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OPTIMIZATION OF THE SHOE FURROW OPENERS DESIGNED IN DIFFERENT HEIGHTS FOR VACUUM SINGLE-SEED PLANTER

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This study aimed to determine the effects of tractor forward speed using shoe furrow openers designed in different sizes (seed drop height) in the conventional and reduced tillage systems on the intra-row spacing, deviations from rows, sowing depth, and the metering unit performance of vacuum precision planter (multiple index, miss index, quality of feed index and precision). The experiments were carried out at the 12, 18, and 24 cm seed drop heights and 1.1, 1.5, and 2.2 ms^{-1} tractor forward speeds using sunflower and maize seeds at two separate fields. Target seed spacing was 400 and 206 mm for sunflower and maize, respectively. According to the results, the optimal values for plant spacing were determined as 399.7 and 204.4 mm at the 1.1 ms^{-1} forward speed for sunflower and maize, respectively, and 403.5 and 209.2 mm also in the 18 cm seed drop height. However, such values substantially increased when forward speed increased to 2.2 ms^{-1} and seed drop height to 24 cm. The precision of the distribution of the plant spacing for tillage systems, seed drop heights and forward speeds experienced was well below 29%, and therefore is acceptable for both sunflower and maize seeds. The values closest to the target sowing depth were obtained from low forward speed and high seed drop height. Overall, with the increased tractor forward speed the quality of feed index decreased. The highest quality of feed index for sunflower and maize crops was about 88% for both tillage systems.
Keywords: Maize, Sowing depth, Seed drop height, Seed spacing, Sunflower, Tillage.

INTRODUCTION

The rapid and uniform seed germination depends on a good seed-soil contact. One of the reasons for reduced yield is irregular seed germination (Nafziger, 1996). The metering systems are significant devices for seed-soil contact in the single seed sowing. These systems have two important parts including a metering mechanism and a furrow opener. The seed metering systems are devices affecting the precision of seed distribution uniformity in the planters. The performance of the metering devices may have been affected by soil particle size, soil roughness, stubble condition, seed drop height during sowing, and tractor forward speed. During sowing, the seeds are, however, under the influence of many factors until placed in a row. These factors may directly affect both sowing quality and yield. One of these factors is the effect of furrow openers. Even in a planter with the most current equipment, horizontal (seed spacing and row interval) and vertical (sowing depth), seed distribution deteriorates when the furrow openers do not function properly.

The ability to modify seed metering devices and furrow openers in the single seed planters allows for sowing seeds with different physical properties. To obtain a furrow profile that is suitable for different seed varieties, different types of furrow openers have been developed. One of them is the commonly used shoe type furrow opener. Many studies have been carried out concerning the furrow openers (Hayden and Bowers, 1974; Morrison *et al.*, 1988; Gebresenbet and Jönsson, 1992; Chaudhuri, 2001; Karayel and Özmerzi, 2008). However, few studies were found to test the effect of drop height of seed and the size of the furrow opener (Wanjura and Hudspeth, 1969; Parish and Bracy, 2003; Kuş and Yıldırım, 2020). Besides, some physical properties such as shape, size, and weight of the seeds, operating parameters such as tractor forward speed and tillage system are among the important factors affecting the seed planter performance and sowing quality (Ivancan *et al.*, 2004; Staggenborg *et al.*, 2004).

In market research conducted in Turkey, it was determined that there are generally three types (small, standard or medium and large) of shoe furrow opener at the pneumatic single seed planters. The height of these furrow openers generally ranges from 12 to 24 cm. But, the height of the standard furrow opener produced in a company may be different in another company. This difference also causes significant differences in the seed distribution pattern as it changes the drop height of the seed. In this study, the shoe furrow openers with three different heights were designed by taking into consideration the current furrow openers. This study aimed to investigate the sowing quality and the performance of the pneumatic single seed planter in conventional and reduced tillage conditions and the different forward speeds of the tractor, using the shoe furrow openers designed.

MATERIALS AND METHODS

The study was carried out in the areas given soil properties in Table 1 at Erzurum province of Turkey in the growing seasons of 2011 and 2012. Sunflower (*Helianthus annuus L.*) and maize (*Zea mays*) seeds were used for the experiments. The physical properties of these seeds were given in Table 1. Depending on the physical properties of the seeds, the recommended practical spacing between plants within a row ranges between 200-500 mm for sunflower and 100-300 mm for maize. Per the values used in practice, the target spacings between plants intra-row for sunflower and maize were 400 mm and 206 mm, respectively. The seeds were sowed at the 60 mm sowing depth by a pneumatic single seed planter (Özmerzi *et al.*, 2002). The single seed planter has air suction and four rows, and its shoe furrow openers were modified (Fig. 1).

The seed spacing adjustment of the planter can be done by changing the number of seed plate holes or the transmission ratio. The ability to hold to vacuum plate of the seeds was driven by tractor PTO. The negative air pressure generated by the fan was 7.5 kPa for sunflower and 8.8 kPa for maize (Önal, 2011). The hole diameters of the seed metering plate were selected as 3 mm in sunflower and 5 mm in maize, depending on the geometric mean diameter size of the seeds. The geometric mean diameter of the seeds was calculated by equation (1). The geometric mean diameter was measured from 100 samples randomly selected from each kernel (Mohsenin, 1986).

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

Where: d is the geometric mean diameter (mm), l (mm), w (mm), and t (mm) are the length, width, and thickness, respectively.

