuck behind aperture due to increase in centrifuge force exerted on the seed. Therefore, filling percentage was decreased. A significant difference was observed in the speed of 0.5 m s^{-1} between vacuum pressure of 980 and 1380 Pa, whereas a significant difference was not observed between the pressure of 1180 Pa and pressures of 980 Pa and 1380 Pa (Figure 4(b)-small letters). There was no significant difference in speed of 1 m s^{-1} between the pressure of 980 Pa and pressures of 1180 and 1380 Pa. While there was a significant difference between vacuum pressure of 1180 Pa and another pressure of 1380 Pa. significant difference was not observed in the speed of 1.5 m s^{-1} between 980 Pa and 1180 Pa, while significant pressure was observed between pressures of 980 and 1180 Pa and pressure of 1380 Pa (Figure 4(b) - small letters). The force exerted on the seed was increased due to increase in the in-cylinder vacuum pressure and the seed stuck to behind the aperture with more pressure force. The test performed by Singh et al. (2005) on the cottonseed, showed that the feed index (filling percentage) improved with increasing the vacuum pressure of 2 kPa and reaches 94.7% that approves the above results.



(a) Mechanical method

(b) Pneumatic method

Figure 4 Comparing the average effect of vacuum pressure inside cylinder and progress speed on the filling percentage with two kinds of seed separators from the metering drum by mechanical and pneumatic method

When comparing Figure 4(a) and (b), it was observed that condition of filling percentage of the metering drum in the pneumatic separator was better than that in the mechanical separator. In the equal condition in terms of vacuum pressure and speed of planter (speed of grease belt), the number of seeds that stick to behind metering drum aperture should be the same in both kinds of separators. The filling percentage of metering drum aperture was reduced because some seeds were not separated from the metering drum and rotate with it when passing the site of separator equipped with a mechanical separator. Since metering drum filling percentage was gotten through counting the number of seeds leaving the drop tube then it was compared with the number of seeds that should leave it (Equation (9)) although the number of seeds stuck behind the aperture of the metering drum was the same, we observe different filling percentage.

3.2 Effect of in-cylinder vacuum pressure and forward movement speed on multi-planting

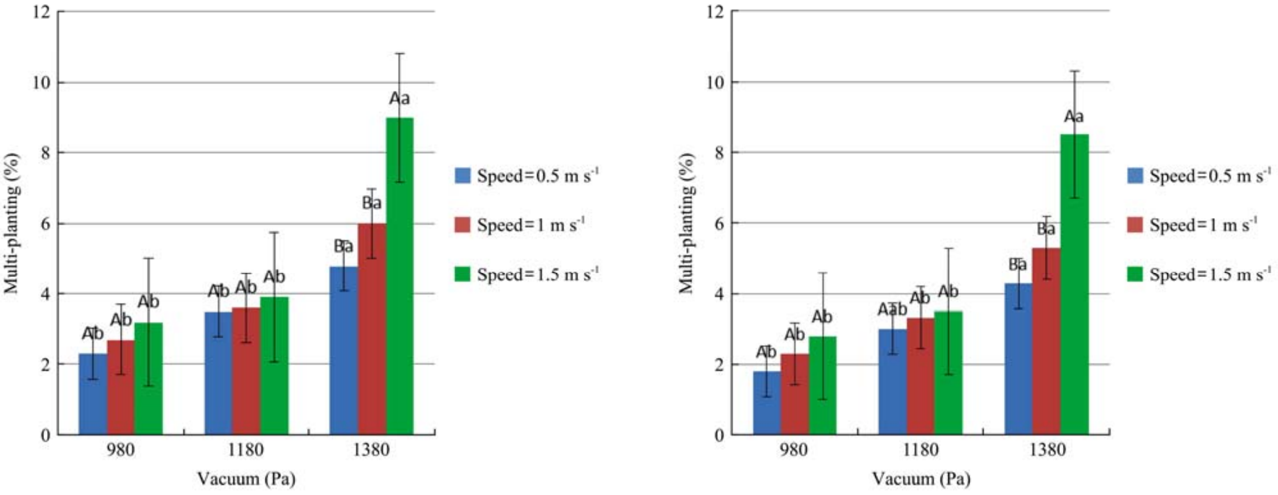
The results of data analysis indicated that the difference between in-cylinder vacuum pressure and speed of p progress and their counter-effect were significant in terms of multi-planting percentage of metering drum aperture in the levels of 1% and 5% (Table 2).

