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An Attempt to Evaluate the Performance Parameters of a Precision Vacuum Seeder in Different Seed Drop Height

Emrah KUŞ[1*]

ABSTRACT: This study examined the effects of seed drop height changing depending on furrow openers of precision seeders, and the forward speed of tractors which is constantly aimed to be increased by producers on the uniformity of seed distribution. The experiments were made with a precision seeder unit positioned on a sticky belt trial setup at seed drop heights of 100, 200 and 300 mm, the forward speeds of 0.5, 1.0, and 1.5 m s^{-1}, and the vacuum pressures of 6.0, 7.5, and 9.0 kPa. Maize and sunflower seeds were used in experiments. According to the results, the effects of seed drop height and forward speed on seed spacing and deviation from row were significant for both seed types ($P<0.01$). The increase in the forward speed led to a deviation of approximately 15 mm in maize and 17 mm in sunflower between the mean seed spacing and the target seed spacing. In general, miss and multiple indices were found to be fewer than 9%. The optimum performance of the seeder unit in sowing sunflower and maize was obtained at the seed drop height of 100 mm, the forward speed of 0.5 m s^{-1}, and the vacuum pressure of 9.0 kPa. Consequently, it is suggested that, in contrast to what is demanded, the forward speed cannot be increased as much as one desires, and the dimensions of furrow openers that changed depending on the seed drop height should be designed under certain standards.

Keywords: Forward speed, furrow opener, vacuum pressure, maize, sunflower

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INTRODUCTION

For the process of sowing, which is a stage of plant production, the factor of time is crucial. While there is a certain time interval for intervention, though limited, for stages other than sowing, after achieving seed-soil contact in the process of sowing, it is not possible to make any change. This is why it is needed to determine the parameters affecting the sowing process precisely.

Since one of the main goals in the planting process is the uniformity of the plant living area in the field, seed distribution uniformity has been the focus of the studies on the precision metering unit. In previous studies, the parameters that determine the performance of a precision seeder were reported to be mean and standard deviation of seed or plant spacings (Parish et al., 1991; Hollowell, 1992), miss and multiple indexes (Brooks and Church, 1987), and coefficient of variation (Jasa and Dickey, 1982; Hofman, 1988). In addition, (Karayel and Özmerzi, 2001) reported that field and operation parameters (especially the forward speed) also affected the performance of a precision seeder. However, they are listed here also studies realized in the recent past on precision planters. Yazgı and Değirmencioğlu (2014) examined the performance of the intra-row spacing uniformity of the precision metering unit as a function of the number of holes in the vacuum plate. Koller et al. (2014) also, defined the temporal seed spacing in terms of parameters that precisely define the seed exit trajectory, in addition to determining the seed spacing or frequency where seed singling systems are commonly used. They reported that this method focuses on the behavior of the seed at the point of origin and precisely explains the interface between a precision planter and the downstream seed metering system. Navid et al. (2011) compared the seed distribution on the sticky belt with the camera measuring system to evaluate the performance of the seed metering unit and seed spacing uniformity. Çay et al. (2017) on the other hand compared the success of the opto-electronic measurement system they developed to measure the seed spacing in precision planters with the seed distribution measurements on the sticky belt. They reported that the system gave very fast and accurate results. Bakhtiari and Ahmad (2017) designed a vacuum seed metering unit for single-seed planting of kenaf plant and developed it based on the physical and aerodynamic properties of the seeds. Yin et al. (2018) showed that the low-cost precision planting control system they developed to control the seed spacing in corn planting works accurately and consistently.

In addition to these studies, another parameter that can affect seed distribution uniformity, planting quality, and ultimately yield in precision planters is the height from which the seed is dropped from the precision metering unit. Breece et al. (1981) stated the effect of seed drop height in their books. Parish and Bracy (2003) tested the drop height of the seed from the metering unit in the lab using seed tube and seed slide. Together with these, studies on the subject are in a minority.

