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RESEARCH ARTICLE

Effects of Seed Drop Height and Tillage System on the Emergence Time and Rate in the Single Seed Planters

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ABSTRACT

This study was conducted to determine the effects of seed drop height and tractor forward speed in different tillage systems on the mean emergence time, emergence rate index, and percentage emergence in single seed planters. The experiments were carried out in the conventional and reduced tillage systems, at seed drop heights of 120, 180, and 240 mm and tractor forward speeds of 1.1, 1.5, and 2.2 m s^{-1}. Sunflower and maize seeds were used in the study. The results of the study showed that seed drop height significantly affected the mean emergence time, emergence rate index, and percent emergence in both experiments (P<0.05). Also, the tillage system significantly affected the mean emergence time and emergence rate index. The lowest mean emergence time and the highest emergence rate index were 10 d and 0.19 seedlings d^{-1} m^{-1} in the reduced tillage system for sunflower, respectively. The same parameters were 12 d and 0.37 seedlings d^{-1} m^{-1} in the reduced tillage system for maize, respectively. As a result, the seeds of sunflower and maize should be sowed in reduced tillage system, 180 mm seed drop height, and 1.1 - 1.5 m s^{-1} tractor forward speeds for rapid germination and high percentage emergence.

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Introduction

Single seed planters have been developed for seeds such as sunflower, maize, cotton, and sugar beet. Sowing uniformity of these planters is an important factor that influences the germination rate (percent emergence), development of the plant, and consequently the yield. Staggenborg et al. (2004) reported that the most common characteristics used by producers to evaluate sowing performance are plant spacing and field emergence rate. In sowing, there is a significant relationship between germination rate and vertical seed distribution uniformity (Önal, 2011). Therefore, an important benchmark that can be used to control the precision of the planter is whether if the seeds are sown in the correct sowing depth. The uniform germination rate can be achieved when using a consistent sowing depth (Chen et al., 2004). Unevenness in vertical seed distribution (sowing depth) leads to reductions in the percentage emergences. Sunderman (1964) reported that the mean emergence rate dropped from 74% to 23% as sowing depth changed from 7.6 to 12.7 cm in wheat sowing. Moreover, Krall et al. (1979) found that, while the maize sowing depth increased from 2.5 cm to 7.5 cm, the mean emergence time increased about 3 days and the final yield decreased.

In single seed planters, the part which allows seed-soil contact is furrow openers. Furrow openers can vary depending on the type of seed to be sowed. During sowing, the seeds are under the influence of many factors until placed in a row. These factors may directly affect both sowing quality and yield. The design of furrow openers is one of these factors.

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Karayel and Özmerzi (2008) reported that the design of the furrow opener is also a factor affecting the seed distribution in the soil. Even in a planter with the most current equipment and high-quality metering device, sowing may fail due to the fact that the furrow openers do not function properly (Önal, 2011). Therefore, the furrow opener is one of the most important parts of a planter. Furrow openers on planters have an important effect on seed distribution, especially in the vertical plane. Many studies have been conducted on furrow openers (Hayden and Bowers 1974; Morrison et al. 1988; Gebresenbet and Jönsson 1992; Chaudhuri 2001; Raoufat and Matbooei, 2007; Karayel ve Özmerzi 2008). In general, these studies were about opener types (Choudhary et al., 1985; Raoufat and Mahmoodieh, 2005; Karayel and Özmerzi, 2005), and opener design (Tessier et al., 1991; Karayel and Özmerzi, 2003).

In order 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. In prior market research, it was determined that generally, three types (small, standard or medium, and large) of shoe furrow openers used at the single seed planters. The height of these furrow openers generally ranges from 12 to 24 cm. However, heights of standard furrow openers may differ according to the manufacturing company. This difference also causes significant differences in the seed distribution pattern as it changes the drop height of seed. In addition, there are few studies investigating the effect of seed drop height can vary depending on the size of the furrow opener. Wanjura and Hudspeth (1969) used a vacuum wheel designed to perform the single seed sowing of the cottonseed in the stick tape experiment. The researchers reported that the seed spacing uniformity was disrupted by increase of seed drop height. Parish and Bracy (2003) modified vacuum planter by adding a slide or an enclosed tube to the metering unit to reduce the effect of seed drop height on the seed distribution uniformity. The seed tube or slide was about 15 cm long. As a result of the study, they determined that although the seed drop height disrupted the seed spacing, the slide and tube did not have a positive contribution.