Table 2 The results of data analysis of in-cylinder vacuum pressure and forward movement speed on the multi-planting

Variables	Mechanical method, cv=18.5		Pneumatic method, cv=22.86	
	DF	Mean Square	DF	Mean Square
Pressure inside pneumatic cylinder	2	31.25**	2	34.08**
Forward movement speed	2	7.8**	2	8.04**
Pressure inside pneumatic cylinder × forward movement speed	4	3.2*	4	3.61*
Error	8	0.85	8	0.56

Note: * and ** have significant difference at levels of 1 and 5% (LSD).

Comparison of average treatments in terms of multi-planting in the metering drum equipped with mechanical seed separator, Figure 5(a) and metering drum equipped with pneumatic seed separator that was shown in Figure 5(b) indicated that there was no significant difference in the in-cylinder vacuum pressure of 980 Pa and 1180 Pa between the speed of 0.5 m s^{-1} and speed of 1.5 m s^{-1}. Also, no significant pressure was observed in the vacuum pressure of 1380 Pa between the speed of 0.5 m s^{-1} and speed of 1 m s^{-1} whereas, while there was a significant difference between speeds 0.5 m s^{-1} and 1 m s^{-1} and speed of 1.5 m s^{-1} (Figure 4(a) and (b)-capital letters).



(a) Mechanical method (b) Pneumatic method

Figure 5 Comparing the average effect of in-cylinder vacuum pressure and forward movement speed on the multi-planting percentage with two kinds of seed separator from the metering drum by (a) mechanical and (b) pneumatic methods

According to Figure 5, generally, multi-planting was increased with increase in the pressure and speed. No significant difference was observed in speeds of 0.5, 1, and 1.5 m s^{-1} in the vacuum pressure of 980 and 1180 Pa, while there was a significant difference in the speed of 0.5, 1, and 1.5 m s^{-1} between vacuum pressures of 980 and 1180 Pa and vacuum pressure of 1380 Pa (Figure 4(a) and (b) small letters). Since multi- planting means that the distance between two seeds next to each other on the cultivation row was less than half arranged distance, when metering drum was examined with naked eyes, no aperture, containing more than one seed, was seen. All multi-planting was related to the unequal path of seed passage in the drop tube. Regarding the speed of airflow in the drop tube (56 m s^{-1}, to transfer separated seeds to the end of drop tube) and created disturbance in the movement path of seed, as soon as the seeds were separated from metering drum, it passes random, unpredictable path. Therefore, each time when the seeds separated from metering drum was not equal to the time when the seed leaves and seats on the grease belt. This causes the distribution uniformity of seed and multi-planting. The comparison between two diagrams of Figure 5(a) and (b) show that multi- planting in metering drum equipped with the pneumatic separator was less than that of the metering drum equipped with a mechanical separator. This results in the better separation of seed from the metering drum.

3.3 Effect of in-cylinder vacuum pressure and forward movement speed on the non-plantation percentage

The results of data variance analysis show that there was significant difference between in-cylinder pressure levels and forward movement speed and counter-effect in terms of non-planting percentage of metering drum aperture in the level of 1% (Table 3).

