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Seeding Performances of No-Till Seeders Equipped with Different Furrow Openers, Covering Components and Forward Speeds for Winter Wheat

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ABSTRACT

In the no-till method, seeds are placed in rows opened by furrow openers that can work under stubble field conditions, and are covered with soil and plant residue using covering components. Furrow openers and their properties are extremely effective in sowing seeds at certain depths and intra-row distances for various emergence and growth conditions. The purpose of this study is to determine effects of no-till seeders with different furrow opener types, covering components and forward speeds on certain important physical properties of the soil, stubble distribution, and seed emergence of winter wheat. Two different types of no-till seeders; disc (NS-1) and narrow hoe (NS-2), two different types of covering components; chain (CC) and spring type (SC), and two forward speeds; FS-1 (0.75 m s⁻¹) and FS-2 (1.5 m s⁻¹) were used to achieve the purpose of this study. The no-till seeder with a disc type furrow opener achieved better stubble distribution on the soil surface and percentage of seed emergence in comparison to no-till seeder with narrow hoe type openers. The best coverage rate of stubble on the soil surface and percentage of seed emergence were obtained at the forward speed of 0.75 m s⁻¹. While the spring type covering component increased percentage of seed emergence in comparison to the chain type covering component, it decreased the mean emergence time.

Keywords: Covering component; Forward speed; Furrow opener; No-till seeder; Stubble

Doğrudan Ekim Makinalarının Farklı Gömücü Ayak, Kapatıcı Düzen ve İlerleme Hızlarında Kışık Buğday Ekim Performansları

ESER BİLGİSİ

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ÖZET

Doğrudan ekim yönteminde, tohumlar anızlı tarla koşullarında çalışabilen gömücü ayakların açtığı çizilere yerleştirilir ve kapatıcılar tarafından üzerleri toprak ve bitki artıkları ile kapatılır. Tarla filiz çıkışları ve bitki büyüme koşulları

incelendiğinde, gömücü ayak tipi ve özelliklerinin tohumları belirli ekim derinliğine ve sıra üzeri mesafeye yerleştirmede önemli derecede etkili olduğu anlaşılmaktadır. Bu çalışmanın amacı, farklı tip gömücü ayaklara ve kapatıcı düzenlere sahip doğrudan ekim makinalarının kışlık buğdayda, farklı traktör ilerleme hızlarında kullanılmasının önemli bazı toprak fiziksel özelliklerine, anız dağılımı ve tarla filiz çıkışlarına olan etkilerini belirlemektir. Bu amaçla, diskli (NS-1) ve dar çapa (NS-2) tip gömücü ayaklara sahip iki farklı doğrudan ekim makinası; zincirli (CC) ve yaylı (SC) tipten oluşan iki farklı kapatıcı ile 0.75 m s^{-1} (FS-1) ve 1.5 m s^{-1} (FS-2)'ten oluşan iki farklı traktör ilerleme hızında kullanılmıştır. Elde edilen sonuçlara göre; diskli tip gömücü ayaklara sahip doğrudan ekim makinası ile ekim yapılan parsellerde, dar çapa tip ayaklara göre daha iyi anız dağılımı ve daha yüksek tarla filiz çıkışları elde edilmiştir. Tarla yüzeyinde en iyi anız kaplama oranı ile en iyi tarla filizi çıkışları 0.75 m s^{-1} traktör ilerleme hızında elde edilmiştir. Yaylı tip kapatıcı, zincirli tipe göre daha iyi tarla filiz çıkış oranı ile daha kısa çıkış zamanının elde edilmesine yol açmıştır.

Anahtar Kelimeler: Anız; Çizi kapatıcı; Doğrudan ekim makinası; Gömücü ayak; İlerleme hızı

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1. Introduction

In the no-till method, sowing is carried out using a no-till seeder under stubble covered field conditions, with no need to do anything regarding the soil after the harvest of the previous crop. During sowing, the seeds are placed in furrows opened by furrow openers that can work under stubble conditions, covered with soil and plant residue, and soil is firmed with special firming components (Çelik 2009). In this method, the amount of stubble covering the field surface decreases between 10% and 15%, depending on the stubble type in comparison to before sowing (McVay 2003). In comparison to conventional tillage, the no-till method enables more nitrogen to accumulate in the soil and improves soil aggregates and the ability to retain soil moisture (Huang et al 2008). In addition, the no-till method increases the N and C concentration, the microbial biomass, and bacteria and fungi population (Cookson et al 2008), decreases emissions of CO_2 and N_2O into the air, decreases fuel consumption compared to the conventional tillage (Yalçın & Çakır 2006), decreases soil erosion (Buschiazzo et al 2007), and increases crop yield in the long term (Huang et al 2008). In this method, the mass of stubble per unit area on the field at sowing is 10% to 15% less than immediately after harvest the previous growing season (McVay 2003).

