



## Effects of Direct and Conventional Planting on Soil Properties and Yield Characteristics of Second Crop Maize\*

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**Abstract:** Conventional tillage (CT), a commercial direct planter (DP<sub>1</sub>), and a modified direct planter (DP<sub>2</sub>) were used in this study to determine the performance of DP<sub>2</sub> compared to CT and DP<sub>1</sub> in second crop maize after winter wheat. Experiments were conducted with six replications through complete randomized block design. Average seed spacing was about 18 cm and the quality of seed index was about 90% in all methods. Multiple index was the smallest (0.56%) in CT, suggesting best horizontal seed distribution whereas DP<sub>1</sub> had the highest rate (3.89%). Variation about the mean seed spacing was less than the upper limit of 29% in precision in spacing in all cases. The adjusted seeding depth was 6.0 cm in CT (5.99 cm) with the best placement and the poorest placement was found in DP<sub>2</sub> (2.90 cm). Seed depth distribution was different in the three cases (P<0.01). Planting method did not have a significant effect on emergence rate and yield. Although the performance of the modified direct planter is very encouraging, the modified direct planter should probably be improved further so that higher down forces can be applied to maintain the set value of seeding depth for seeding in hard soil conditions.

**Key Words:** Tillage, direct planting, seed distribution, seeding indices, emergence rate, maize yield.

### Doğrudan ve Geleneksel Ekimin Toprak Özelliklerine ve İkinci Ürün Mısır Verim Karakteristiklerine Etkisi

**Öz:** Bu çalışmada; birinci ürün kışlık buğday sonrası ikinci ürün mısır üretiminde filizlenme oranı, ürün verimi, toprak özellikleri ve çizi karakteristikleri dikkate alınarak, modifiye edilmiş doğrudan ekim makinesinin performansının (DP<sub>2</sub>), geleneksel (CT) ve doğrudan ekim (DP<sub>1</sub>) yöntemlerine göre karşılaştırılması amaçlanmaktadır. Tarla denemeleri tesadüf parselleri deneme planına göre altı tekrarlı olarak yapılmıştır. Sıra üzeri mesafe 18 cm ye ayarlanmış ve kabul edilebilir aralık oranı tüm yöntemlerde yaklaşık %90 olarak bulunmuştur. İkiçizlenme oranı değeri en düşük CT (%0.56) yönteminde, en yüksek ise DP<sub>1</sub> (%3.89) yönteminde elde edilmiştir. Tohumun sıra üzeri dağılım varyasyon katsayısı bütün uygulamalarda üst sınır kabul edilen %29'dan daha düşük hesaplanmıştır. Ekim derinliği 6 cm ye ayarlanmış ve en iyi ekim derinliği CT uygulamasında (5.99 cm) ve en kötü ekim derinliği ise DP<sub>2</sub> (2.90 cm) uygulamasında elde edilmiş ve ekim derinliği her üç yöntemde istatistiksel olarak farklılık göstermiştir. Toprak işleme yöntemleri filizlenme oranını ve ortalama verimi istatistiksel olarak etkilememiştir. Modifiye edilmiş doğrudan ekim makinesinin performans parametreleri oldukça iyi görünmesine rağmen, sert toprak koşullarında daha iyi ekim derinliği elde edebilmek için makinenin daha fazla baskı kuvveti uygulayabilecek hale getirilmesi gerekli görünmektedir.

**Anahtar Kelimeler:** Toprak işleme, doğrudan ekim, tohum dağılımı, ekim indisleri, filizlenme oranı, mısır verimi.

#### Introduction

Tillage plays a critical role in the technological development in the evolution of agriculture (Opara-Nadi 2008). The objectives of soil tillage are seedbed preparation, water and soil conservation, and weed control (Morrison and Abrams 1978, Lemunyon, 2008). Direct planting is a tillage and planting system that maintains at least 30% crop residue on the field after planting. Erosion is reduced by at least 50% in direct

planting compared to bare soils (McCarthy et al. 1993, Fallahi and Raoufat 2008). Direct planting systems not only reduce erosion and improve the soil conditions for crop growth, but conserve energy and decrease the labor cost of farming. Crop residue left on the soil surface especially is effective in reducing evaporation rate of water (Cassel and Wagger 1996), provides plants with nutrients, improves organic matter level of

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the soil, and increases soil water content by decreasing evaporation and increasing infiltration rate and enhances crop growth (Chastin et al. 1995, Fallahi and Raoufat 2008). Soil erosion is a leading cause of soil degradation due to the loss of organic matter (Al-Kaisi 2001).