Commercial single seed planters usually consist of shoe type furrow openers which are designed according to physical properties such as dimension and size of seeds. The nature and behavior of furrow openers with different heights are likely to produce depth fluctuations resulting in variations in plant emergence time, plant growth, percent emergence, and yield. The specific objective of this research was to evaluate the field performance of single seed planter with three different heights of furrow openers for emergence time and percent emergence of plants in different tractor forward speeds and tillage systems.

Materials and Methods

The study was carried out on a research field at the Erzurum province of Turkey in the growth seasons of 2011 and 2012. The experiments were conducted in 2011 for sunflower and 2012 for maize. The sunflower experiment was carried out in a field of 18 decares with a width of 100 m and a length of 180 m, and the maize experiment in a field of 13.2 decares with a width of 55 m and a length of 240 m. The soil properties related to the experiment fields are given in Table 1. The average temperature at the trial site is around 20 ° C in the warmest month. The average annual rainfall is below 500 mm and the majority of rainfall takes place in April, May, and June. After sowing, no irrigation was done during the period of measurements, so that they were not affected by soil moisture, seed germination, and percentage of emergence. In addition, there was no rainfall in the period between the start of the germination process and the completion of the experiments.

Table 1. Some of the important properties for experiment fields and the seeds

Some soil properties of experiment fields				
The soil property	Sunflower planting field		Maize planting field	
	CT*	RT	CT	RT
Bulk density, g cm^{-3}	1.31	1.18	1.16	1.14
MCAS, %	37.20	37.46	22.81	26.12
MCAE, %	26.48	26.32	14.82	14.78
Penetration resistance, MPa^{+}	1.16	0.97	0.85	0.43
MWD, mm	33.05	23.95	23.81	9.96
pH, %	7.26	7.26	7.62	7.62
Organic matter, %	0.73	0.73	1.01	1.01
Sand, %	39.23	39.23	39.11	39.11
Clay, %	35.36	35.36	37.80	37.80
Silt, %	25.41	25.41	23.09	23.09
Texture class	Loamy	Loamy	Loamy	Loamy

Physical properties of the seeds		
Seed property	Sunflower	Maize
Bulk density, g cm^{-3}	0.26	0.91
TGW, g 1000^{-1} grain	140	326
Repose angle, °	30	22
Length, mm	19.52	10.02
Width, mm	8.77	6.95
Thickness, mm	4.64	5.97
Sphericity, %	47	74
Geometric mean diameter	9.26	7.46
Variety	Confeta	Bora

TGW: thousand grain weight,

CT: conventional tillage, RT: reduced tillage, MCAE: moisture content after emergence, MCAS: moisture content after sowing, MWD: mean weight diameter, $^{+}$: for depth 10 cm

Sunflower and maize seeds were used for the experiments. The physical properties of these seeds are displayed in Table 1. Sowing rates for sunflower and maize were 35 714 and 69 348 seeds/ha, respectively. 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. In accordance with the values used in practice, the seed metering unit was adjusted to the target seed spacing of 400 mm for sunflower and 206 mm for maize. The spacing between the rows was 700 mm. Both types of seeds were sowed at 60 mm nominal sowing depth by means of single seed planter with air suction and four rows. The planter was calibrated in the laboratory before field operation.

The seed spacing adjustment of the planter can be done by changing the number of seed plate holes or the transmission ratio. The air suction required for hold of seeds to the vacuum plate was provided by the fan unit of the planter. The fan was driven by tractor PTO (Power Take Off). 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 metering unit plate were selected as 3 mm for sunflower and 5 mm for maize.

In the experiments, each field was divided into 54 plots. The plots were 40 m in length and 3 m in width. 27 plots treated by conventional tillage and the remaining 27 plots were treated by reduced tillage. The experimental setup was a randomized factorial design with three repetitions. The main treatments of the study included conventional and reduced tillage systems. Sub treatments were sowing speeds and seed drop heights. In each repetition, four rows were sowed with a single pass of the planter. All plots were sowed inter-row of 700 mm. To measure the impact of parameters, the sub–plots were established for both of the experiments. These sub-plots were established in the center four rows of each sub-treatment (Heege 1993; Staggenborg et al. 2004). The lengths of sub-plots were 25 m for sunflower and 15 m for maize. Seedling counts were performed on three rows randomly selected from each sub-treatment. As a result of these counts, mean emergence time (MET), emergence rate index (ERI), and percent emergence (PE) were calculated to determine factors indicative of sowing success.