In order to obtain the expected effect from no-till seeders, important structural properties, such as furrow openers and covering components of the

seeders must be compatible with the climate, soil type, field conditions, and crop species. Sowing success depends on weed control and soil conditions, as well as seeder performance.

Studies conducted to determine the effects of no-till furrow openers on soil physical properties investigate important properties such as the soil bulk density, penetration resistance, moisture content, temperature and the furrow profile. According to Chaudhry et al (1990), hoe openers used in the no-till method decrease the soil bulk density in the furrow region, and increase oxygen diffusion, in comparison to disc openers. As a result, they stated that there was an increase in the number of earthworms in the soil. In a study conducted by Riethmuller (1995), two hoe-type furrow openers with different widths, and two different covering components (toothed and rotating) were used. They found that soil disturbance increased as the width of the furrow opener increased, so the widest furrow openers had the greatest effectiveness in decreasing soil bulk density. Another result was that the rotated type covering components decreased the soil bulk density in comparison to the toothed type covering components.

Choudhary & Baker (1980) stated that sowing with triple disc openers, which have a single coulter cutting residue and soil ahead of a double disc opener, under dry farming conditions was affected more by soil moisture positively in comparison to sowing performed with hoe and chisel type furrow

openers. According to Janelle et al (1993) and Parent et al (1993), disc openers heave the soil less, break it up less, and leave a more controlled seed furrow in comparison to hoe type furrow openers.

Stubble comprises of plant residues such as plant stalks and leaves from the previous harvest and weeds killed in various ways. Stubble can be found in various forms on the field surface; short, long, moist, dry, loose, tangled, upright, piled, newly harvested, post-winter, shredded or as it is, laid on the soil surface or partially buried in the soil. Stubble may affect the performance of the seeder by blocking the furrow openers, preventing the soil from entering, and blocking other row units of the seeder (Çelik 2009).

The cutting resistance stubble displays towards the furrow opening unit is directly proportional to the soil moisture content (Guerif et al 2001). As a result, the sowing performance decreases as the moisture content of the stubble on the soil surface increases (Price 1999). The hard-to-cut stubble either blocks the seeder by getting caught in its parts or the stubble is left in a pile, where the seed is sown. In order to prevent this from happening, either the stubble covering the row is pre-cleaned or a cutter unit is placed in front of the furrow opener so that the stubble is cut before it reaches to the furrow (Guerif et al 2001). According to Bahrani et al (2007), it is best that the corn and sunflower stubble is cleaned from the row in order to increase the performance of the no-till seeder. When stubble on the soil is buried in the soil before being cut by the furrow opener, the seeds are then left close to the soil surface and there is less seed-soil contact (Payton et al 1985).

The fact that the furrow opener is able to sow seeds at the required intra-row distance and at a homogenous depth is extremely important in plant growth and decreasing harvest loss. As a general rule, increasing the sowing depth allows the seed to get maximum benefit from the moisture in the soil. However, sowing too deep may reduce the seed's access to oxygen, thereby endangering the seed. In addition, the energy in the seed, during deep

sowing, may not be enough to enable emergence. McGahan & Robotham (1992) concluded that in the event sowing depth deviates from the intended depth by 30 mm, productivity decreases between 5% and 35%. Heege (1993) stated that an increase in the coefficient of variation in the sowing depth adversely affected the emergence rate. According to Slattery (1997), seeds must be sowed at the optimum sowing depth in order to obtain maximum productivity.

Tessier et al (1991a) conducted studies to determine the effect no-till seeders with various furrow openers had on the sowing depth. They concluded that the greatest sowing depth was obtained for plots where hoe type openers were used, while the shallowest sowing depth was obtained for triple disc openers. According to Krall et al (1979), double disc openers have less variability in sowing depth in comparison to stub-runner and chisel openers. The winged hoe type furrow opener, developed by Riley et al (1997), sows seeds on a large area, both vertically and horizontally.