Seed drop height in precision vacuum seeders may vary based on the size of the furrow opener. According to market research carried out in Turkey, the seed metering devices and furrow openers of precision seeders may differ from firm to firm. This situation leads the distance between the point the seed is released from the distribution mechanism (seed disc or seed metering device) and the bottom of the furrow to become different. Lack of a standard about this allows firms to determine the furrow opener dimensions as they desire. This is why the current study is based on seed drop height.

The uniformity of plant spacing is ensured by the uniformity of seed spacing. Seed spacing is measured by sowing stand in the field or a sticky belt (greased band) in the laboratory. Measurements in the field are possible by digging the furrow after sowing or measuring the distances between plants after germination. In the laboratory, this may be possible by measuring the distances between consecutive seeds on a sticky belt. In field measurements made by digging the furrow after sowing, it is difficult to find especially small seeds without changing their place (Kocher et al., 1998). In addition to this, in plant spacing measurements made in the field, the miss index (skipping rate) of the seed plate holes (unless determined with a sensor) or the ratio of seeds that have not germinated after sowing cannot be known. As the data obtained from measuring plant spacings in the field and measuring seed spacing on a greased belt would include the same factors, it is possible to make these measurements on a greased belt. The specific purpose of this study is to determine the effects of different seed drop heights, vacuum pressures, and forward speeds on the performance and sowing quality of a pneumatic (vacuum) precision seeder on a sticky belt. For this purpose, it is to determine the optimum vacuum pressure, forward speed, and seed drop height values in the sowing of maize and sunflower seeds which have a substantial difference between their thousand-grain masses.

MATERIALS AND METHODS

This study was carried out in an experiment stand installed at the Laboratory of the Department of Biosystem Engineering at the Faculty of Agriculture at Iğdır University. Maize (Zea mays) and sunflower (Helianthus annuus L.) seeds were used in the study (Table 1). The thousand-grain weights, bulk densities, moisture contents, and angles of repose of the seed varieties were determined accordingly ASAE Standard (2005). The intra-row distance was selected as 200 mm for maize and 300 mm for sunflower.

Table 1. Some physical properties of maize and sunflower seeds

Physical properties	Maize	Sunflower
Thousand-grain weight, g	381.76±0.66	240.72±0.63
Moisture content, % (d.b)	10.78±0.15	8.09±0.07
Bulk density, kg m^{-3}	781.12±2.20	312.76±0.66
Repose angle, °	27.75±1.47	25.93±1.53
Length, mm	13.51±1.10	23.17±1.46
Width, mm	8.35±0.70	9.65±1.18
Thickness, mm	4.89±0.49	4.21±0.70
Geometric mean diameter	8.20	9.80
Sphericity, %	60.70	42.31

The experiment stand included a precision vacuum sowing unit and a sticky belt. The hole diameter of the sowing unit disk was 5 mm for maize and 3.5 mm for sunflower. The negative pressure required for the seeds to adhere to the holes of the distribution disk was provided by a fan unit.

The sticky belt was designed between two cylinders (each with a diameter of 145 mm) with a length of 10 m and a width of 0.5 m. The central line of the sticky belt was accepted to represent the bottom of the furrow opened by seeder openers in the field. The belt central line (BCL) was the line drawn by a laser along the belt's long axis and used to measure the deviations of the seeds from the line. A support stand was designed to position the seed metering unit over the sticky belt. This unit was placed in a way to overlap the point where the seeds were freely dropped from the disc and the central line of the belt. Additionally, lines were drawn perpendicularly to the long axis of the belt with 25 mm distances, and 400 measurement strips were formed (Fig. 1).

The experiments were carried out with three seed drop heights (100, 200, and 300 mm), three vacuum pressures (6.0, 7.5, and 9.0 kPa), and three belt forward speeds (0.5, 1.0, and 1.5 m s^{-1}) in a split-plots based on a factorial experimental design with three repetitions. In the experiments, the intra-row consecutive seed spacings and the amounts of deviation of seeds from the row (deviation from BCL) were measured by using a meter scale. Measurements of deviation from the row are made to determine whether or not the seeds are dropped onto the bottom of the row opened by the furrow opener. This was determined by measuring the distances of the seeds to the sticky belt's central line (BCL) from the right and the left. The measurements were carried out on an 8100-mm part of the sticky belt.