In the conventional tillage system, the soil was tilled by moldboard plow, disc harrow twice, and using a roller twice. The soil was tilled by a power harrow, which was followed by a roller in reduced tillage. Tillage depth was set at 250 mm for conventional tillage, 120 mm for reduced tillage (Peterson et al. 1983; Raoufat and Mahmoodieh 2005; Stipesevic et al. 2009; Topakci et al. 2011). The experiment fields have not been processed within the previous year.

The nominal sowing speeds were selected as 1.0, 1.5, and 2.0 m s^{-1}. The closest values to these speeds determined as 1.1, 1.5, and 2.2 m s^{-1} in the field conditions depending on tractor gear stages.

The seed drop heights obtained by designing shoe furrow openers of different sizes. The seed drop height values determined by taking into consideration the smallest and largest dimensions of the shoe type furrow openers in market research conducted 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 120 mm, 180 mm and 240 mm, respectively (Figure 1). In the manufacturing of shoe furrow openers, 60 mm high cast material on the bottom side of the furrow opener and 8 mm thick sheet material on the upper side were used.

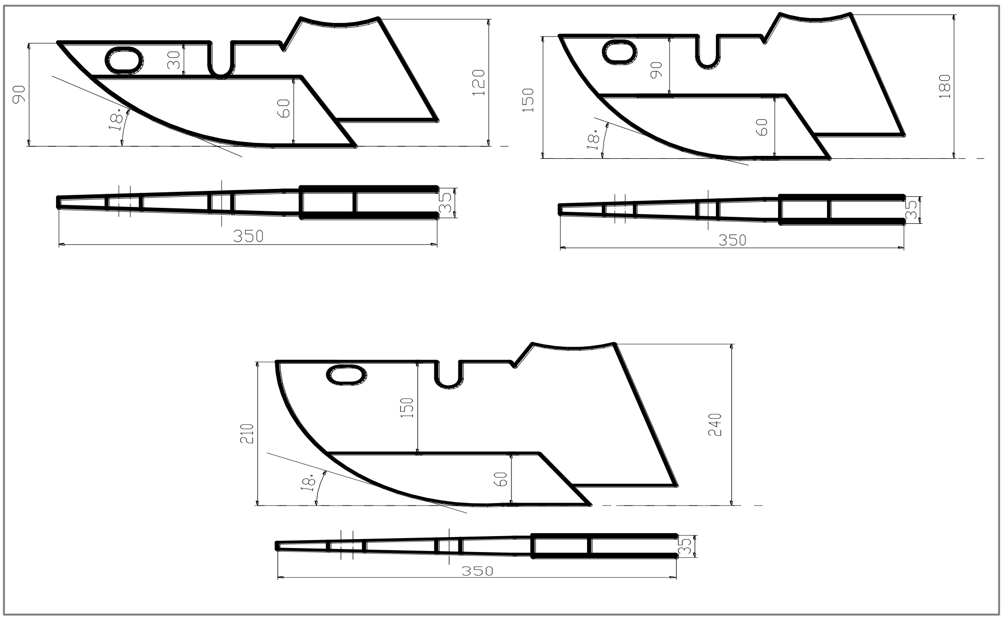

Figure 1. The shoe furrow openers

The plants were counted every day and 16 days throughout, after the first plant emergence (Bilbro and Wanjura, 1982). In order to ensure that the plant emergences are fixed, the stand counts were taken at least four times until emergence was deemed complete (Staggenborg et al. 2004). Mean emergence time (MET), emergence rate index (ERI), and percent emergence (PE) were calculated related to the number of plants on the 16th day. MET, ERI, and PE were determined using the following equations (Bilbro and Wanjura, 1982; Altıkat and Çelik, 2011).

$$MET = \frac{N_1T_1+N_2T_2+N_3T_3+\cdots+N_nT_n}{N_1+N_2+N_3+\cdots+N_n} \quad (1)$$

$$ERI = \frac{S_{te}}{MET} \quad (2)$$

$$PE = \left(\frac{S_{te}}{n}\right) * 100 \quad (3)$$

where $N_{1,\dots,n}$ is the number of emerged seedlings since the time of the previous count; $T_{1,\dots,n}$ is the number of days after sowing; Ste is the total number of emerged seedlings per meter; n is the number of seeds sown per meter; MET is the mean emergence time (day), ERI is the emergence rate index (seedling day^{-1} m^{-1}) and PE is the percentage of emergence (%).