In the experiment areas, each field was divided into 54 plots, including two tillage systems, three seed drop heights (or furrow opener height), three tractor forward speeds, and three replicates. All plots in each experiment area were uniform in terms of soil physical properties. The experimental set up was a randomized factorial design in three repetitions. The plots were 40 m in length and 3 m in width. In 27 plots conventional tillage and the remaining 27 plots were treated with reduced tillage. The tractor forward speed and seed drop height treatments were set up random over plots of each tillage. It was allowed a space of 3 m between plots to turn the tractor into and out of the plot. In each repetition, four rows were sowed with a single pass of the planter. All plots were sowed inter-row of 70 cm. To carry out measures of the intra-row

Table 1. Some of the important properties for the experimental areas and the seeds

Soil properties			Seed physical properties		
The soil property	**Sunflower sowing area**	**Maize sowing area**	**Seed property**	**Sunflower**	**Maize**
Bulk density, g cm^{-3}	1.4	1.3	Thousand-grain weight, g	140	326
Porosity, %	48	53	Repose angle, ˚	30	22
Penetration resistance, MPa	1.3	1.9	Bulk density, g cm^{-3}	0.3	0.9
pH	7.3	7.6	Length, mm	19.5	10.0
Organic matter, %	0.7	1.0	Width, mm	8.8	7.0
Sand, %	39.2	39.1	Thickness, mm	4.6	6.0
Clay, %	35.4	37.8	Sphericity, %	47	74
Silt, %	25.4	23.1	Geometric mean diameter	9.3	7.5
Texture class	Clay loam	Clay loam	Seed Variety	Confeta	Bora

Figure 1. Pneumatic single seed planter. Vacuum meter (a), seed plate (b), and seed drop point (c)

spacing (plant spacing), inter-row spacing (deviation from rows), and sowing depth, the sub−plots with length 25 m for sunflower and 15 m for maize were established in the four rows center of each treatment (Heege, 1993; Staggenborg *et al.*, 2004). The sub-plots were determined considering the center of the 54 main plots. The measurements of intra-row spacing, deviation from rows, and sowing depth were performed on three rows randomly selected from each plot. As a result of these measurements, sowing quality was determined depending on the spacing between plants, deviation from rows of plants, sowing depth, and the variation coefficient values of plant spacing and sowing depth.

In the conventional tillage system, the soil was tilled by moldboard plow, disc harrow twice, and using a roller twice. In the reduced tillage system, the soil was tilled by a power harrow, combined with a roller. Tillage depth was set at 250 mm by moldboard plow for conventional tillage, and 120 mm by a power harrow for reduced tillage (Peterson *et al.*, 1983; Özmerzi and Barut, 1996; Raoufat and Mahmoodieh, 2005; Yalçın *et al.*, 2008; Stipesevic *et al.*, 2009; Topakci *et al.*, 2011; Uzun *et al.*, 2012). Soil moisture content almost after tillage was measured at a soil depth of 20 cm by TDR 300 device (Time Domain Reflectometry). The moisture content of the soil in the sunflower experiment field was about 37% for both tillage systems. The moisture content of the soil in the experiment field of maize was also about 23% and 26% for conventional and reduced tillage systems, respectively. The experiment areas had not been processed in the previous two years.

The target sowing speeds were selected as 1.0, 1.5, and 2.0 ms^{-1}. But real forward speeds of tractor determined closest to these values were 1.1, 1.5, and 2.2 ms^{-1} depending on tractor gear stages. The real forward speeds were determined in the experiment field, by measuring time at a distance of 30 meters.

The seed drop heights were obtained from designing shoe furrow opener of different sizes. The seed drop height values were determined by taking into consideration the smallest and largest dimensions of the shoe type furrow openers available on the market in Turkey. In this way, three different shoe furrow opener sizes, small, medium (standard), and large were obtained. The small, medium and large shoe furrow opener heights were 12 cm, 18 cm, and 24 cm, respectively (Fig. 2). In the manufacturing of shoe furrow openers, 60 mm high cast material on the bottom side of the furrow opener and an 8 mm thick sheet composed of iron material also on the upper side was used.

Seed distribution intra-row was characterized using the mean plant spacing and the coefficient of variation in plant spacing (Kachman and Smith, 1995). The intra-row spacing was determined by measuring 75 plant spacing in each of the sub-plot (Heege, 1993; Staggenborg *et al.*, 2004). Spacings between adjacent plants were measured in the field 16 days after sowing for each plot. Using these values of measurement, the mean ($\bar{x}$) spacing between plants, the standard deviation (s) of spacing between plants, and the coefficient of variation (CV) were computed by equations 2, 3, and 4, respectively (Kachman and Smith, 1995). In

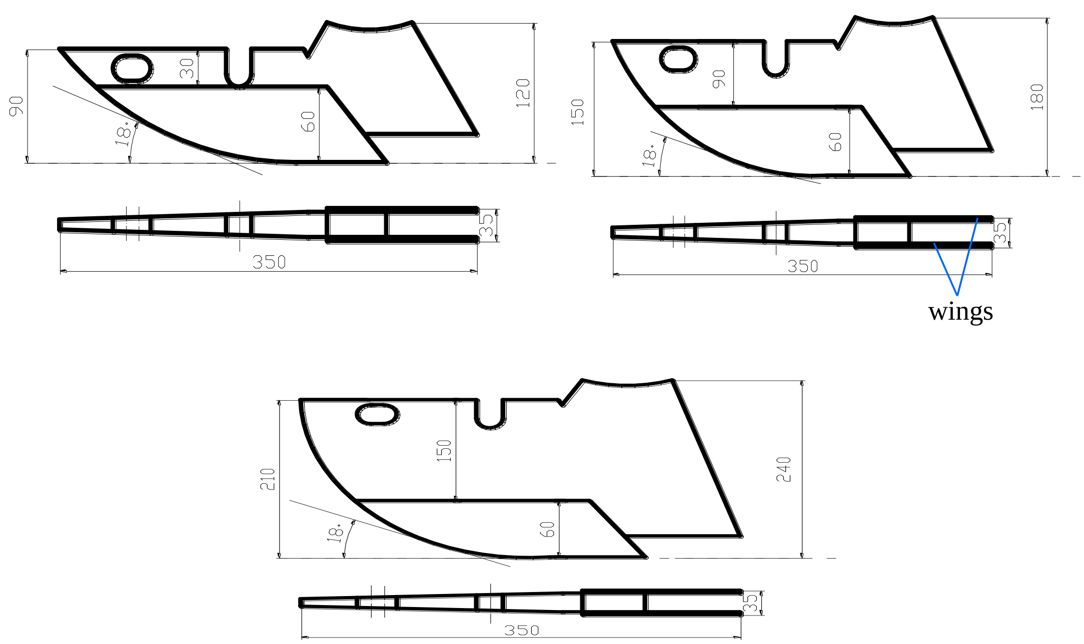


Figure 2. **Shoe furrow openers used in the experiments. Units of dimensions are mm. (a) small, (b) medium or standard and (c) large type furrow openers (the upper views in each furrow openers are left side views and lower views are top views).**

computing the coefficient of variation, those which were double or more than the theoretical spacing between plants from the measured values were not taken into consideration (ISO, 1984).

$$\bar{x} = \sum_{i=1}^{N} \frac{x_i}{N} \quad \text{......} \; (2)$$

$$s = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \bar{x})^2}{N-1}} \quad \text{......} \; (3)$$

$$CV = \frac{s}{\bar{x}} \quad \text{......} \; (4)$$

where x_i is spacing between plant i and next plant intra-row, and N is the total plant spacings measured.