The majority of studies, conducted to assess the performance of furrow openers, are carried out under field conditions, and these studies investigate the seed emergence rate and productivity. Studies conducted by Woodruff et al (1966), Choudhary & Baker (1980), Choudhry et al (1990), and Ward et al (1991) suggest that hoe openers enable a higher seed emergence rate and a higher productivity in certain conditions compared to the disc openers. However, according to Krall et al (1979) double disc openers cause a low sowing depth variation and a high emergence rate in comparison to stub-runner and hoe openers. Whereas, Tessier et al (1991b) compared the effects of a no-till seeder, with different disc openers having various diameters (500 mm, 640 mm, and 660 mm), and a hoe opener, on the seed emergence rate of wheat. Results showed that the seeder with a disc opener enabled a higher emergence rate in a shorter time in comparison to the seeder with a hoe opener. Similarly, Doan et al (2005) stated that disc openers enabled a faster emergence rate than hoe openers.

Choudhary & Baker (1980) conducted studies, in a laboratory, to compare effects of chisel, triple disc, and hoe openers on the seed emergence rate in the no-till method. According to results obtained under dry soil conditions; the seed emergence rate was 58.4% for the chisel opener, 31.3% for the hoe opener, and 10.5% for the triple disc opener; the seed emergence rate under irrigated farming conditions averaged 68.8% for chisel and hoe openers, and 42% for the triple disc opener.

Çelik et al (2009) conducted studies to compare different type no-till seeders under different stubble conditions; they concluded that, in general, hoe openers gather stubble together at the end of plots. The best result for sowing depth was obtained for the no-till seeder with the wide hoe opener.

The purpose of this study is to investigate the effects of different furrow openers and covering components used in no-till seeders and effects of different forward speeds on the soil physical properties, stubble distribution and seed emergence.

2. Material and Methods

This study was conducted at the production area belonging to the Agricultural Research and Publication Directorate of the Faculty of Agriculture at Atatürk University, under stubbly vetch field conditions. In August 2008, winter wheat was harvested from the experiment area using a combine harvester with a stubble height of 120 mm, and the field was left for the winter without conducting any other process. In April 2009, summer vetch was sowed on the same area using the no-till method. In August 2009, the summer vetch was harvested using a lawnmower with a stubble height of 100 mm. The stubble in the experiment field was mostly in standing conditions. After harvesting the vetch, a winter wheat experiment was prepared under stubbly vetch field conditions and seeding was successfully completed with no-till machines as planned. At the time of seeding in the last week of September 2009, the soil had adequate moisture content, referred as normal seeding condition. Table 1 illustrates some of the important physical properties of the soil at the experiment area.

Table 1- Some important physical properties of the experiment area soil (0-100 mm)

Çizelge 1- Deneme alanı topraklarına ait önemli bazı fiziksel özellikler (0-100 mm).

<i>Physical properties of the soil</i>	<i>Values</i>
Bulk density, Mg m ⁻³	1.65
Porosity, %	37.7
Moisture content, d.b. %	11
Penetration resistance, MPa	1.78
Soil texture class	Clay loam
Sand, %	30.7
Silt, %	21.8
Clay, %	47.5
Stubble cover rate, %	89.7

Two no-till seeders with different furrow openers were used with two different covering components in this study. Furrow openers were disc (NS-1; Özdöken Tarım Makinaları Sanayi ve Ticaret A.Ş., Konya, Turkey) and narrow hoe (NS-2; Aitchison, Reese Agri-Usa, Braymer, Mo, 64624, USA), types and covering components were chain (CC) and spring (SC) types. Table 2 illustrates some of the important technical properties of no-till seeders, Figure 1 illustrates the schematic diagrams of no-till seeders and furrow openers and Figure 2 illustrates the schematic diagrams of covering components.

For the experiment, Bezostaya cultivar winter wheat seed (1000 grains per 35.5 g) were sowed at 50 mm depth at a 165 kg ha⁻¹ seeding rate. Field conditions, the crop species, and the sowing time were taken into consideration in determining the sowing depth. The seeds were disinfected with powder fungicide DS-2 (tebuconazole 2%) before sowing. Diammonium phosphate (18% AN, 46% P₂O₅) fertilizer was broadcast-applied at a rate of 150 kg ha⁻¹ at sowing.

Furrow openers, covering components and tractor forward speeds were considered as treatments and three replications were used. The experiment was designed as a randomized complete block with plots 40 m long and 10 m wide. Field conditions and the power requirements of the no-till seeders

were taken into consideration when determining the different tractor forward speeds; the chosen speeds were 0.75 m s^{-1} (FS-1) and 1.5 m s^{-1} (FS-2). A Ford 5000 S model tractor [49.4 kW at 2100 rpm (ASAE Standards 1972)] was used to pull the no-till seeders.