In spite of advantages of the direct planting, it increases the risk of poor stand establishment and therefore limits its adoption by farmers (Wells et al. 1983). Weed infestations and difficulties in seeding due to residue are also problems in the adoption of direct seeding (Yalçın and Çakır 2006). Frye and Lindwall (1986) determined that the seeding implements are usually insufficient for planting seeds in untilled soils under various soil and crop residue conditions. Swan et al. (1994) observed that surface residues decrease planting depth and uniformity and increases the number of seeds placed closer to the surface. In order to overcome the seed placement problems in direct planting systems, Erbach (1981) suggested equipping row-crop planters with rolling coulters. Rolling coulters cut the soil and trash, increasing accuracy in seed placement. According to Raoufat and Mahmoodieh (2005), planters equipped with rolling coulters attachments improve seeding indices in direct planting systems.

Direct planting has not become a practice for Turkish farmers, yet. Thus, extension aspect of these practices and hence the adoption of direct planting lags scientific research that has been conducted in the last two decades in Turkey. The desire of farmers to conserve the soil and water resources seems to have secondary importance as most decisions to change cultural practices are frequently influenced by economic factors. The risks associated with conservation farming, however, can be minimized through planning and progressive management (Bucher et al. 1983). Considering the disadvantages of intensive farming and the related costs, direct seeding becomes more vital for farmers with less plant production problems for Turkish farmers (Yalçın and Çakır 2006).

The furrow openers of a planter are working elements which are required to place the seed simultaneously in the seedbed and create an optimum physical environment around the seed for germination and plant growth.

Two approaches are commonly used to evaluate the performance of planters (Karayel and Özmerzi 2007). In the first approach, planter performance is related to seed emergence and crop yield. The second approach takes soil properties and

furrow characteristics (seeding indices) into consideration, which indirectly affect seed emergence and crop yield. Some of these variables are soil penetration resistance, soil moisture and bulk density, seed distribution in horizontal (seed spacing) and vertical plane (seeding depth). The International Organisation for Standardization (1984), Kachman and Smith (1995) and Singh et al. (2005) gives a number of measures to be used for assessing the performance of precision planters based on the theoretical spacing for the planter. These measures include multiple index, miss index, quality of feed index, and precision in seed spacing. Seed depth uniformity is determined by measured seeding depth in the vertical plane (Heege 1993, Darmora and Pandey 1995, Karayel and Özmerzi 2007).

The lack of appropriate and affordable planting equipment has limited direct planting practices in crop production in Turkey. Therefore, a precision planter was modified and equipped with a coulter and pressing wheels to construct an affordable direct planter for small farmers and was tested in a previous study (Korucu 2002). The present study tests this modified direct planter to make observations to develop the planter further as a better direct planter. Therefore, the objectives of this study were to determine the effects of different planting methods on furrow characteristics, soil properties, seed emergence and yield in second crop maize. The methods to be compared include conventional tillage and planting (CT), conservation tillage with a commercial direct planter (DP<sub>1</sub>), and conservation tillage with a modified direct planter (DP<sub>2</sub>).

## Materials and Methods

**Materials:** The experiments were conducted in 2007 in Kahramanmaraş Province on clay soil (24-30 % sand, 15-23 % silt, and 50-56 % clay) in the eastern Mediterranean region of Turkey at an altitude of 640 m. Mean values for organic matter were 2.38% and 1.95%, respectively at depths of 0-10 cm and 10-20 cm.

A direct planter (DP<sub>1</sub>), a modified direct planter (DP<sub>2</sub>) and a precision planter (CT) were used in the field tests. The planters used maize seed (Pioneer 3394), operated at an average ground speed of 4.5 km/h, and were adjusted to deliver an 18 cm target seed spacing. Herbicide (Ekip) was used once for weed control in all treatments. Seedbed preparation in CT application before seeding consisted of chiseling to an approximate depth of 17 cm, disk harrowing (twice) and levelling.

DP<sub>2</sub> was equipped with an 8 wave coulters with a diameter of 0.42 m and a double disc furrow opener (Figure 1a). The coulters assembly was formed such that the coulters could work at the same depth as furrow opener discs. The seeds are placed in the furrow via curved runner type furrow openers and pressed by a covering wheel.

DP<sub>1</sub> had row cleaners of a diameter of 0.33 m in front of the 13 wave coulters (diameter of 0.4 m). Row cleaner and coulters attachments are assembled on the row crop planter ahead of the furrow opener discs, followed by double disc seeders (Figure 1b). CT is done using a four-row precision drill.