After sowing, the amounts of deviation from the row axis of plants were measured, to determine inter-row distribution uniformity of plants (Karayel, 2005). A rope was tied up between two iron bars on each row of the sub-plots to measure amounts of deviation from row of the plants. The mean deviation amount was determined by measuring the distance of plants from the right and left to the rope. The measurements were carried out for 45 plants randomly selected from the rows for each repetition.

The depths of the seeds beneath the soil surface were measured. After the plant germination completed it has been dug out from the soil. The mesocotyl length of 45 maize and sunflower plants for each repetition measured (Özmerzi and Keskin, 1983). Depending on these measurements were calculated the mean ($\bar{x}$) sowing depth of plants. After then, the coefficient of variation of sowing depth was computed by equation 4.

In determining the performance of the metering unit of the single seed planter was used the measurement methods described in Kachman and Smith (1995). These are multiple index, miss index, quality of feed index, and precision. The multiple index is the percentage of spacing between consecutive plants in the row, less than or equal to half of the target seed spacing (Z) ($I_{mult} \leq 0.5Z$). The miss index is the percentage of spacing greater than 1.5 times the target seed spacing ($I_{miss} > 1.5Z$). The quality of feed index is the percentage of plant spacing that is more than 0.5 times but not more than 1.5 times the target seed spacing ($0.5Z < I_q \leq 1.5Z$). The quality of feed index is simply an alternative way of presenting the information contained in the other two indices (the miss and multiples). In the sowing process, the lower miss and multiple indices, the better the sowing quality. The precision index is the coefficient of variation of seed or plant spacing in a row (Kachman and Smith, 1995; Singh *et al.*, 2005).

SPSS package program was used for statistical analysis of the data. The data were evaluated by analysis of variance (ANOVA), to determine the effect of the parameters on sowing quality. In addition, the multiple range (Post-Hoc) tests used to determine the significant difference and similarities, according to significance levels of 0.01 and 0.05, between groups in the experimental. Analysis results were evaluated separately for each seed variety.

RESULTS AND DISCUSSION

Sowing quality**:** The effects of soil tillage system, tractor forward speed, and seed drop height on the sowing quality were statistically significant ($P<0.01$) for sunflower and maize sowing by single seed planter. According to the results of the multiple comparison test, the effect on the sowing quality of the levels of tractor forward speed was generally different. All levels of seed drop height were different from each other only in sowing depth (Table 2 and 3). In the experiments, the values closest to the target seed spacing were obtained from 18 cm seed drop height. The average seed spacing values at 12 cm and 24 cm seed drop heights were higher than 18 cm (Fig. 3a). The variation coefficient values of the seed spacing also support these results. Because of the increase in the fall time, depending on the increase of the seed drop height, the bounce amount and displacement in the furrow of the seed increased. Accordingly, the plant spacing in the row was disrupted. The variability in seed spacing increased the coefficient of variation used to determine the uniformity of seed distribution. The variation coefficient values of the seed spacing obtained from this study were lower than the practical upper limit (29%) of the variation coefficient value reported by Kachman and Smith (1995). However, the variation coefficient values of the seed spacing

Table 2. The sunflower experiment analysis results

		Plant spacing, mm		CV, %		Deviation from row, mm		Mean, mm		Sowing depth, mm		CV, %	
				RT	CT			RT	CT			RT	CT
Seed drop height, cm	12	407.7	b♦	19.1	22.2	16.0	a♦	12.9	19.1	45.6	c♦	19.3	16.8
	18	403.5	b	21.0	17.6	6.8	b	7.1	6.6	51.3	b	16.3	16.8
	24	415.5	a	22.3	19.5	15.0	a	12.6	17.5	53.0	a	19.9	21.1
P		*0.001***				*0.000***				*0.000***			
Forward speed, ms^{-1}	1.1	399.7	c	17.7	17.2	8.6	c	9.2	8.0	51.2	a	16.8	14.2
	1.5	408.2	b	21.6	19.7	12.8	b	10.8	14.7	50.4	a	18.6	18.5
	2.2	418.8	a	23.2	22.5	16.5	a	12.5	20.5	48.3	b	20.2	22.1
P		*0.000***				*0.000***				*0.000***			

RT: reduced tillage; CT: conventional tillage; *P*: level of significance; ♦: In each section, the differences between the means followed by the same letter are non-significant at the 95% probability level.

Table 3. The maize experiment analysis results

		Plant spacing, mm		CV, % RT	CV, % CT	Deviation from row, mm		Mean, mm RT	Mean, mm CT	Sowing depth, mm		CV, % RT	CV, % CT
Seed drop height, cm	12	213.0	a♦	17.2	18.3	13.5	a♦	12.0	14.9	40.7	c♦	19.0	20.1
	18	209.2	b	16.5	17.3	9.8	b	8.2	11.3	53.1	b	16.9	17.2
	24	213.8	a	17.9	19.6	14.3	a	13.6	15.1	56.8	a	20.4	21.9
P		*0.004***				*0.000***				*0.000***			
Forward speed, ms^{-1}	1.1	204.4	c	16.3	17.7	8.5	c	8.8	8.3	52.2	a	15.9	17.8
	1.5	208.9	b	17.0	18.2	11.9	b	10.0	13.8	51.3	a	19.0	19.1
	2.2	222.7	a	18.3	19.3	17.1	a	15.0	19.2	47.2	b	21.4	22.3
P		*0.000***				*0.000***				*0.000***			