Measurements were taken both before and after the experiment in order to determine the soil bulk density and porosity of the experiment area. Soil samples were taken from each plot in three replicates (0 to 50 mm, and 50 to 100 mm), their wet weights were determined, and they were then dried at $105 \text{ }^{\circ}\text{C}$ for 24 hours. The samples removed from the drying oven were re-weighed to determine their dry weight. The bulk density and porosity were calculated from the dry weight of soil samples and the specific density of the experiment area soil (Demiralay 1993).

An Eijkelkamp analogue soil penetrometer (Eijkelkamp Agrisearch Equipment, Giesbeek, The Netherlands) with 100 mm^2 cone base area was used to determine the penetration resistance of the soil. Measurements were taken immediately after sowing, both intra-row and inter-row, at several locations in each plot. Penetrometer readings were made over the 0 to 200-mm depth range, at each 50-mm increment, and four replications were used (ASABE Standards 2010; Mataba & Colvin 2002). The measurements taken as kN were later converted into MPa (Çelik 1998). The line transect method was used on the experiment area to determine the field coverage rate of stubble before sowing, and the effect of furrow openers on the stubble distribution, both intra-row and inter-row after sowing. For this purpose, a 5 m long rope, marked with 100 mm intervals was used. Before the experiment the rope was placed parallel to harvested rows and after the experiment, the rope was placed parallel to the seeded rows. The stubbles that coincided with the intervals marked on the rope were noted, and their % value was calculated (Morrison & Gerik 1985).

A 1-mm thick, iron sheet frame, used by Chen et al (2004) was used to measure the amount of stubble buried into the furrow under the effect of

furrow openers. The frame, which is open at the top and bottom, was 200 mm long, 50 mm wide, and 50 mm deep. The frame was buried parallel to the furrows opened by the furrow openers, and removed together with the stubble and soil inside it once the free stubble on the surface was removed. The soil, after removal of stubble, was left to dry. The length of stubble was measured by taking into consideration the stubble left on the frame surface, and the stubble removed from inside of the frame. These measurements determined how effective the furrow openers were in cutting stubble.

After each pass to the end of plots, the stubble accumulated on the front and rear furrow openers of the seeders was collected and dried in a $60 \text{ }^{\circ}\text{C}$ drying oven for 48 hours. Dry weight was recorded to determine the amount of stubble gathered by furrow openers (Allmaras et al 1988). Stubble biomass data were converted into kg ha^{-1} by taking into consideration the length of the plots and the width of the seeders.

Table 2- Some technical properties of no till seeders

Çizelge 2- Doğrudan ekim makinalarının bazı teknik özellikleri

<i>Technical properties</i>	<i>NS-1</i>	<i>NS-2</i>
Furrow opener type	Disc	Narrow hoe
Number of openers	15	12
Width of opener, mm	5	36
Inter-row distance, mm	120	120
Type of seed metering unit	Straight corrugated sheave	Ribbed sponge
Tilt and disc angle, $^{\circ}$	2 / 9	-
Total weight, kg	1000	534
Weight per furrow opener, kg	66.7	44.5
Type of attachment to tractor	Towed	Hung
Manufacturer and model	Özdöken	Aitchison/ Seed Matic