The PTO was used to provide vacuum needed for disc seeders for CT and DP<sub>2</sub> while DP<sub>1</sub> employs a hydraulic motor to drive the fan of the planters. DP<sub>2</sub> is a common four-row precision planter equipped with 8 waved coulters. Another difference between the two planters is that DP<sub>1</sub> is normally equipped with a liquid fertilizer (which was not mounted on the machine) whereas DP<sub>2</sub> has granular fertilizer tanks. Finally, the number of rows was four on DP<sub>2</sub> and six on DP<sub>1</sub>.

Penetration resistance (PR) was measured with a hand-held digital soil penetrometer (Eijkelkamp) with a measurement range of 0-5 MPa up to 80 cm depth. The standart soil cone penetrometer has a cone with 60°, a base area of 2 cm<sup>2</sup>. PR measurements were taken at 1.0 cm intervals, pushing the penetrometer vertically into the soil with a speed of 3 cm s<sup>-1</sup>. The PR data were averaged from 0 to 10 cm, 10 to 20 cm, and 20 to 30 cm to relate PR to other parameters in each layer.

Image processing method was used to estimate percent residue cover after each planting treatment. Crop residue coverage ranges across the field after planting were 90-94% in direct planting 1 (DP<sub>1</sub>), 89-90% in direct planting 2 (DP<sub>2</sub>), and 18-22% in conventional tillage.

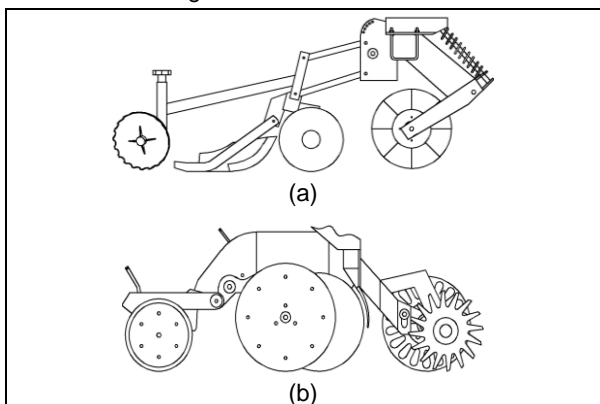


Figure 1. The schematics of the coulters of modified planter (a) and direct planter (b)

**Methods:** Complete randomized design was used with six replicates in clay soil. The size of experimental area was 8.7 da (55.4 x 158 m) (Figure 2). Plots were 8.4x50 m in all applications. The tillage implements used in each tillage method were as follows:

- 1) Conventional tillage (CT): chisel + disc harrow + fertilizer spreader + disc harrow + float + planter (Sönmezler),
- 2) Direct planting 1 (DP<sub>1</sub>): direct planter (JD 1700),
- 3) Direct planting 2 (DP<sub>2</sub>): modified direct planter (Sönmezler).

The first crop wheat was combine harvested, and the field was covered with residue of previous crop in direct planting methods. Row spacing, seed spacing, and seeding depth were adjusted to be 70 cm, 18 cm, and 6 cm respectively on the three planters. Although CT and DP<sub>2</sub> were equipped with granular fertilizer, the fertilizing was done by a broadcast fertilizer in all methods to eliminate the effect of fertilizer application method on maize growth and yield since DP<sub>1</sub> is not equipped with granular fertilizer.

The measured parameters for comparing the three methods include the soil properties (moisture content, bulk density, penetration resistance), crop yield and planter performance in terms of furrow characteristics (seeding depth, plant spacing, emergence rate, multiple index, miss index, quality of feed index, and precision in spacing index).

The effect of applied methods on seeding depth, seed distribution, emergence rate, and yield along with the effect of interactions were determined through multiple mean comparison tests. Emergence rate was transformed before the data were analyzed through the comparison tests. The effect of CT, DP<sub>1</sub>, and DP<sub>2</sub> on moisture content, bulk density, and penetration resistance was determined only in terms of descriptive statistics.

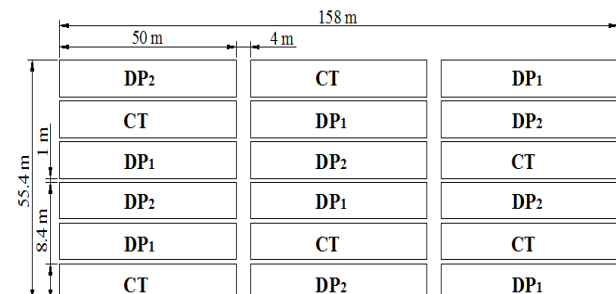


Figure 2. Experimental design (CT: Conventional tillage; DP<sub>1</sub>: Direct planting, JD 1700; DP<sub>2</sub>: Direct planting with a modified planter, Sönmezler)

**Soil properties:** Undisturbed soil samples from 0-10 cm, 10-20 cm, and 20-30 cm depths were collected at about the centre of each plot using core samplers of 100 cm<sup>3</sup>. The soil samples were used to determine the gravimetric moisture content and bulk density of soil samples, using oven drying for 24 h at 105 °C.