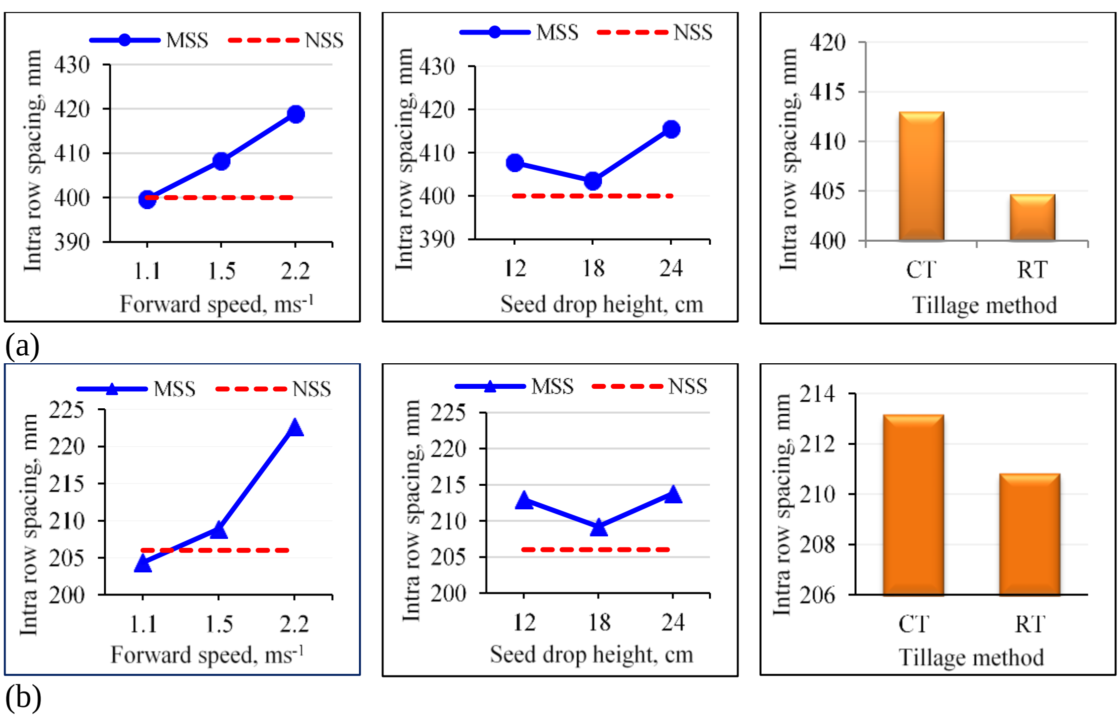
RT: reduced tillage; CT: conventional tillage; *P*: level of significance; ♦: In each section, the differences between the means followed by the same letter are non-significant at the 95% probability level.

(16% to 20% in sunflower and 17% to 24% in maize) obtained from this study were lower than also the coefficient of variation (24% to 28%) obtained from maize sowing, reported by Raoufat and Mahmoodieh (2005).

The variation coefficient values of seed spacing varying by the effect of seed drop height were greater in conditions of reduced tillage for sunflower and conventional tillage for maize (Table 2 and 3). The poorer performance the higher variation in the case of smallest seed drop height (12 cm) is due to the fact that the furrow opener was more affected by the field conditions (stubble, clod, etc.) during the sowing. When sowing with this furrow opener, the filling of the soil into the wings of the shoe furrow opener disrupted the seed distribution evenness due to increased rolling and blockage.

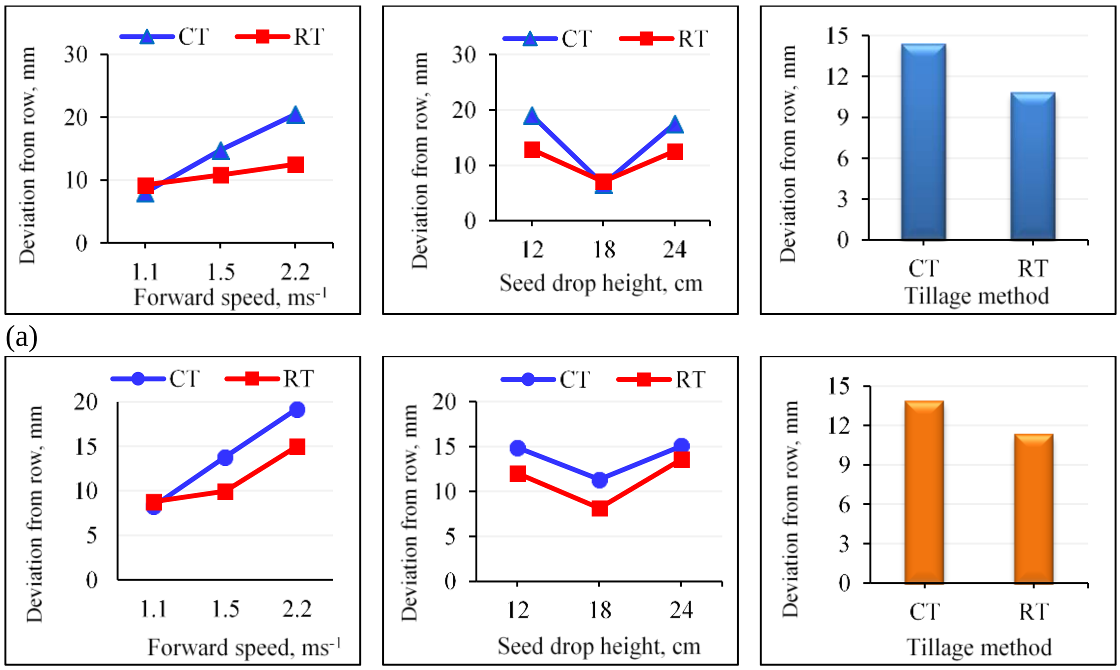
The drop height of the seed from the metering unit is an important factor that changes the position of the seed in the furrow due to rolling and bouncing. The deterioration of seed distribution uniformity caused by increasing the seed drop height in the studies of Wanjura and Hudspeth (1969) and Parish and Bracy (2003), where a single seed planter was used supported the results obtained from our study. Also, Bracy *et al.* (1999) reported that the coefficient of variation increased as the seed spacing in a row decreased. They obtained the highest coefficient of variation at the small seed spacing in row.