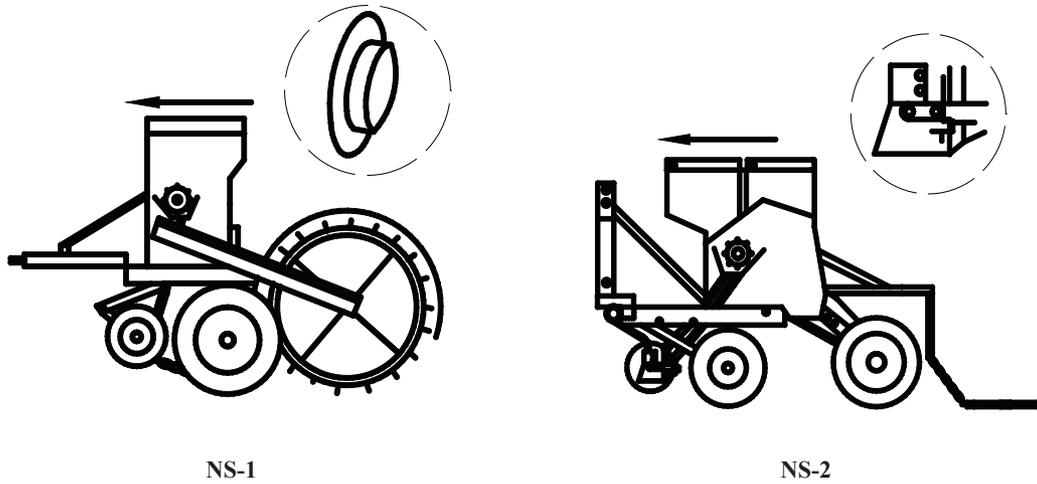


Figure 1- Side views of no-till seeders and furrow openers (NS-1: Disc type, NS-2: Narrow hoe type)

Şekil 1- Doğrudan ekim makinaları ve gömücü ayakların şematik görünüşleri (NS-1, Diskli tip; NS-2, dar çapa tip)

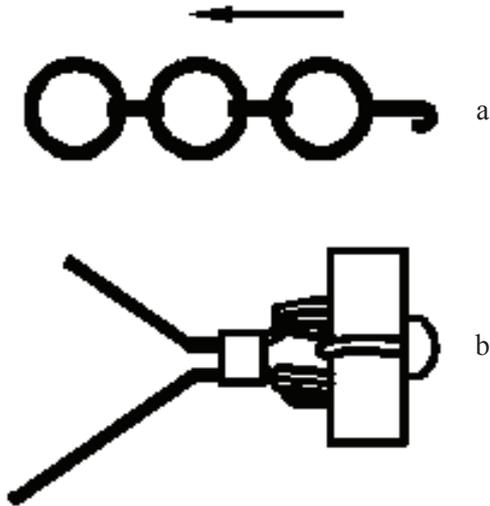


Figure 2- Top view diagrams of covering components (a, chain type; b, spring type)

Şekil 2- Kapatma ünitelerinin üstten görünüşleri (a, zincirli tip; b, yaylı tip)

The grass length measuring method was used in order to determine the uniformity of sowing depth of seeders. The emerged seeds reached 100 mm above soil, ten seedlings were pulled out in each marked row used for the plant count approximately six weeks after seed emergence. The chlorophyll-free stem and coleoptiles' length of seedlings (from seed remnants to onset of green stem) was measured as effective sowing depth (Tessier et al 1991b).

Seedlings emerged from randomly selected three 1-m sections in each plot were used, to determine the mean emergence time (MET), the emergence rate index (ERI), and the percentage of emergence (PE). Counts were conducted every two days from the start of emergence until it concluded. Data obtained were assessed using the equations stated below (Bilbro & Wanjura 1982).

$$MET = \frac{(N1 T1 + N2 T2 + \dots + Nn Tn)}{(N1 + N2 + \dots + Nn)} \quad (1)$$

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

$$PE = \frac{100\% Ste}{n} \quad (3)$$

Where; MET is the mean emergence time, day; ERI is the emergence rate index, seedling day⁻¹ m⁻¹; PE is the percentage of emergence, %; N1...n are the numbers of seedlings emerging since the time of previous count; T1...n are the numbers of days after sowing; Ste is the number of total emerged seedlings per meter; n is the number of seeds sown per meter.

The ANOVA procedure was used to perform the analysis of variance, which was appropriate for a randomized complete block design. Significant differences were determined among means using the protected least significant difference (LSD) tests at a 0.05 probability level.

3. Results and Discussion

The effect of furrow openers had on the soil bulk density and penetration resistance was statistically significant; however, the forward speed and covering components were insignificant. Soil bulk density increased as depth increased. The greatest soil bulk densities were 1.49 Mg m⁻³ for the 0-5 and 1.63 Mg m⁻³ for the 50-100 mm depth ranges were obtained in seeders equipped with disc openers. The soil bulk densities for the hoe openers were 1.44 and 1.55 Mg m⁻³ (Table 3).

The increase in penetration resistance was similar to that of soil bulk density. The greatest penetration resistance was seen for the plots sown with seeders having disc type furrow openers. For the 0-50 mm depth, the penetration resistance was 1.31 MPa for the seeder with disc openers, and 1.13 MPa for the narrow hoe openers. The penetration resistance increased as depth increased. For the 50-100 mm soil depth, the penetration resistance was 1.54 MPa for the seeder with disc openers and 1.43 for narrow hoe openers (Table 3). The factors investigated had no statistical effect on the penetration resistance measured at the 100-150 mm and 150-200 mm depths. The average penetration resistance was 1.68 MPa at the depth of 100-150 mm, and was 1.72 MPa at the 150-200 mm depth.