The first set of data was collected to determine the initial conditions of soils. The second set of data were collected after the plants have emerged to evaluate the soil moisture availability based on the method used and penetration resistance of soils during the rapid growth stage of the plants. The second set of measurements related to soil conditions were collected just before the second irrigation.

Soil sample collection for soil moisture content (MC) and penetration resistance (PR) measurements were done at about the centre of each cell. Undisturbed soil samples from 0-10 cm, 10-20 cm, and 20-30 cm depths were used to determine both bulk density and moisture content in each plot (Smith, 1981). PR measurements were done using a digital soil penetrometer from 0 to 30 cm with 1 cm intervals and were replicated three times around the soil sampling location. PR data were averaged over 10 cm intervals to obtain a mean PR value for each layer corresponding to soil sampling depths.

**Planter Performance:** The performance of the planting methods was determined by 1) seeding indices, and 2) emergence rate and yield. The performance parameters of the tested methods include seeding depth, seed/plant spacings, multiples index, miss index, quality of feed index and precision in spacing index.

The horizontal and vertical seed distributions were assessed in field tests. The seeding depths and plant spacings were measured over 10 m distances with three replicates in the middle three rows of each block. Plant spacings were measured after the emergence has been completed. The number of plants was counted ten days after the emergence of the plants. The ratio of theoretical number of plants seeded over number of emerged plants was calculated to be the percent emergence rate (Bilbro and Wanjura 1982).

The sowing depths were measured in the vertical plane by measuring the mesocotyl length of 21 maize plants for each treatment (Özmerzi and Keskin 1983). Mean sowing depth, standard deviation and coefficient of variation were calculated.

Seed spacing of 30 seeds with misses and multiples was measured in each plot (30x6=180 seeds

for each application). The data were statistically analysed to determine the effect of planting method on performance indices. The following performance indices were calculated as given by Kachman and Smith (1995) and Singh et al. (2005):

The multiple index ( $I_{mult}$ ) is the percentage of spacing less than or equal to half of the theoretical spacing (S).

$$I_{mult} = \frac{n_1}{N} \quad (1)$$

where:  $n_1$  is number of spacing  $\leq 0.5 S$ .

The miss index ( $I_{miss}$ ) is the percentage of spacing greater than 1.5 times the set planting distance (S).

$$I_{miss} = \frac{n_2}{N} \quad (2)$$

where:  $n_2$  is number of spacing  $> 1.5 S$ ; and N is total number of measured spacings.

The quality of feed index ( $I_q$ ) is the percentage of spacings that are more than half but not more than 1.5 times the set planting distance S in mm. The quality of feed index is an alternate way of presenting the performance of misses and multiples.

$$I_{fq} = 100 - (I_{miss} + I_{mult}) \quad (3)$$

Precision in spacing ( $I_p$ ) is a measure of the variability (coefficient of variation) in spacing (S), between seeds or plants after accounting variability due to both multiples and misses.

$$I_p = \frac{S_d}{S} \quad (4)$$

where:  $S_d$  is standard deviation of the spacing more than half but not more than 1.5 times the set spacing S.

Maize yield was determined by hand harvesting over 5 m lengths with five replicates in each block and then weighing maize kernels, corresponding to 3.5 m<sup>2</sup> area with row spacing of 0.7 m. The average yield for each block and each method was expressed in kg ha<sup>-1</sup> (Yalçın 1998, Aydın et al. 2007).

## Results and Discussion

**Soil properties:** Descriptive statistics for soil moisture content, bulk density, and penetration resistance at three layers are given in Table 1, which were measured before seed placement to determine the initial soil conditions while statistics in Table 2 correspond to soil conditions two weeks after emergence, which relates to soil state before the second irrigation. Means correspond to the average of six replicates.