The increase in the forward speed increased the seed spacing in row and the amounts of deviation from row of plants (Fig. 3 and 4). The coefficient of variation has also increased due to



*MSS; measured seed spacing, NSS; target seed spacing, CT; conventional tillage, RT; reduced tillage

Figure 3. Change of plant spacing intra-row in sunflower (a) and maize (b) experiments



(b)

* CT; conventional tillage, RT; reduced tillage

Figure 4. Change of deviation from row in sunflower (a) and maize (b) experiments

the increase the seed spacing in row. The closest values to the target seed spacing and the lowest average deviation were obtained at 18 cm seed drop height and 1.1 ms^{-1} tractor forward speed. Kachman and Smith (1995), Karayel and Özmerzi (2001) and Singh *et al.* (2005) also obtained the closest values to the target seed spacing at lower forward speeds. A larger variation in seed distribution was observed in the sunflower experiment, where a larger target seed spacing was chosen. This can be explained by the fact that sunflower seeds, with lower thousand-grain weight are more subjected to rolling during sowing. Nevertheless, Ivancan *et al.* (2004) reported highly disrupted seed distribution uniformity when choosing larger target seed spacing as a result of increased tractor forward speed. Wanjura and Hudspeth (1968) stated that increasing the forward speed with single seed planter up to 2.8 ms^{-1} could be applied in the cotton sowing, but the variation in speed significantly affects the coefficient of variation, which is an indicator of the precision index.

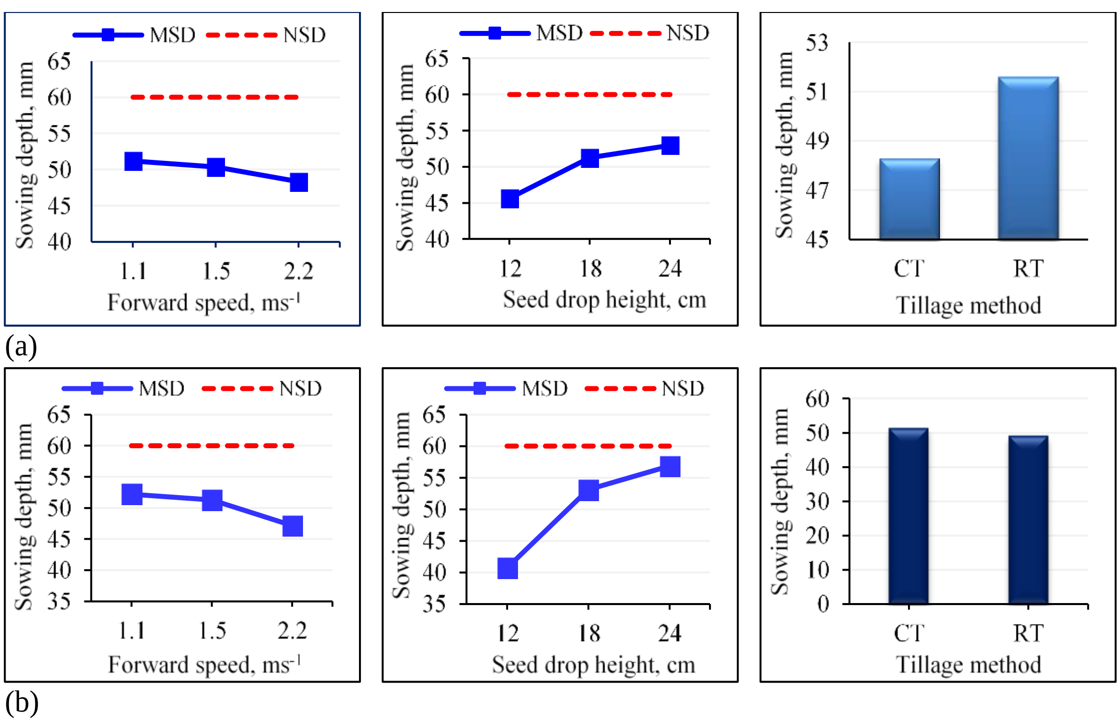
In general, the best values were obtained from 18 cm seed drop height, 1.1 ms^{-1} tractor forward speed, and reduced tillage system. The increase in seed drop height and forward speed increased displacement of seed in row. The displacement occurred as a bouncing at the seed drop height and a drag in the forward speed. This is more pronounced in conventional tillage. The exceptional situation at the smallest seed drop height was due to the inability to obtain the desired working efficiency from this furrow opener. A relatively lower stubble and hard field surface was obtained at the conventional tillage system while a softer and stubbly a field surface was obtained at the reduced tillage system. The smallest shoe furrow opener has a small seed drop height affected more by field conditions. The planter used in the operation has a single connection of the setting of the furrow opener with the presser wheel. To obtain the target sowing depth (60 mm), the press wheel was set to the highest level. Therefore, the smaller shoe furrow opener was more buried in the soil. With the effect of the clod and stubble in the field, the blockages occurred at this furrow opener. This situation caused the seed to either rolling in furrow or remaining on the edge without falling to the target depth. The seed that did not fall to the target depth shifted to the right or left from rows and increased the degree of deviation in plant germinations.

A significant advantage in furrow was that the seeds with a high weight of one thousand grains fall more evenly on the base of the furrow. A major disadvantage also was that spherical seeds rolling more, shapeless seeds less. The low sphericity rate of the sunflower seeds prevents rolling. However, fewer thousand-grain weights of the sunflower seeds may cause them to drop in more time and further rolling in furrow of the seeds during sowing. In maize, which has high both a thousand-grain weight and sphericity, there was an opposite situation. Although the sowing was made under the influence of the same factors, CV values regarding intra-row were higher in the sunflower experiment. This result can be explained by the thousand-grain weight of seeds. The thousand-grain weight of maize seeds used in the study was about 2.5 times of sunflower seeds. Considering the difference between the thousand-grain weights of the seeds, the maize seeds would fall in less time into the furrow. Accordingly, the plant distribution over the row in maize was better than the sunflower. This situation resulted in a lower variation in the maize experiment, but the target seed spacing was chosen as half of the sunflower.