After sowing, the seeder with disc type openers had the highest stubble covering rate intra-row with 70.2%, closely followed by hoe openers with 69%. The highest stubble coverage rate for inter-row was obtained using the disc openers at 68.6%, followed by hoe openers at 64.8%. The difference between the amounts of stubble collected by seeders was statistically significant. The stubble was dragged along as the seeder moved forward and accumulated on the opener per unit area was 210 kg ha⁻¹ for the seeder with narrow hoe openers, 170 kg ha⁻¹ for disc openers (Table 4). The depth the stubble was buried into the soil for a furrow length of 1 m by the furrow openers, which was also statistically significant. The seeder that buried the stubble deepest into the furrow was the seeder with disc type furrow openers, with 32.8 g m⁻¹. This was followed by narrow hoe openers with 29.7 g m⁻¹. The effect of furrow openers on stubble cutting length was also statistically significant. The average length of the cut stubble for the seeder with 61 mm for hoe openers, and 49 mm for disc type openers (Table 4).

The effect of forward speeds on the stubble coverage rate in the intra-row and inter-row was statistically significant. The intra-row stubble coverage rate was 66.4% for the forward speed of 0.75 m s⁻¹ and 61.2% for 1.5 m s⁻¹. Similar to intra-row, the inter-row stubble coverage rate decreased from 64.1% to 60.6% as forward speed increased. No statistical significance was determined regarding the effect covering components have on the intra-row and inter-row stubble distribution. The forward speed and covering components had no significant effect on the average stubble length buried, gathered, and cut by the furrow openers (Table 4).

The mean seed emergence time, emergence rate index, and percentage of emergence were taken into consideration to determine the seed emergence performance of seeders. The mean emergence time increased together with the increase in the forward speed as 15.8 days at 0.75 m s⁻¹ to 16 days at 1.5 m s⁻¹. The mean emergence time for chain coverers 16.1

Table 3- Analysis of variance and mean comparisons of the soil bulk density and penetration resistance

Çizelge 3- Hacim ağırlığı ve penetrasyon direnci değerlerinin varyans analizi ve ortalama karşılaştırma sonuçları

Factor		Soil dry bulk density (Mg m ⁻³)				Penetration resistance (MPa)			
		Depth (mm)				Depth (mm)			
		0-50		50-100		0-50		50-100	
Seeders	NS-1	1.49	a √	1.63	a	1.31	a	1.54	a
	NS-2	1.44	b	1.55	b	1.13	b	1.43	b
	P	0.00		0.00		0.00		0.00	
Seed covering component	CC	1.44	a	1.57	a	1.21	a	1.47	a
	SC	1.45	a	1.58	a	1.20	a	1.49	a
	P	0.06		0.83		0.21		0.88	
Forward speed	FS-1	1.45	a	1.58	a	1.20	a	1.48	a
	FS-2	1.46	a	1.57	a	1.20	a	1.47	a
	P	0.39		0.89		0.77		0.88	
SEM		0.007		0.009		0.017		0.012	
NS-1 :		No-till seeder with disc openers				CC :		Chain coverer	
NS-2 :		No-till seeder with narrow hoe openers				SC :		Spring coverer	
SEM :		Standard error of the mean				FS-1 :		0.75 m s ⁻¹	
√ :		For each factor, within each column, means followed by the same letter are not significantly different at $\alpha = 0.05$ (LSD).				FS-2 :		1.5 m s ⁻¹	
						P :		Significance level	

days was longer in comparison to spring covers, 15.8 days (Table 5). A greater emergence rate index is accepted as an advantage for furrow openers. The emergence rate index was 21.8 seedlings day⁻¹ m⁻¹ for disc type furrow openers, 21.1 seedlings day⁻¹ m⁻¹ for narrow hoe openers. The emergence rate index decreased with the increase in forward speed. It decreased from 21.6 seedlings day⁻¹ m⁻¹ at 0.75 m s⁻¹ speed to 19.4 seedlings day⁻¹ m⁻¹ at 1.5 m s⁻¹ speed. Covering components had no significant effect on the emergence rate index (Table 5). In the study, the percentage of emergence was 74.2% for disc openers, 72.1% for narrow hoe openers. At low forward speeds, higher percentages of emergence were obtained, whereas covering components showed similar percentages of seed emergence.