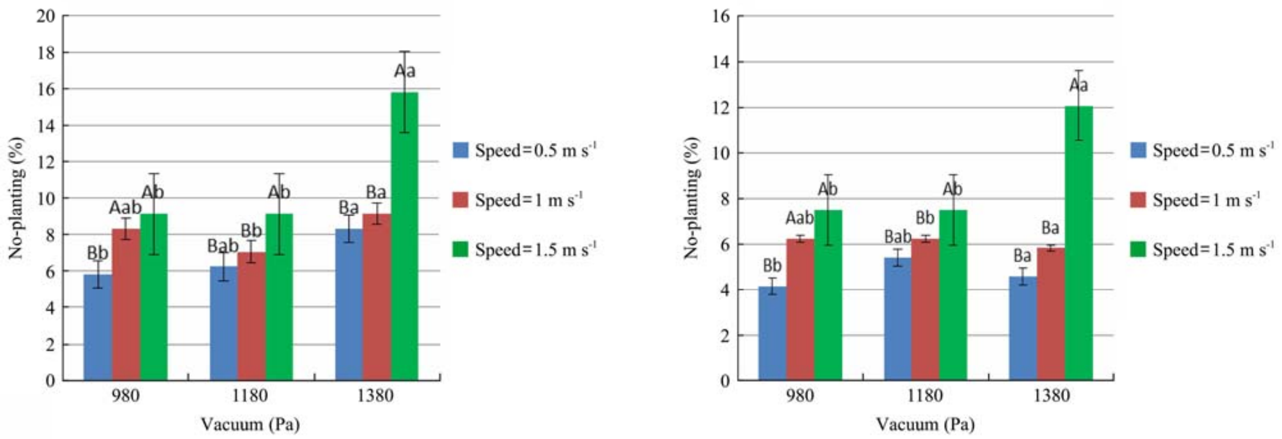
Table 3 Results of variance analysis of in-cylinder vacuum pressure and forward movement speed on the non-plantation percentage

Variables	Mechanical method, cv=18.5		Pneumatic method, cv=22.86	
	DF	Mean Square	DF	Mean Square
Pressure inside pneumatic cylinder	2	36.34**	2	5.61**
Forward movement speed	2	49.71**	2	43.46**
Pressure inside pneumatic cylinder × forward movement speed	4	8.53**	4	8.39**
Error	8	0.68	8	0.53

Note: ** and * have significant difference at levels of 1 and 5% respectively (LSD).

Comparing average treatment in terms of non-planting percentage in the metering drum equipped with mechanical seed separator that was shown in Figure 6(a) and metering drum equipped with pneumatic seed separator that was shown in Figure 6(b) indicated that there was a significant difference in the in-cylinder vacuum pressure of 980 Pa between the speed of 0.5 m s^{-1} and speeds of 1 and 1.5 m s^{-1}.

There was no significant difference in the pressure of 980 Pa between the speed of 1 m s^{-1} and speed of 1.5 m s^{-1}. in addition, there was a significant difference in the vacuum pressure of 1180 and 1380 Pa between speeds of 0.51 m s^{-1} and speed of 1.5 m s^{-1}, while there was no any significant difference in the vacuum pressure of 1180 and 1380 Pa between the speed of 0.5 m s^{-1} and speed of 1 m s^{-1} (Figure 6(a) and (b) capital letters). No significant difference in the speed of 0.5 m s^{-1} between the pressure of 980 Pa and pressure of 1180 Pa and between the pressure of 1180 Pa and pressure of 1380 Pa, while the significant difference was observed at this speed between 980 Pa and 1380 Pa. No significant difference was observed in the speed of 1 m s^{-1} between the pressure of 980 and pressures of 1180 Pa and 1380 Pa, while significant difference was observed in this speed between 1180 Pa and 1380 Pa. No any significant difference was observed at speed of 1.5 m s^{-1} between the pressure of 980 Pa and 1180 Pa, while there was a significant difference between pressure 1380 Pa and pressures of 980 and 1180 Pa (Figure 4(a) and (b) small letters). If the distance between two seeds next to each other in the crop row was more than one and half times of arranged distance, it can be calculated the free distance as non-planting area. Of non-planting factors, it can be pointed to these factors such as (1) non-stickiness of seeds to the aperture behind the metering drum, (2) non-separation of seeds from behind metering drum aperture, (3) passing through an unequal path in the drop tube (in the argument of multi-planting, it was explained). In the fixed pressure, the more the rotational speed of the metering drum was increased (the more the forward speed was), the less the filling percentage of metering drum aperture was (Figure 4), so non-planting was increased (Figure 6). The more the pressure was increased in the fixed speed, the more the filling percentage of metering drum aperture was increased (Figure 4). Multi-planting was increased in the same condition (Figure 5), but increase in multi-planting was more than reduction in the aperture with no seeds (increase in the filling percentage of metering drum aperture), consequently non-plantation was increased in this condition (Figure 6).