According to the results of sowing depth, the seed drop heights were statistically different from each other. The mean values of the forward speeds also were significantly different from each other. The difference between 1.1 ms^{-1} and 1.5 ms^{-1} was insignificant and the forward speed of 2.2 ms^{-1} was statistically different from the remaining forward speeds. The values closest to the target sowing depth were obtained from reduced tillage conditions, 24 cm seed drop height and 1.1 ms^{-1} tractor forward speed (Fig. 5). The increase in the seed drop height generally increased the coefficient of variation in the sowing depth. However, the variation coefficient values of 12 cm seed drop height were greater than 18 cm. The increase in the tractor forward speed decreased the sowing depth but increased the coefficient of variation. However, the increase in the seed drop height (furrow opener size) increased the sowing depth. Raoufat and Matbooei (2007) determined at the lower forward speed the closest value to the target sowing depth. We determined the lowest coefficient of variation in the sowing depth at 18 cm seed drop height and 1.1 ms^{-1} forward speed. However, the values closest to the target sowing depth were obtained from the lowest tractor forward speed and the highest seed drop height. Therefore, it is necessary to work at low tractor forward speeds to achieve better sowing depth with a pneumatic single seed planter.

***Metering device performance*:** In the sunflower experiment, the seed drop height and the tractor forward speed increased the miss index while decreasing the multiple index. But, the miss index measured at 12 cm seed drop height was higher than 18 cm (Figure 6a). The lowest multiple index was obtained from the plot with tilled by conventional tillage, at the 18 cm and 24 cm seed drop heights and 2.2 ms^{-1} tractor forward speed. Further, the minimum miss index was obtained from 18 cm seed drop height and 1.1 ms^{-1} tractor forward speed (Table 4). The single seed metering device showed a worse performance under reduced tillage conditions. This situation shows that the stubble has a negative effect on the shoe furrow openers. These results were supported by the increasing the miss index and the decrease in the multiple index, due to the increase in the tractor forward speed (Singh *et al.*, 2005).

The higher the quality of feed index values the better the performance of the single seed metering device. The quality of feed index decreases as the multiple index and miss index increase. Therefore, the increase in the tractor forward speed shows decreased the quality of feed index. The best quality of feed index was obtained from a seed drop height of 18 cm. In the current planters, the quality of feed index the closer is to 100%, the better the sowing quality. The best quality of feed



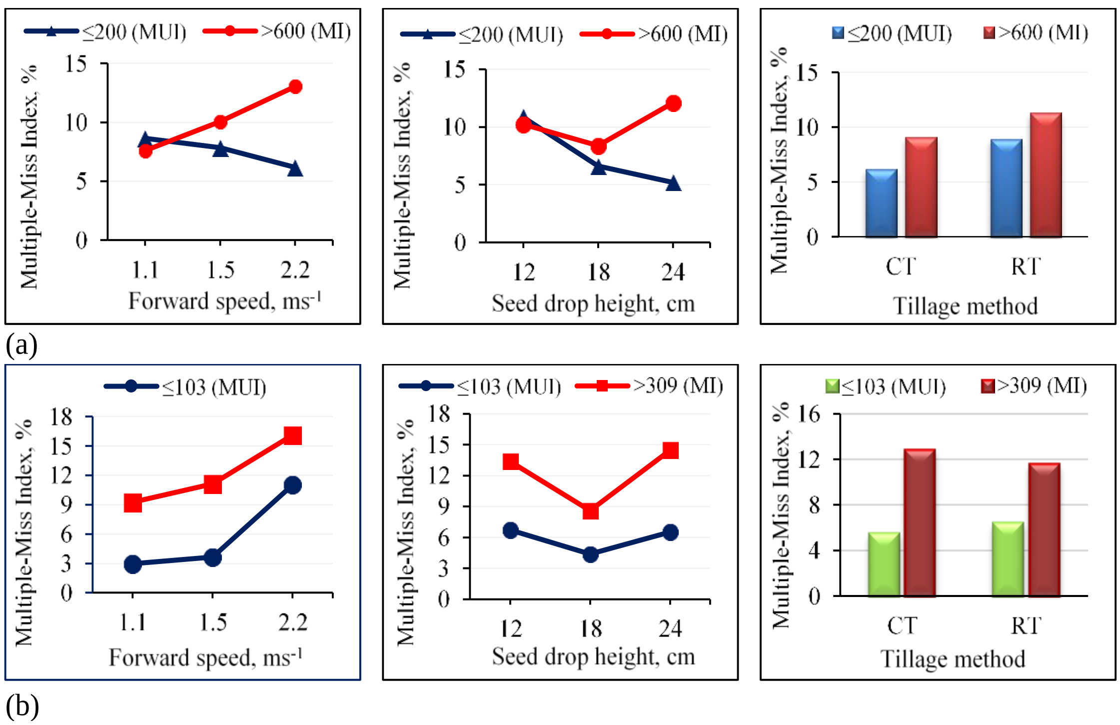
*MSD; measured sowing depth, NSD; target sowing depth, CT; conventional tillage, RT; reduced tillage