Table 1. Soil properties before planting

Applications		Soil moisture content (%)			Bulk density (g cm <sup>-3</sup> )			Penetration resistance (MPa)		
		0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm
CT	Mean	14.99	26.14	24.81	1.27	1.39	1.46	1.44	1.54	1.61
	Std. dev.	2.01	1.37	2.23	0.02	0.02	0.04	0.40	0.43	0.45
	CV %	13.40	5.23	9.00	1.62	1.49	3.05	27.52	27.72	28.01
DP <sub>1</sub>	Mean	15.75	24.76	22.60	1.23	1.37	1.48	1.12	1.44	1.44
	Std. dev.	6.78	5.07	0.83	0.12	0.11	0.02	0.29	0.20	0.13
	CV %	43.02	20.47	3.67	9.34	8.37	1.58	26.00	13.66	9.25
DP <sub>2</sub>	Mean	19.29	23.01	23.36	1.35	1.45	1.52	1.43	1.48	1.55
	Std. dev.	0.98	2.61	2.44	0.13	0.08	0.06	0.12	0.16	0.20
	CV %	5.06	11.36	10.43	10.00	5.60	3.63	8.06	11.04	12.97

CT: conventional tillage, DP<sub>1</sub>: direct planter; DP<sub>2</sub>: modified direct planter

Table 2. Soil properties after planting

Applications		Soil moisture content (%)			Bulk density (g cm <sup>-3</sup> )			Penetration resistance (MPa)		
		0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm
CT	Mean	26.15	23.36	24.73	1.21	1.43	1.40	0.95	1.78	1.84
	Std. dev.	18.49	2.13	3.24	0.08	0.09	0.08	0.36	0.50	0.37
	CV %	70.69	9.10	13.11	6.47	6.07	5.38	38.16	27.98	19.96
DP <sub>1</sub>	Mean	17.29	19.26	22.17	1.29	1.36	1.49	1.14	1.76	1.75
	Std. dev.	4.13	2.48	3.43	0.13	0.02	0.09	0.23	0.34	0.33
	CV %	23.90	12.89	15.45	10.18	1.30	6.32	20.28	19.46	18.99
DP <sub>2</sub>	Mean	17.59	22.46	22.36	1.23	1.47	1.48	1.22	1.93	1.81
	Std. dev.	4.91	3.14	0.79	0.13	0.15	0.10	0.12	0.20	0.24
	CV %	27.92	13.96	3.54	10.99	10.11	6.88	10.24	10.42	13.24

CT: conventional tillage, DP<sub>1</sub>: direct planter; DP<sub>2</sub>: modified direct planter

As expected, soil moisture content increased as the sampling depth increased both before planting and after emergence (Table 1-2), with some exceptions as depth increased from 20 to 30 cm. Mulla and Bratney (2000), Wilding et al. (1994) and Upchurch et al. (1988), as cited by Akbaş (2004), categorized the coefficient of variation as low (< 15%), medium (16 to 35%) and high (> 36%) for soil characteristics. Thus, the upper layer (0-10 cm) showed high level of moisture variations about the mean while the other layers mostly had medium or low moisture variations. Initial moisture contents were not similar in all blocks, ranging from 14.99% to 19.29%, which is the layer the seeds were placed (Table 1). The irrigation following the planting brought the topsoil to field capacity, reducing the soil penetration resistance, and creating a more favorable seedbed for germination and root growth.

Bulk density showed a different behavior compared to soil moisture content variations in that there was no apparent trend as a general increase with sampling depth. Rather the bulk density either slightly increased or decreased from the second layer to the third layer. The inconsistency in soil bulk density variations as depth increases might imply topsoil compaction at this layer along with natural variations in soil properties.

Penetration resistance increased from first layer to the second layer in all three methods. When PR values are above 2.0 MPa, root growth of many crops can be restricted and further increase in PR can impede the plant growth (Junior et al. 2006). Measured PR values show slightly sharper rises before planting compared to PR variations before the second irrigation (Figure 3).

Conventional tillage blocks had lower PR data in Figure 3b due probably to loosened topsoil resulting from the conventional tillage applications. It can be observed that the highest PR measurements at deeper layers occurred in the case of DP<sub>2</sub>. Modified direct planter had four rows whereas commercial direct planter had six rows, which caused less passes in DP<sub>1</sub> applications compared to DP<sub>2</sub>. The increased soil compaction in the second and third layer in modified planter applications may be attributed to the field traffic.

PR less than 2 MPa is generally accepted to be the threshold that limits root growth and yield. PR measurements show that the penetration resistance did not exceed the limiting value during the seed germination and early root growth stages. Based on this generally accepted criterion, it may be assumed that soil resistance did not affect the yield in this study. The furrow characteristics, emergence rate and yield hence will be related to the performance of the planting method applied.