(a) Mechanical method (b) Pneumatic method

Figure 6 Comparing average effect of in-cylinder vacuum pressure and progress speed on the non-plantation percentage with two kinds of separator by (a) mechanical and (b) pneumatic methods

Comparing two kinds of seed separator, it was observed that pneumatic separator can separate seeds stuck behind metering drum aperture better than a mechanical separator. In higher speed, the rubber wheel of seed separator that rotates due to the contact with inner wall of the cylinder was stopped due to severe shake and vibration and contact of the wheel with the inner wall of the metering drum. This causes the seed to be separated from the metering drum. Furthermore, in the higher rotational speed of the metering drum, the mechanical separator has not enough chance to eliminate the pressure difference between inside and outside the cylinder. Therefore, some seeds, without separation from the location of the separator, pass and rotate outside of the cylinder. This results in the increase in the non-plantation percentage. Also, if the pressure difference was eliminated inside and outside the cylinder by a mechanical separator, the seed should drop in the drop tube due to its gravity force until it is transferred on the cultivation line by airflow available in the drop tube. Procrastination in seed drop into drop tube was one of the main reasons of disarrangement in seed's distribution uniformity and multi-planting percentage (distance between two seeds on the plantation line was less than half arranged distance) and non-plantation (distance between two seeds next to each other was more than one and half times of arranged distance) was increased. While pneumatic separator not only eliminates the pressure difference inside and outside of cylinder but also throws a seed in the drop tube by pressure force exerted on the seed. This result approves the report of Önal et al. (2012).

3.4 Determination of seed's distribution uniformity

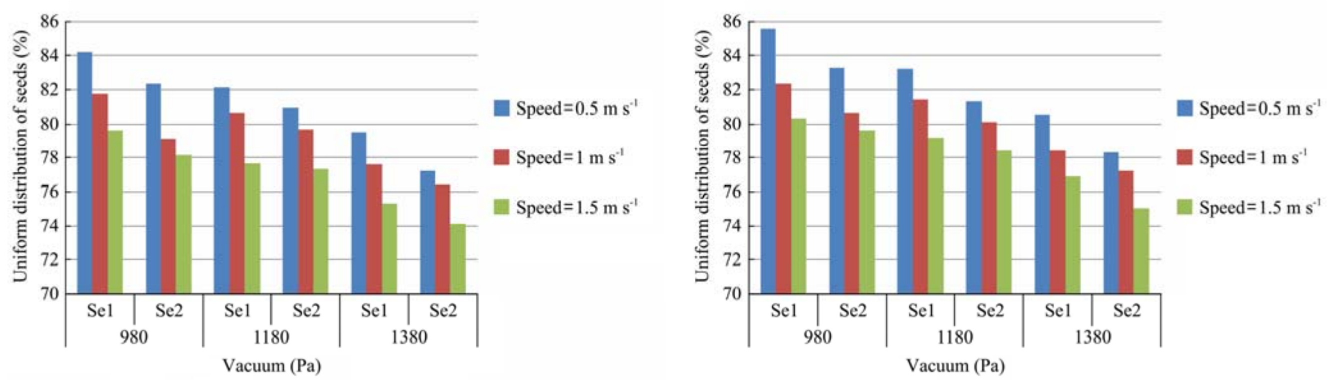
The results of variance analysis for effect of in-cylinder pressure and speed on the deviation from plantation line were shown Table 4. The results of this table show that effect of in-cylinder pressure and speed on the amount of deviation from cultivation line.

Table 4 Variance analysis for effect of in-cylinder pressure and speed on the amount of deviation from cultivation line

Variables	Mechanical method		Pneumatic method	
	DF	Mean Square	DF	Mean Square
Pressure inside pneumatic cylinder	2	0.5715 ns	2	0.6815 ns
Forward movement speed	2	0.04924 ns	2	0.05124 ns
Pressure inside pneumatic cylinder × forward movement speed	4	0.2416 ns	4	0.2367 ns

Note: "NS (or ns)" is abbreviation of "non- significant".

Figure 7 shows uniformity coefficient of seed's metering drum in different vacuum pressures and different speed of planter. Uniformity coefficient of seed (in percent) was reported around set distance (Se1) and around average distance of seeds poured on the grease belt (Se2).