Figure 5. Change of sowing depth in sunflower (a) and maize (b) experiments

Table 4. Results for performance of the single seed metering device

Drop height, cm	Forwar dspeed, ms^{-1}	Maize experiment						Sunflower experiment					
		CT**			RT			CT			RT		
		*Performance parameters, %						Performance parameters, %					
		Mult	Miss	QFI	Mult	Miss	QFI	Mult	Miss	QFI	Mult	Miss	QFI
12	1.1	5.8	11.7	82.5	2.9	12.4	84.7	11.6	5.8	82.5	12.2	10.1	77.8
	1.5	5.8	13.4	80.8	4.6	13.1	82.2	11.1	9.0	79.9	11.6	13.2	75.1
	2.2	10.0	14.6	75.4	11.2	15.1	73.7	9.0	10.1	81.0	9.5	13.2	77.3
18	1.1	2.7	5.1	92.2	2.2	6.1	91.7	4.8	2.1	93.1	10.6	9.0	80.4
	1.5	1.7	9.3	89.1	2.2	6.1	91.7	4.2	7.4	88.4	9.5	8.5	82.0
	2.2	7.5	14.1	78.3	10.0	11.0	79.1	3.2	12.7	84.1	7.4	10.6	82.0
24	1.1	0.5	11.7	87.8	3.7	8.5	87.8	4.2	7.4	88.4	8.5	11.1	80.4
	1.5	3.4	13.1	83.5	4.1	11.7	84.2	4.2	10.1	85.7	6.4	12.2	81.5
	2.2	11.4	21.9	66.7	16.1	20.0	64.0	3.2	17.5	79.4	4.8	14.3	81.0

* Mult; multiple index, Miss; miss index, QFI; quality of feed index. **CT; conventional tillage, RT; reduced tillage



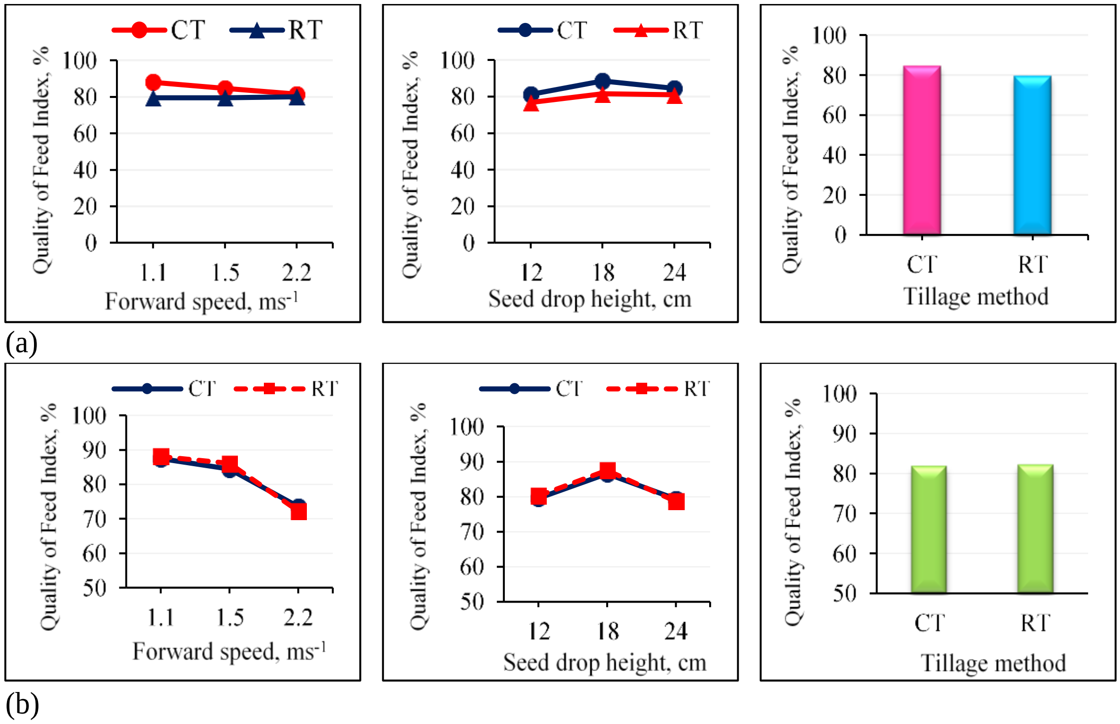
*MUI; multiple index, MI; miss index, CT; conventional tillage, RT; reduced tillage

Figure 6. Change of multiple and miss index in sunflower (a) and maize (b) experiments

index in sunflower was obtained in the conventional tillage system, in the seed drop height of 18 cm and tractor forward speed of 1.1 ms^{-1} (Fig. 7a).

Increasing seed drop height and tractor forward speed in maize trial increased multiple index and miss index. Multiple index was obtained the opposite results in the maize and sunflower experiments. This is due to the smaller selected target seed spacing in the maize experiment. Bracy *et al.* (1999) reported that the seed which was dropped from a certain height showed a poor distribution in small seed spacing and better distribution in the large seed spacing. In this study, increased seed drop height caused to increase in the miss index in row of maize plant more than the sunflower. Also, the multiple index was generally high in the sunflower experiment. Indeed, Ivancan *et al.* (2004) and Sing *et al.* (2005) reported that the miss index increases with increasing the tractor forward speed.

In the maize experiment, the multiple index was high in reduced tillage and the miss index was high in conventional tillage. Depending on the seed drop height, the highest multiple index and miss index were determined as 6.7% and 14.5%, respectively. In addition, the highest multiple index



*CT; conventional tillage, RT; reduced tillage

Figure 7. Change of quality of feed index in sunflower (a) and maize (b) experiments

and miss index were determined as 11% and 16.1% due to the forward speed, respectively (Figure 6b). The increase in the tractor forward speed increased the multiple index and miss index in both tillage systems. Raoufat and Mahmoodieh (2005) determined the multiple index as 4% and the miss index as 40% in the sowing of maize after plow tillage application. The increase in multiple and miss index disrupted the quality of sowing as it decreased the quality of feed index. Bracy *et al.* (1999) reported that the miss and multiple indexes increased in the narrow seed spacing and the largest the quality of feed index was achieved in large seed spacing. However, the quality of feed index was numerically higher in sunflower than maize in the current study.

Conclusion: This study proposed sowing quality of maize and sunflower seeds by precision planter depending on tractor forward speed and the conventional and reduced tillage systems and focused on the design of the shoe furrow openers with different heights, and performance of the vacuum single seed planter. In this paper, it showed that deteriorated of the sowing quality in the high and low seed drop heights obtained from designing of the shoe furrow openers. The field experiments revealed that sowing quality and performance of vacuum single seed planter get worse in heights of 12 and 24 cm of the shoe furrow openers and tractor forward speeds more than 1.5 ms^{-1}. In general, seedbeds prepared by conventional and reduced tillage systems were more consistent for sunflower and maize experiments, respectively. As a result, the best seed distribution uniformity was obtained from 18 cm seed drop height, 1.1 ms^{-1} forward speed, and reduced tillage system for both experiments.