Seed emergence decreased from 73.3 % at 0.75 m s⁻¹ speed to 66.9% at 1.5 m s⁻¹ speed (Table 5).

The deviation of the measured sowing depth uniformity from the target sowing depth was measured and expressed as the coefficients of variation; 16.0% for the seeder with disc openers and 20.0% for narrow hoe openers. Coefficients of variation also increased together with the increase in forward speeds as 18.1% at 0.75 m s⁻¹ speed to 22.1% at 1.5 m s⁻¹ speed (Table 5).

The values of soil bulk density and penetration resistance increased with increases in soil depth, and the overall bulk density and penetration resistance were low in the seedbed layers compared to the initial field conditions. The bulk density post-seeding changed depending on furrow opener types and

measurement depths in comparison to bulk density pre-seeding; it was lower by 1-13%. Bulk density and penetration resistance in the 0-50 and 50-100 mm depth ranges for the disc opener were about 4-6% greater than for the narrow hoe (Table 3).

There are a number of reasons why high bulk density and high penetration resistance were obtained for the disc type furrow openers. The weight of disc type no-till seeder per furrow opener unit is approximately 30% more than the other seeder and the furrows opened by the disc type of opener are smaller. Also, disc openers cause less soil disturbance than hoe openers because they create a narrower furrow (Janelle et al 1993). As the furrow cross-sectional area is narrower for disc type openers, the seeder weight has a higher compression effect for the soil beneath the furrow more than that along the side of the furrow. Kushwaha et al (1986) stated that the vertical force necessary to push a disc coulter into the soil increased significantly with depth and when straw was pushed into the soil. This increased force requirement might also increase compaction of the soil at the seeding depth. At the 0-100 mm depth, at which the furrow openers are effective, the penetration resistance obtained after sowing was 13-35% less than the penetration resistance before sowing. The penetration resistance at depth between 100- 500 mm was close to the initial values.

The effect of seeders on inter-row stubble distribution was similar to intra-row distribution. However, the inter-row stubble coverage rate was lower than the intra-row values. From these results, it is understood that, especially on the furrow centerline, the furrow openers collected and removed the stubble by dragging them outside the furrow area.

A portion of the stubble on the soil was dragged by the furrow openers and covering components; they were gathered or thrown outside the width of the furrow line. The remaining stubble was either cut by the furrow openers, or buried into the furrow without being cut. This situation might

change according to types of the furrow openers and covering components used; the soil might be covered in more or less stubble in comparison to the amount before sowing. As a result, stubble distribution may be different for inter-row and intra-row areas. According to research data, the stubble covered soil surface post-seeding decreased 28.8% intra-row, and 30.4% inter-row in comparison to pre-seeding, as a result of the seeder dragging, burying, and gathering the stubble (Table 4). Normally, no-till drills should leave 60-95% stubble coverage on the field surface after seeding (Eck et al 1992).

The no-till seeder with disc type furrow openers scattered the stubble in the furrow zone more homogeneously and cut in shorter length. In using the disc type furrow opener, pieces of straw that were not cut, were observed to be pushed or buried (hairpinned) into the soil. For this reason stubble buried in the furrow was found to be greater for the disc opener. The stubble coverage in the intra-row and inter-row area was also greater for the disc opener. A portion of the cut straw remained upright, in the furrow, sandwiched between the soil, similar to the finding by Kushwaha et al (1986), and a portion of it remained on the soil surface.

The stubble coverage on the soil decreased with increasing forward speed. Greater forward speed increased soil displacement and displacement of the stubble, and causing stubble to be dragged and collected in a pile. This result also agrees with the finding by Liu et al (2010) that higher tillage speed resulted in larger soil and straw displacement that also buried more straw (Table 4).

The type of furrow opener played a significant role in the mean emergence time and percentage of emergence. The disc opener showed an average of 0.6 shorter emergence time and 3% higher percentage of emergence than narrow hoe type openers (Table 5). The compaction effect that disc opener applied to the seed level improved soil-seed contact (Hadas & Russo 1974).