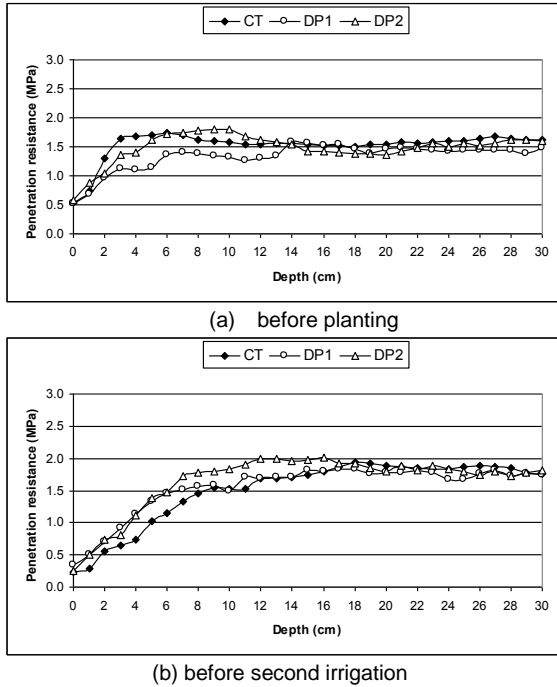


Figure 3. Penetration resistances as a function of soil depth

**Performance indices:** The theoretical spacing was used to divide the observed spacings into three regions which are  $(0, 0.5x_{ref})$ ,  $(0.5x_{ref}, 1.5x_{ref})$ ,  $(1.5x_{ref}, \infty)$ , corresponding to  $(0 \text{ cm}, 9 \text{ cm})$ ,  $(9 \text{ cm}, 27 \text{ cm})$ ,  $(27 \text{ cm}, \infty)$  for  $x_{ref}=18 \text{ cm}$ . The regions for CT, DP<sub>1</sub> and DP<sub>2</sub> applications are illustrated in Figure 4.

The seed spacing observed in CT varied from 9 to 40 cm with a mean of 18.4 cm, while the variation was from 5 to 40 cm with a mean of 19 cm in DP<sub>1</sub> and from 7 to 36.5 cm with a mean of 18 cm in DP<sub>2</sub>.

Average values of multiple index, miss index, quality of seed index and precision in spacing for the three applications are presented in Table 3.

Table 3. Performance indices of different planting methods in field tests

Method	$I_{mult}$	$I_{miss}$	$I_{fq}$	$I_p$
CT	0.56	6.67	92.78	20.22
DP <sub>1</sub>	3.89	6.11	90.00	19.61
DP <sub>2</sub>	2.22	6.67	91.11	23.40

$I_{mult}$  : multiple index,  $I_{miss}$  : miss index,  $I_{fq}$  : quality of feed index,  $I_p$  : precision in spacing

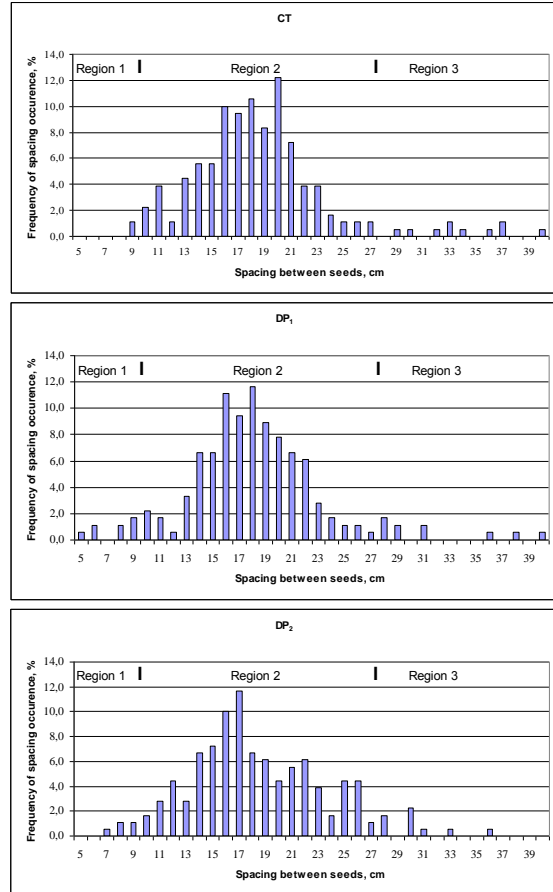


Figure 4. Frequency distribution of seed spacing in different planting applications

Multiple index was at a minimum in CT, followed by the DP<sub>2</sub> and DP<sub>1</sub>. With a theoretical spacing of 18 cm, the multiple index is the percentage of spacings that is less than or equal to 9.0 cm. Only one of the observations was less than 9.0 cm, yielding a multiple index of 0.56 % for CT whereas 6.67 % was spacing intervals between 27 and 40 cm. Other methods created less favorable conditions in terms of multiple index and miss index. Miss index (about 6%) and quality of feed index (about 90%) were approximately similar in all applications.