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REFERENCES

Bracy, R.P., R.L. Parish and J.E. McCoy. 1999. Precision seeder uniformity varies with theoretical spacing. Horttech. 9:47-50.

Chaudhuri, D. 2001. Performance evaluation of veriustypes of furrow openers of seed drills-a review. J. Agric. Eng. Res. 79:125-137.

Gebresenbet, G. and H. Jönsson. 1992. Performances of seed drill coulters in relation to speed, depth and rake angles. J. Agric. Eng. Res. 52:121-145.

Hayden, C.W. and S.S. Bowers. 1974. Emergence and yield of bean planted with a seed orienting planter. Agron. J. 66:50-52.

Heege, H.J. 1993. Seeding method performance for cereals, rape and beans. Transactions of the ASAE. 36:653-661.

ISO, 1984. Sowing Equipment – Test Methods. Part I: Single Seed Drills 7256/1.

Ivancan, S., S. Sito and G, Fabijanic. 2004. Effect of precision drill operating speed on the intra-row seed distribution for parsley. Biosys. Engn. 89:373-376.

Kachman, S.D. and J.A. Smith. 1995. Alternative measures of accuracy in plant spacing for planters using single seed metering. Trans. ASAE.38:379-387.

Karayel, D. 2005. Effect of coulters and depth control units of a seeder on sowing quality for precision sowing. Ph.D. diss., Inst. Sci., Mediterr. Univ., Antalya, Turkey.

Karayel, D and A. Özmerzi. 2001. Effect of forward speed and seed spacing on seeding uniformity of a precision vacuum metering unit for melon and cucumber seeds. Mediterr. Agric. Sci.14:63-67.

Karayel, D and A. Özmerzi. 2008. Evaluation of three depth control components on seed placement accuracy and emergence for a precision planter. App. Engn. Agric. 24: 271-276.

Kuş, E and Y. Yıldırım. 2020. Effects of seed drop height and tillage system on the emergence time and rate in the single seed planters. Alın. J. Agric. Sci. 35:69-76.

Mohsenin, N.N. 1986. Physical Properties of Plant and Animal Materials. Gordon and Breach Science Publisher, New York.

Morrison, J.E., Jr.R.R. Allen, D.E. Wilkins, G.M. Powel, R.D. Grisso, D.C. Erbach, L.P. Herndon, D.R. Murray, G.E. Formanek, D.L. Pfost, M.M. Herron and D.J. Baumert. 1988. Conservation planter, drill and air-type seeder selection guideline. App. Engn. Agric. 4:300-309.

Nafziger, E.D. 1996. Effects of missing and two plant hills on corn grain yield. J. Produc. Agric. 9:238-240.

Önal, İ. 2011. Sowing, Maintenance, Fertilizing Machines. Ege Univ. Fac. Agric. Public. İzmir, Turkey.

Özmerzi, A. and R. Keskin. 1983. A research on the methods used to measure sowing depth. Uludag Univ. J. Agric. Fac. 1:1-11.

Özmerzi, A. and Z.B. Barut. 1996. 2nd crop comparison of different tillage and sowing methods in sesame. 6th International Agricultural Mechanization and Energy Congress, 2-6 sept, Ankara, Turkey. pp.472-481.

Özmerzi, A., D. Karayel and M. Topakci. 2002. Effect of sowing depth on precision seeder uniformity. Biosys. Engn. 82:227-230.

Parish, R.L. and R.P. Bracy. 2003. An attempt to improve uniformity of a gaspardo precision seeder. Horttech. 13:100-103.

Peterson, C.L., E.A. Dowding, K.N. Hawley and R.W. Harder. 1983. The chisel-planter minimum tillage systems. Trans. ASAE. 26:378-383.

Raoufat, M.H. and R.A. Mahmoodieh. 2005. Stand establishment responses of maize to seedbed residue, seed drill coulters and primary tillage systems. Biosys. Engn. 90:261-269.

Raoufat, M.H. and A. Matbooei. 2007. Row cleaners enhance reduced tillage planting of corn in Iran. Soil Till. Res. 93:152-161.

Singh, R.C., G. Singh and D.C. Saraswat. 2005. Optimizing of design and operational parameters of pneumatic seed metering device for planting cottonseeds. Biosys. Engn. 92:429-438.

Staggenborg, S.A., R.K. Taylor and L.D. Maddux. 2004. Effect of planter speed and seed firmers on corn stand establishment. App. Engn Agric. 20:573-580.

Stipesevic, B., D. Jug, I. Jug, I. Zugec, M. Stosic and D. Kolar. 2009. Influence of different soil tillage systems on soybean yield and yield components. J Agric. Mach. Sci. 5:263-267.

Topakci, M., D. Karayel, M. Çanakci, S. Furat and B. Uzun. 2011. Sesame hill dropping performance of a vacuum seeder for different tillage practices. App. Engn. Agric. 27:203-209.

Uzun, B., E. Yol, Ş. Furat, M. Topakçı, M. Çanakçı and D. Karayel. 2012. The effects of different tillage methods on the post wheat second crop sesame: seed yield, energy budget, and economic return. Turk. J. Agric. For. 36:399-407.

Wanjura, D.F. and E.B. Hudspeth. 1968. Metering and seed-pattern characteristics of a horizontal edge-drop plate planter. Trans. ASAE 11:468-473.

Wanjura, D.F. and E.B. Hudspeth. 1969. Performance of vacuum wheels metering individual cottonseed. Trans. ASAE.12:775-777.

Yalçın, H., E. Çakır, E. Aykas, İ. Önal, E. Gülsoylu, B. Okur, S. Delibacak, A. R. Ongun, Y. Nemli and S. Türkseven. 2008. Reduced tillage and direct seeding applications on second crop maize and sunflower. J Agric. Mach. Sci.4:157-164.

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