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 MET, ERI, and PE. In addition, the multiple comparison (Post-Hoc) test was used to determine significant differences and similarities between groups in the experiment at 0.01 and 0.05 significance levels. The results of the analyses were evaluated separately for each seed variety.

Results and Discussion

Sowing success of sunflower and maize sowed by the single seed planter was analyzed first. MET, ERI, and PE were combined for analysis of variance to determine significant differences in the variability among the parameters. The results of the analysis show that there were no significant differences in PE between two tillage systems, while the effect of tillage system on MET and ERI was statistically significant ($P<0.05$) for sunflower and maize (Tables 2 and 3). Depending on the tillage systems, the highest PE was 87.52% in the reduced tillage system for maize, while the lowest PE occurred as 76.09% in the conventional tillage system for sunflower (Figures 2 and 3). The average sunflower plant population for CT and RT were 2.70 and 2.80 plants m^{-2} respectively, which are 21.5 and 28.0% lower than the nominal sowing rate (3.57 plants m^{-2}). The number of plants that emerged in the unit area in the maize experiment was 5.90 and 6.00 plant m^{-2} respectively, for conventional and reduced tillage. These values were 14.86% and 13.41% lower than the nominal sowing rate (6.93 plants m^{-2}). In general, PE values were higher in the maize experiment, although the moisture values measured in furrow after sowing were higher in the sunflower experiment. However, penetration resistance values measured in the sunflower experiment field were higher than those of the maize experiment field (Table 1). Therefore, higher values of PE obtained in the maize experiment are thought to a consequence of a lower penetration resistance measured in the furrow.

Tillage system significantly affected both MET and ERI. MET was higher in the conventional tillage system for both experiments (Figures 2 and 3). In connection to MET, ERI was lower. Higher MET values in the conventional tillage system suggest that such higher values are due to higher penetration resistance. Bilbro and Wanjura (1982) reported that the penetration resistance of the soil was a critical factor affecting mean emergence time.

Table 2. The sunflower experiment analysis results

Parameters		MET, day	ERI, seedlings day^{-1} m^{-1}	PE, %	NSD*, mm	MSD, mm
Tillage system	CT	11.62^{a}	0.167^{b}	76.09^{a}	60	48.30
	RT	10.36^{b}	0.194^{a}	78.97^{a}	60	51.60
	P	*0.033*	*0.000*	*0.186*		
Seed drop height, mm	120	9.63^{b}	0.214^{a}	81.39^{a}	60	45.64
	180	11.12^{a}	0.177^{b}	81.60^{a}	60	51.25
	240	12.21^{a}	0.151^{c}	72.13b	60	52.98
	P	*0.003*	*0.000*	*0.003*		
Tractor forward speed, m s^{-1}	1.1	10.88^{a}	0.186^{a}	78.73^{a}	60	51.19
	1.5	10.86^{a}	0.186^{a}	76.64^{a}	60	50.36
	2.2	11.22^{a}	0.171^{b}	77.20^{a}	60	48.33
	P	*0.846*	*0.046*	*0.714*		

*: NSD; nominal sowing depth, MSD; measured sowing depth

Table 3. The maize experiment analysis results

Parameters		MET, day	ERI, seedlings day^{-1} m^{-1}	PE, %	NSD*, mm	MSD, mm
Tillage system	CT	14.66^{a}	0.299^{b}	86.10^{a}	60	51.30
	RT	11.92^{b}	0.368^{a}	87.52^{a}	60	49.10
	P	*0.004*	*0.002*	*0.374*		
Seed drop height, mm	120	11.67^{b}	0.375^{a}	85.03^{b}	60	40.71
	180	13.87^{ab}	0.333^{ab}	90.92^{a}	60	53.10
	240	14.32^{a}	0.292^{b}	84.47^{b}	60	56.83
	P	*0.046*	*0.011*	*0.003*		
Tractor forward speed, m s^{-1}	1.1	13.66^{a}	0.323^{a}	86.60^{a}	60	52.20
	1.5	13.27^{a}	0.336^{a}	87.37^{a}	60	51.26
	2.2	12.93^{a}	0.341^{a}	86.45^{a}	60	47.17
	P	*0.804*	*0.771*	*0.878*		