Quality of feed index, showing how often the measured distance between the seeds are close to the theoretical spacing of 18 cm, suggested that more than 90% of the measured spacings are close to the desired spacing (Table 3). Thus, modified direct planter achieved sufficiently accurate horizontal seed placement compared to other two methods tested. The results imply that the best horizontal seed uniformity was accomplished in CT (92.78%).

Precision in spacing is a measure of variability in seed spacings and the practical upper limit for the precision in spacing is 29%, according to Raoufat and Mahmoodieh (2005). Precision in spacing values ranged from 19.61% to 23.40% in this study, suggesting that the seed placement precision was sufficient and favorable as compared to the theoretical spacing in all cases.

Measured plant spacings showed that the averages were close to the adjusted spacing of 18 cm, which is also supported by high rates in quality of feed index at about 90%. All applications were in the same group statistically (Table 4). Coefficient of variations ascertains that plant spacing had medium level of variations. All methods could be deemed successful in terms of horizontal seed distribution based on average values and therefore the performance of the modified direct planter was comparable to CT and DP<sub>1</sub>.

The residue cover was much higher in direct planting methods due to the fact that the wheat straw had been spread across the field by the combine and no stubble or straw had been removed from the field before maize planting. This could also partly explain the difficulty of penetration of coulters into the soil, resulting in misplaced seeds in terms of horizontal and vertical seed distribution.

Seeds should be placed at the desired depth below the seedbed surface. Permissible deviations from the given depth of planting are ± 5 mm, ± 7 mm and ± 10 mm for seeding depth of 30-40 mm, 40-50 mm and 60-80 mm, respectively (Bosoi et al. 1987; Darmora and Pandey 1995). The planters were adjusted to place seeds at a 6 cm depth, which was achieved on an average only in CT with 5.99 cm. The direct planter (DP<sub>1</sub>) is much heavier compared to DP<sub>2</sub>. Additionally, hydraulic power is used to increase the down pressure to achieve the desired planting depth. More accurate vertical seed placement in DP<sub>1</sub> compared to DP<sub>2</sub> might be explained by these differences between the two direct planters.

The methods had significant effect on the depth of seed placement (P < 0.01). The best placement was accomplished in CT, followed by DP<sub>1</sub> and DP<sub>2</sub> (Table 5). While the average seeding depth in CT and DP<sub>1</sub> is within the permissible deviation range, the deviation was greater in DP<sub>2</sub> application. The seeding depth varied considerably in each application as suggested by coefficient of variations larger than 15% in all cases. Skewness was slightly higher or less than 0.5 implying normality in the data set.

Table 4. Descriptive statistics for horizontal seed distribution in field tests (cm)

Method	Mean	Std. dev.	CV (%)	Skewness	N
CT	18.43	5.06	27	0.61	126
DP <sub>1</sub>	19.00	3.04	16	0.61	126
DP <sub>2</sub>	18.04	5.34	30	0.35	126

Table 5. Descriptive statistics for seeding depth (cm) distribution in CT and DP

Method	Mean	Std. dev.	CV (%)	Skewness	N
CT	5.99 <sup>a</sup>	1.63	27	0.39	126
DP <sub>1</sub>	5.30 <sup>b</sup>	1.03	19	0.53	126
DP <sub>2</sub>	2.90 <sup>c</sup>	1.02	35	0.27	126

It was concluded that the average seed spacings were statistically the same and hence horizontal seed distribution in the three methods was similar whereas the differences in average seeding depths were significant (P<0.01) with the most accurate vertical placement in CT.

The seeds utilize soil moisture better as the sowing depth increases whereas too deep placement prevents seeds from sufficient oxygen intake and diminishes seed emergence rate (Karayel and Özmerzi 2005). Therefore, it may be concluded that shallow seed placement might affect yield but may not be influential on seed emergence rate.

**Emergence rate and yield:**The emergence rate was the lowest in DP<sub>1</sub> with 80.3% whereas the highest emergence rate was obtained in DP<sub>2</sub> with 88.0% (Table 6). According to descriptive statistics, all applications resulted in the same emergence rate with small coefficient of variations. Tillage alone did not have an effect on emergence rate, implying similar performances in conventional tillage method and direct planting methods.