(a) Mechanical method

(b) Pneumatic method

Figure 7 Distribution conformity of seed around arranged distance (Se1) and average distance (Se2) with two kinds of seed separator of metering drum by (a) mechanical and (b) pneumatic method

The measurement of the distance between seeds poured on the cultivation line and calculation of seed's distribution uniformity by means of Equation (11) show that distribution uniformity coefficient of seed in the equal condition of pressure and speed of planter in metering drum equipped with pneumatic separator has better condition than metering drum equipped with a mechanical separator. The sum of the reasons explained in the section of multi-planting and non-plantation did not make that difference. In addition, in the condition of fixed pressure in both separating methods of seeds, the more the speed increases, the less the uniformity decreases. This was due to procrastination of seeds happened in the time of separation from the metering drum. Singh et al. (2007) get distribution uniformity coefficient of seed for a pneumatic metering drum for plantation of cotton seeds in 88% laboratory condition. Rahmati and Hajiahmad (2008) report distribution uniformity coefficient of seed for a pneumatic metering drum of tomato seed around the arranged distance of machine about 97.5% and around average distance about 95.2%. In the tested machine, the length of drop tube was longer than machine evaluated by Singh et at. (2007) and Rahmati and Hajiahmad (2008), so the values reported by them have a better condition.

4 Conclusion

The results of the experiment indicated that regardless of types of metering drum separator, the amount of non-planting, multi-planting and filling percentage of metering drum aperture was increased with increase in speed of metering drum (grease belt) in metering drum under vacuum pressure, in fixed vacuum pressure. Filling percentage, non-plantation, multi-planting was increased with increase in in-cylinder vacuum pressure in the fixed speed of the metering drum.

The evaluation of machine was indicated that multi-planting was done not because of sticking more than one seed to behind metering drum aperture, but because of the manner of seeds' separation from metering drum until its seating in the drop tube as well as the path of seeds' movement in drop tube along with air flow until its' seating on the grease belt. In addition, the assessment of metering drum's performance indicated that the lack of plant was due to some factors such as the manner of seed's separation from the metering drum, unequal path moved by seeds in drop tube (completely random, zigzag path) as well as non-separation of some seeds when passing through the location of seed's separator.

The evaluation of metering drum with the mechanical separator and pneumatic separator indicated that generally, the performance of pneumatic was better than that of mechanical performance. Especially, if the metering drum was used in real condition, this had a negative effect on the performance of mechanical separator due to shaking exerted on this machine, while the pneumatic separator has better performance because it does not have contact with the inner wall.

Using the results achieved, it was found out that the seeds have better distribution's uniformity in less vacuum pressure. Under specified pressure, the more the forward movement speed, the less the uniformity coefficient of metering drum's seed. In this condition, seed's uniformity coefficient can be improved with the mild curvature of drop tube such that seed movement witnesses fewer disturbances in the passage of movement.

Since pneumatic planter less damage to seeds, meanwhile, the accurate planting of products can be done by means of such planter. So, their use was increasingly growing. Pneumatic metering drum under vacuum pressure not only does acceptably accurate planting but also needs less prime cost. Using results of this study, the pneumatic planter with metering drum under vacuum pressure with the pneumatic separator was recommended for the planting of row crop especially soybean seed.

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Nomenclature

$MC_{d.b.}$	Wet basis (%)
$MC_{w.b.}$	Dry basis (%)
m_1	Mass of sample before drying (g)
m_2	Mass of sample after drying (g)
l	Length (mm)
w	Width (mm)
t	Thickness (mm)
d_s	Geometrical inner diameter (mm)
d_a	Average mathematical diameter (mm)
Φ	Sphericity (%)
S	lateral surface (mm^2)
F	Vacuum force (N)
m	Mass of soya been (g)
g	Acceleration of gravity (m s^{-2})
β	Angle of the era (rad)
N	Force applied to the seed from the outer wall (N)
r	Cylindrical radius (m)
ω	Angular velocity of the cylinder (rad s^{-1})
P_o	Vacuum pressure (Pa)
α	Angular cone angle (rad)
n	The number of seeds leaving the drop tube
n'	The number of seeds that should leave the drop tube
x_i	The distance between two seeds next to each other (cm)
$\bar{x}$	Average distance (cm)
SD	Standard deviation (cm)
Se	Distribution Uniformity Coefficient of Seed (%)
D	Average distance of seeds (cm)
Y	Mean absolute value of the difference of data from their mean and set distance (cm)