*: NSD; nominal sowing depth, MSD; measured sowing depth

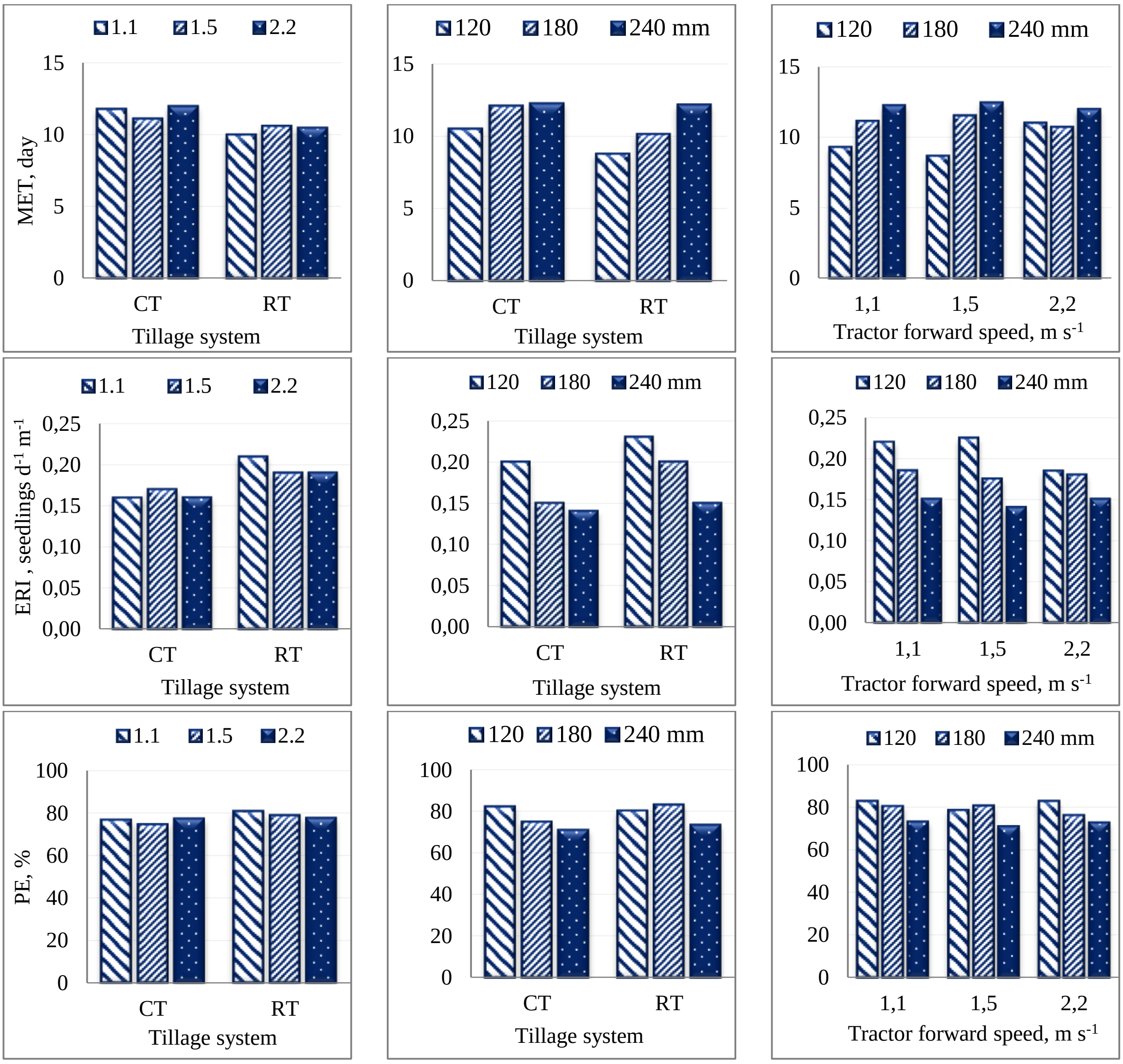

Figure 2. The change of MET, ERI, and PE in sunflower experiment

According to the results of the multiple comparison test, the effect of seed drop height on MET, ERI, and PE was generally significant. PE and ERI decreased and MET increased in the sunflower experiment as seed drop height increased (Table 2 and Figure 2). However, in the maize experiment, due to the increase in the seed drop height, MET increased while only ERI decreased (Table 3 and Figure 3). The largest MET values were obtained from a 240 mm seed drop height as 12.21 days for sunflower and 14.32 days for maize. On the other hand, the lowest MET values were obtained from 120 mm seed drop height as 9.63 and 11.67 days for sunflower and maize experiments, respectively. Depending on the seed drop height, the highest values of the percentage emergence were determined in seed drop height of 180 mm as 81.60% and 90.92% for sunflower and maize experiments, respectively. In both experiments, MET increased by about three days as a result of the increase of seed drop height from 120 mm to 240 mm. In addition, the measured sowing depth approached to the target sowing depth 7 mm and 16 mm for sunflower and maize, respectively.

The results of statistical analysis showed that the effect of tractor forward speeds was insignificant on MET, ERI, and PE in both of the experiments. However, the effect on ERI of 1.5 and 2.2 m s^{-1} forward speeds in sunflower experiment were statistically different from each other (Table 2). Depending on the forward speed, germinations in the sunflower experiment were completed in a shorter time than the maize experiment. While the shortest MET and the largest ERI were obtained at forward speed of 1.5 m s^{-1} in the sunflower experiment, they were obtained at forward speed of 2.2 m s^{-1} in the maize experiment. However, the highest percentage emergences in fields determined as 78.73% at 1.1 m s^{-1} forward speed for sunflower experiment and 87.37% at forward speed of 1.5 m s^{-1} for maize experiment (Tables 2 and 3).