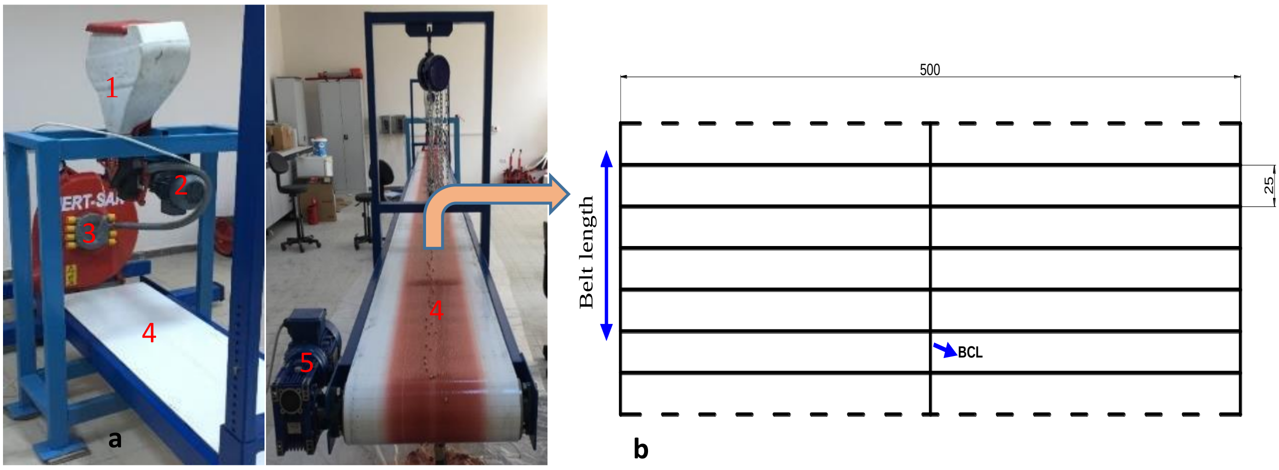

Figure 1. The sticky belt test stand (a); single-seed unit (1), AC motor (2), Fan (3), sticky belt (4), AC motor (5). The units of dimensions are mm (b).

The seed drop heights were determined by considering the minimum and maximum dimensions of the shoe and disc furrow openers. To adjust the forward speed of the sticky belt to the traveling speed of the seeder, the transmission ratio between the belt cylinder and the distribution disk (0.23) was utilized. The pressure values required for the maize and sunflower seeds to hold to the holes of the seed distribution disc were also determined experimentally between 6.0 and 9.0 kPa. For each replication, the experiments were initiated by the seeds fall onto the belt when running electric motors that drive the seed metering unit, fan, and the sticky belt, and they ended when the seeds reached the sticky belt driving cylinder. To prevent the seeds from rolling or bounding on the belt, grease was applied. The amount of grease was determined by preliminary trials at the greatest drop distance (300 mm) and the highest belt speed (1.5 m s^{-1}).

Seeder performance indices: the multiple index ($I_{mult} \leq 0.5Z$) refers to whether or not the distance between two consecutive seeds is equal to or less than half of the target seed spacing (Z), while the miss index ($I_{miss} > 1.5Z$) refers to whether or not this distance is greater than 1.5 times the target seed spacing. Distances between consecutive seeds that are larger than half of but not more than 1.5 times of the target seed spacing ($0.5Z < I_q \leq 1.5Z$) are considered as a quality of feed index (Kachman and Smith, 1995; Singh et al., 2005). The precision coefficient is the coefficient of variation of seed distances that are not equal to and more than 2.0 times the target seed spacing (ISO, 1984).