Average seeding depth was the smallest (2.9 cm) whereas the emergence rate was the highest (88%) in DP<sub>2</sub> (Table 5-6). Too deep seeding might cause seeds to use up their energies until emergence take place, resulting in poor emergence rates. Shallow seeding depth, however, did not seem to prohibit seeds from benefiting the water available in the soil.

The moisture content of hand harvested crop was measured using a portable grain moisture tester and the measured yield was converted to yield values at 15% moisture content (Table 7).

Table 6. Descriptive statistics for emergence rates (%) for in CT and DP

Method	Mean	Std. dev.	CV (%)	Skewness	N
CT	83.80	8.10	10	-1.13	18
DP <sub>1</sub>	80.30	12.15	15	-0.42	18
DP <sub>2</sub>	88.00	8.80	10	-1.16	18

Table 7. Descriptive statistics for crop yield (kg ha<sup>-1</sup>) for tillage methods

Method	Mean	Std. Dev.	CV (%)	Skewness	N
CT	9016.06	2040.27	23	-0.27	18
DP <sub>1</sub>	8588.74	1727.46	20	-0.43	18
DP <sub>2</sub>	8672.08	938.34	11	-1.00	18

The tillage method did not have a significant effect on yield. The highest yield was found in method CT. The yield varied from 8588 and 9016 kg ha<sup>-1</sup>, which seems to be a considerable difference. Nonetheless, the coefficient of variation was at the medium level, causing yield to fluctuate about the average yield resulting in average yields to be in the same group. In another study, Korucu et al. (2008) found that emergence rate and maize yield was affected by the planting method in a sandy clay loam soil. In the mentioned study, emergence rate was the lowest in the case of modified direct planter, but the yield was the same as conventional tillage whereas the direct planter (DP<sub>1</sub>) resulted in the highest yield.

The vertical seed distribution seemed to be poor in DP<sub>2</sub> considering the permissible deviations for seeding depths. The emergence rate, however, did not differ among the applied methods. The average yield in each method was consistent with emergence rate in that there was no significant difference in measured yields. Therefore, the poor seed placement in DP<sub>2</sub> in the vertical plane did not seem to impede emergence rate and yield in these field tests.

Based on the results of field experiments, direct planting methods were more advantageous since the same yield as conventional tillage was obtained with less number of operations. Improved timelines and reduced labor, which can be related to cost of overall operations, eventually makes direct planters more favorable and the performance of the modified direct planter was comparable to CT and DP<sub>1</sub> in all performance measures except for vertical seeding accuracy.

### Conclusions

Conventional tillage (CT), a commercial direct planter (DP<sub>1</sub>), and a modified direct planter (DP<sub>2</sub>) were used in this study to determine the performance of DP<sub>2</sub> compared to CT and DP<sub>1</sub> in terms of emergence rate, yield, horizontal and vertical seed distribution in second crop maize after winter wheat. The penetration resistances were also measured to see whether emergence rate or yield could have been affected by penetration resistance. The followings were concluded as a result of this study:

- Soil penetration resistance was below 2.0 MPa in all experimental plots, suggesting no effect on emergence rate and yield.
- Mean plant spacing was about 18 cm and the quality of feed index was about 90% in all methods, implying no advantages over any method in terms of horizontal seed distribution uniformity.
- Multiple index was the smallest 0.56(%) in CT, suggesting best horizontal distribution in seed spacing whereas DP<sub>1</sub> had the highest rate (3.89%).
- Variation about the mean seed spacing was less than the upper limit of 29% in precision in spacing in all cases.
- Seed depth distribution was different in the three methods (P<0.01). The adjusted seeding depth was 6.0 cm which was accomplished by CT (5.99 cm) with the highest accuracy and the least accuracy was found in in DP<sub>2</sub> (2.90 cm).
- Tillage method did not have an effect on emergence, implying similar performances in conventional tillage method and direct planting methods with 80-83% emergence rate.
- Yield was not affected by planting method. The yield was the smallest in DP<sub>1</sub> (8590 kg ha<sup>-1</sup>) and the highest in CT (9016 kg ha<sup>-1</sup>). Medium level of coefficients of variation caused yields to fluctuate about the average yield thereby causing yields to be in the same group.
- Although modified direct planter could not achieve the desired planting depth, the emergence rate and maize yield was not affected significantly. The performance parameters of the modified direct planter are encouraging. The planter should probably be improved further so that higher down forces can be applied to maintain the set value of seeding depth.

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