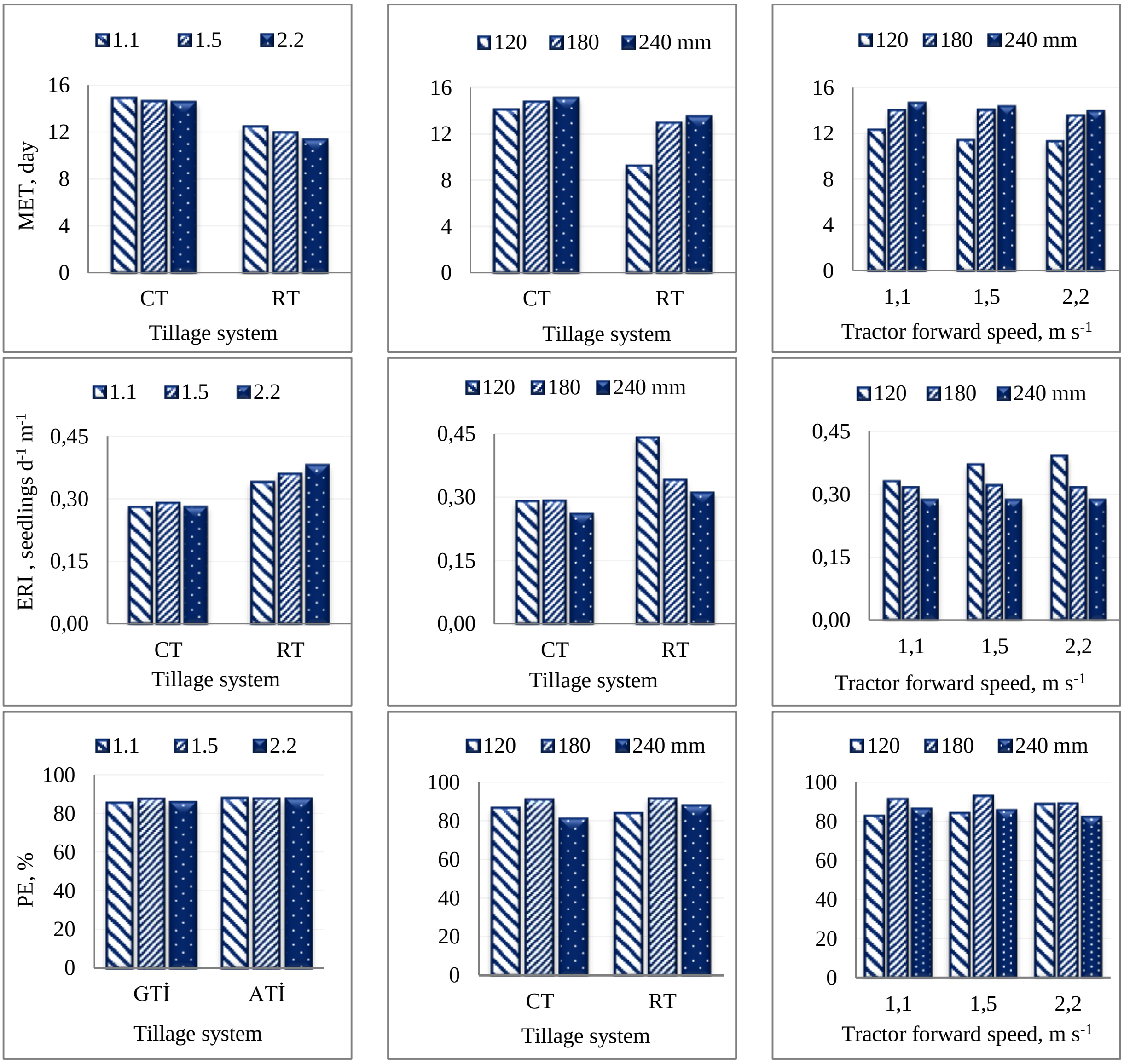

Figure 3. The change of MET, ERI, and PE in maize experiment

Displacement of seeds from the intended position in furrow can occur by bouncing and rolling due to the velocity and time of fall of seeds and by soil movement during the sowing. Karayel and Özmerzi (2008) reported that soil bulk density and seed drop height of furrow openers were effective factors on soil movement and velocity of the fall of seeds. They reported that lower soil bulk density and higher seed drop height increased the displacement of seeds from the intended position. In the present study, the increase in seed drop height increased the displacement of seeds in furrow. This was understood from the different sowing depths obtained in experiments (Tables 2 and 3). The displacement is thought to occur as a result of bouncing at the seed drop height. This is more pronounced in conventional tillage. A relatively lower stubble and hard field surface were obtained in the conventional tillage system while a softer and stubbly a field surface was obtained in the reduced tillage system. Shoe furrow opener with the smallest seed drop height was insufficient in terms of the working performance. This furrow opener was 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. In order to obtain the nominal sowing depth (60 mm), the press wheel was set to the highest level. Therefore, the smaller shoe furrow opener was penetrated deeper into the soil. With the effect of the clod and stubble in the field, 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 nominal depth. Seeds that did not fall to the nominal depth caused disruption of seed distribution in sowing depth. Therefore, seeds falling to different depths were assumed to affect MET and PE.