The SPSS software was utilized for the analyses. Among the analysis, analysis of variance was used to determine the effect of the parameters on the performance of the precision seeder, and Duncan's multiple comparison test was used to determine the differences and similarities between the groups.

RESULTS AND DISCUSSION

According to the results of the analyses, the effects of seed drop height and forward speed on the mean seed spacing, deviation from rows of the seeds, and three indices (miss index, multiple index, quality of feed index) were statistically significant for both seed types (P<0.05, P<0.01). When seed drop height was set at 100, 200 and 300 mm, the change in the intra-row seed spacing was respectively

1.4%, 3.4%, and 5.6% for maize and 0.3%, 2.8%, and 5.2% for sunflower (Tables 2 and 3). When the seed drop height was increased from 100 mm to 300 mm, the deviation rate from the target seed spacing increased by 3.8 times for the maize seeds with a mean grain weight of 0.38 g and 15.6 times for the sunflower seeds with a mean grain weight of 0.24 g. The increase in the seed drop height influenced the intra-row seed spacing of the sunflower seeds more. It was assumed that the lower precision coefficient values obtained from the sunflower experiment were caused by selecting larger target seed spacing.

In the process of sowing, the height between the seed metering disc and the furrow bottom may deviate the seed from the target point, by causing it to roll, bounce, or drift in the furrow. However, in this experiment, as a sufficient amount of grease was applied onto the belt surface, the variation that could be caused by rolling, bouncing, or drifting was prevented. Therefore, it was assumed that the seed was subjected to shifting during released due to the effects of the forward speed and drop height, and thus, its intra-row seed spacing changed. The increase of seed drop height led to an increase not only in the multiple index but also in the miss index rates. Based on this, the quality of the feed index (QFI) decreased. Between the seed drop heights of 100 and 300 mm, the miss index increased by 1.9 times in maize and 2.2 times in sunflower. This increase in the multiple index was 2.0 times in maize and 1.7 times in sunflower. When the seed drop heights were 100 and 200 mm, the QFI was higher than 90%. The results showed that sowing at these heights provides acceptable outcomes.

The forward speed of the seeder has a determining effect on the effectiveness of the sowing process and work efficiency. This is why studies have aimed to increase forward speed. However, as an increase in the forward speed of a seeder affects the intra-row seed spacing, it results in reduced precision. Determining the most suitable sowing speed interval for each variety of seeds will provide easiness in sowing. In the current study, increased forward speed led to a deviation of the mean seed spacing from the target seed spacing by approximately 15 mm in maize and 17 mm in sunflower.

Table 2. Variance analysis and multiple comparison test results for maize

Parameters		Mean seed spacing, mm	Deviation from row, mm	Miss index, %	Multiple index, %	QFI, %	Precision
Seed drop height, mm	100	202.9c	7.5c	3.6b	2.7b	93.6a	16.04
	200	206.8b	11.2b	5.1ab	3.3b	91.6a	19.86
	300	211.1a	12.8a	7.0a	5.5a	87.6b	19.88
Significance		0.000	0.000	0.000	0.000	0.005	
Forward speed, m s^{-1}	0.5	199.4c	8.0c	3.0b	0.6c	96.4a	15.47
	1.0	206.1b	9.8b	4.3b	2.3b	93.4b	18.24
	1.5	215.4a	13.7a	8.4a	8.5a	83.1c	22.07
Significance		0.000	0.000	0.000	0.000	0.000	
Vacuum pressure, kPa	6.0	208.3a	10.0a	5.6ab	4.0a	90.4a	17.55
	7.5	206.8a	10.6a	6.1a	3.3a	90.6a	16.15
	9.0	205.7a	11.0a	4.0b	4.2a	91.9a	15.36
Significance		0.391	0.187	0.187	0.187	0.081	