Table 4- Analysis of variance and mean comparisons of the data regarding stubble distribution

Çizelge 4- Anız dağılımının varyans analizi ve ortalama karşılaştırma sonuçları

Factor		Intra-row stubble distribution (%)	Inter-row stubble distribution (%)	Stubble buried in furrow ($g\ m^{-1}$)	Gathered stubble ($kg\ ha^{-1}$)	Average stubble length (mm)	
Furrow opener	NS-1	70.2 a *	68.6 a	32.8 a	170 b	49 b	
	NS-2	69.0 b	64.8 b	29.7 b	210 a	61 a	
	P	0.00	0.00	0.00	0.00	0.00	
Seed covering component	CC	63.6 a	62.4 a	30.2 a	156 a	66 a	
	SC	64.1 a	63.2 a	29.9 a	151 a	65 a	
	P	0.43	0.05	0.81	0.47	0.71	
Forward speed	FS-1	66.4 a	64.1 a	29.5 a	163 a	66 a	
	FS-2	61.2 b	60.6 b	30.6 a	151 a	65 a	
	P	0.00	0.00	0.24	0.22	0.58	
SEM		1.328	1.116	0.385	0.085	2.116	
NS-1 :		No-till seeder with disc openers			CC :		Chain coverer
NS-2 :		No-till seeder with narrow hoe openers			SC :		Spring coverer
SEM :		Standard error of the mean			FS-1 :		0.75 m s ⁻¹
* :		For each factor, within each column, means followed by the same letter are not significantly different at $\alpha = 0.05$ (LSD).			FS-2 :		1.5 m s ⁻¹
					P :		Significance level

Table 5- Analysis of variance and mean comparisons of the data regarding seed emergence

Çizelge 5- Bitki çıkışlarına ilişkin varyans analizi ve ortalama karşılaştırma sonuçları

Factor		Mean emergence time (day)	Emergence rate index ($seedling\ day^{-1}\ m^{-1}$)	Percentage of emergence (%)	Sowing depth uniformity (CV, %)		
Furrow opener	NS-1	15.8 a *	21.8 a	74.2 a	16.0 b		
	NS-2	15.9 a	21.1 a	72.1 a	20.0 a		
	P	0.34	0.06	0.10	0.00		
Seed covering component	CC	16.1 a	20.2 a	69.7 a	20.3 a		
	SC	15.8 b	20.8 a	70.4 a	19.9 a		
	P	0.00	0.35	0.98	0.32		
Forward speed	FS-1	15.8 b	21.6 a	73.3 a	18.1 b		
	FS-2	16.0 a	19.4 b	66.9 b	22.1 a		
	P	0.00	0.00	0.00	0.00		
SEM		0.044	0.314	0.972	0.704		
NS-1 :		No-till seeder with disc openers			CC :		Chain coverer
NS-2 :		No-till seeder with narrow hoe openers			SC :		Spring coverer
SEM :		Standard error of the mean			FS-1 :		0.75 m s ⁻¹
* :		For each factor, within each column, means followed by the same letter are not significantly different at $\alpha = 0.05$ (LSD).			FS-2 :		1.5 m s ⁻¹
					P :		Significance level

Tessier et al (1991b) and Doan et al (2005) also reported that they obtained shorter emergence time and higher emergence rate with disc opener compared to the hoe type opener. A lower coefficients of variation of sowing depth that is preferred, means a more uniform seeding depth. The higher forward speed increased soil displacement in the furrow along with seed and stubble, thereby causing non-uniform seed depth and a lower seed emergence rate; Çelik et al (2007) also reported the similar results.

4. Conclusions

The no-till seeder with disc type furrow openers scattered and cut the stubble in the furrow zone more homogeneously than the seeders having narrow hoe type openers.

The highest percentage of emergence were obtained from plots sown with the seeder having disc type furrow openers. However, the disc openers compressed the soil more and buried the stubble deeper into the furrow, due to its higher weight per opener.

Forward speed had no significant effect on soil compaction. Better stubble distribution on the soil surface, sowing performance, and percentage of seed emergence were obtained at 0.75 m s⁻¹ forward speed in comparison to 1.5 m s⁻¹ speed. The higher forward speed might cause shallow sowing depth, thereby not covering the seed with enough soil to have enough moisture for emergence.

The spring type covering component increased intra-row and inter-row seed distribution uniformity and percentage of seed emergence, and decreased the mean emergence time, in comparison to the chain type covering component.

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Abbreviations and Symbols

NS-1	Disc type furrow opener
NS-2	Narrow hoe type furrow opener
FS-1	0.75 m s ⁻¹ forward speed
FS-2	1.5 m s ⁻¹ forward speed
CC	Chain type covering component
SC	Spring types covering component
MET	Mean emergence time
ERI	Emergence rate index
PE	Percentage of emergence

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