Displacement of seeds from the intended position in furrow may also occur due to thousand grain weight. Thousand grain weight of corn seeds is about 2.5 times that of sunflower seeds. The heavy seeds were dropped better to the targeted position while the light seeds were sown shallower. It can stay on the edge without falling on the bottom of furrow the seeds that have lower thousand grain weight due to an increase of the seed drop height. In the maize experiment, therefore, it is assumed that the drop to the base of the furrow was better due to the fact that higher thousand grain weight of the maize seeds are effective in increasing MET. The results of this study have supported the results of the study conducted by Krall et al. (1979) examined effects on MET of sowing depth in wheat.

Conclusion

Tillage system affected the mean emergence time and emergence rate index. However, the percentage emergence was not affected by the tillage system. The highest percentages were obtained from the reduced tillage system. While MET, ERI, and PE affected by the seed drop height, they were not affected by tractor forward speed. In general, better results have been achieved in the reduced tillage system and lower seed drop height. In addition to the penetration resistance and bulk density of the soil, it will be useful to take into account the physical properties of the seeds to be sown, such as the sphericity and thousand grain weight. Moreover, it should not be neglected that the drop height of the seeds can negatively affect the uniformity of sowing depth. It can be concluded that the position of seed in the soil effects MET, ERI, and PE of plants. As a result of the deteriorated sowing depth, it should be noted that MET, ERI, and PE can be adversely affected.

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