The lowest values of the miss and multiple indices were obtained at the forward speed of 0.5 m s^{-1}. The minimum precision coefficient values at this speed also supported the results. The increase of forward speed led to an increase in the peripheral velocity of the seed metering disc, and based on this, a reduction in the holding ratio of the seeds to the holes of the disc. Between the forward speeds of 0.5 and 1.5 m s^{-1}, the miss index increased by 2.8 times in maize and approximately 6 times in sunflower. In similarity to the effect of the seed drop height, the sunflower seeds with lower sphericity were affected more by the forward speed while held to the holes of the disk. The increase in the forward speed led to multiple index increases of 14.0 times in maize and 3.6 times in sunflower. It was assumed that, as the distance of free-dropping increased, also with the effect of the operating speed, the seeds were deviated from the target point and increased the number of multiple intra-row spacing based on this. In addition to this, the QFI values of over 90% that were obtained at the forward speeds of 0.5 and 1.0 m s^{-1} were sufficient for the success of sowing. In previous studies, similar results were reported for the plant spacing variation Nielsen (1995) and the miss index (Ivancan et al., 2004; Sing et al., 2005).

Table 3. Variance analysis and multiple comparison test results for sunflower

Parameters		Mean seed spacing, mm	Deviation from row, mm	Miss index, %	Multiple index, %	QFI, %	Precision
Seed drop height, mm	100	301.0c	4.6c	2.5b	3.4b	94.1a	15.0
	200	308.3b	6.8b	3.5ab	4.9ab	91.6a	16.7
	300	315.6a	8.5a	5.5a	5.9a	88.6b	17.4
	Significance	0.001	0.000	0.015	0.015	0.001	
Forward speed, m s^{-1}	0.5	300.1c	4.7c	1.2b	2.4b	96.4a	11.9
	1.0	307.7b	6.3b	3.0b	3.3b	93.7b	15.7
	1.5	317.1a	8.9a	7.3a	8.6a	84.2c	21.4
	Significance	0.000	0.000	0.000	0.000	0.000	
Vacuum pressure, kPa	6.0	316.2a	6.7a	5.7a	3.5b	90.8a	17.6
	7.5	307.5b	6.4a	3.6b	4.7ab	91.7a	16.2
	9.0	301.2b	6.8a	2.2b	6.0a	91.7a	15.4
	Significance	0.000	0.859	0.004	0.014	0.741	

Deviation from the row leads the seed to stay on the edge of the furrow without dropping into the target depth. A seed that stays on the edge of furrow may potentially lead to disruption of both sowing depth and the uniformity of the intra-row seed spacing. As the rate of the seeds dropped to the bottom of the furrow increases, this results in more uniform sowing depth and intra-row seed spacing. In this study, the bottom of the furrow was represented by the central line of the belt (BCL). As the distance of free-dropping decreased, the rate of seeds dropping onto the BCL increased. In other words, sowing depth and intra-row seed distribution were improved. However, increased seed drop heights increased the mean values of deviation from the row. Accordingly, as the height increased, the point where the seed left the disc and the point targeted for the seed to be dropped onto the belt changed. The rate of change in deviation from row was approximately 70% for maize and 85% for sunflower when the seed drop height from 100 mm to 300 mm increasing. According to these results, the sunflower seeds which have lower thousand-grain weight been affected more by the increased seed drop height. The results showed that, in contrast to the demands of crop producers, increasing the seed drop height and the forward speed would risk the precision placement of seeds into the bottom of the furrow.

The results of the different vacuum pressures were statistically similar for the maize. The mean seed spacing obtained at the highest vacuum pressure (9.0 kPa) was closer to the target spacing (Fig. 2) In addition to this, in sunflower, increased vacuum pressure substantially affected the intra-row seed spacing. While high vacuum pressure brought the mean seed spacing closer to the target spacing, low pressure brought it further from the target spacing (Fig. 3). While the vacuum pressure did not affect QFI, it was determined to reduce the miss index and increase the multiple index (Table 2). Although larger target seed spacing was selected for sunflower, the effect of vacuum pressure on the mean seed spacing was found significant. This is also understood by the precision coefficient values that were close to each other despite the different target seed spacings.

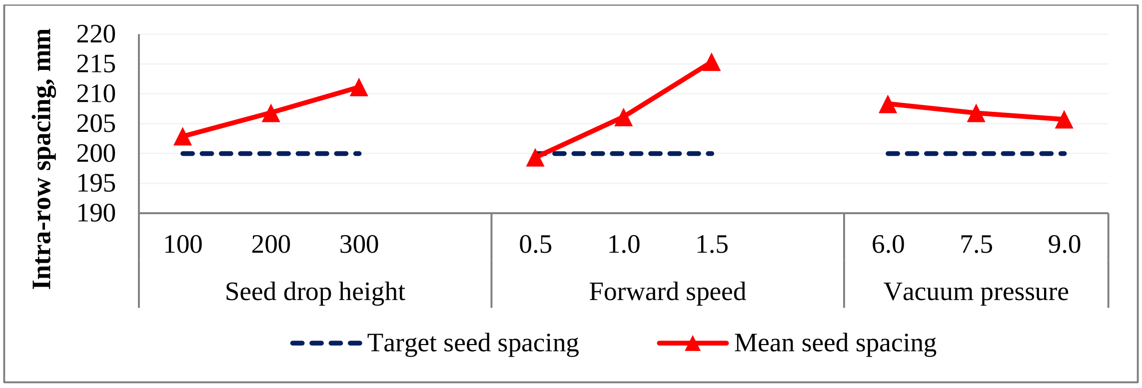

Figure 2. Change of intra-row spacing in maize

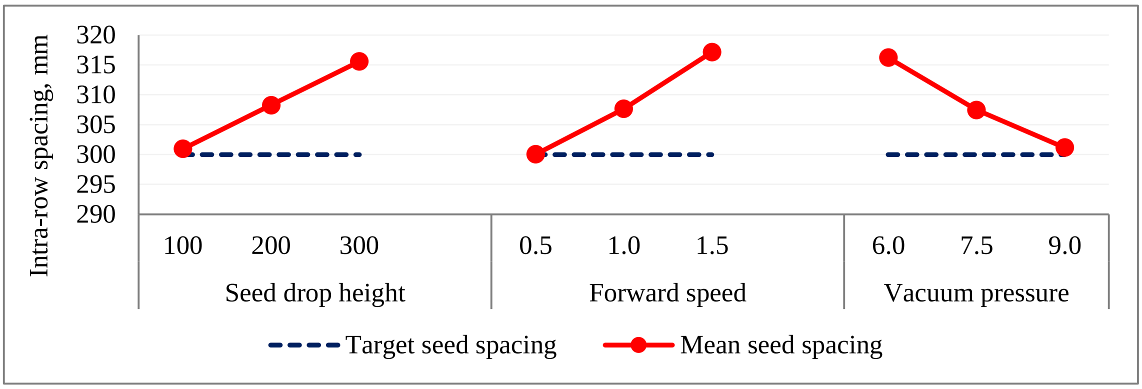

Figure 3. Change of intra-row spacing in sunflower

CONCLUSION

The seed distribution uniformity in maize and sunflower sowing of the precision vacuum seeder was affected by both the seed drop height and the forward speed. Non-uniformity, expressed as a percentage of the target seed spacing, is likely to be affected by the peripheral velocity of the seed metering disc that increases along with increasing the forward speed. Moreover, non-uniformity is an outcome of the combined effect of the forward speed and seed drop height. Vacuum pressure has been not a noticeable effect. Consequently, it is suggested that, in contrast to what is demanded, the forward speed cannot be increased as much as one desires, and the dimensions of openers that determine the seed dropping height should be designed under certain standards.

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Conflict of Interest

I declare that there is no conflict of interest during the planning, execution and writing of the article.

Author’s Contributions

I hereby declare that the planning, execution and writing of the article was done by me as the sole author of the article.

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