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# The Effect of Soil Tillage Systems on Wheat Growth and Yield in the Dry-Land Region of Turkey

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**Abstract:** A wheat stubble field (clay-loam, light alkali; light salty and poor of organic matter) was established to carry out an experiment at Gökhöyük Agricultural Institute, Turkey. Effects of three different tillage systems: conventional tillage, reduced tillage and no-tillage on penetration resistance, emergence time, shooting degree and yield were investigated. Conventional tillage used a moldboard plough for primary tilling and a combined spring tine cultivator-spike tooth harrow for consecutive secondary tilling. Reduced tillage included only a cultivator-tooth harrow combination. No-tillage was accomplished by a direct (stubble) drill. Although the earliest emergence time (17 day) and the highest emergence degree (66.5%) were obtained, yield was the lowest in no-tillage system. The highest penetration resistance (53.71 kg cm$^{-2}$) was measured in no-tillage system. Reduced and no tillage systems could be proposed for Gökhöyük region if alternative solutions is found to prevent soil compaction and reduce mechanical impedance in root growth zone. Long-term investigations were suggested based on the results of this study in order to better understanding of the effects of the tillage systems on crop growth and yield for the region.

**Key words:** Soil tillage, conservation tillage, penetration resistance, crop growth, yield

## INTRODUCTION

Turkey known as an agricultural country has a variable climate and soil properties that allow growing a broad range of agricultural products. Recently, concerns about maintaining soil productivity and quality have forced researchers to search for alternative solutions to replace conventional moldboard plough based soil tillage systems. Soil management decisions are often aimed at improving and maintaining soil productivity. However, conventional tillage increases soil compaction and erosion. Tillage is well known to accelerate the loss of soil organic matter by increasing biological oxidation and often by increasing soil erosion. Because of the decline in soil quality associated with the loss of organic matter, most tillage-based farming systems in dry land environments are not sustainable in the long-term. Conservation tillage systems, particularly no-till that are widely used in developed countries are becoming a viable alternative to conventional tillage in the dry regions of Turkey that exhibit a semi-arid climate pattern (Annual average rainfall ranging from 250-500 mm). Conservation tillage could increase water storage and significantly reduced runoff by leaving more than 30% of the surface covered in climates with intense and relatively rare rainfall events. Water use by plants depends on the amount of water stored in the soil (Scopel *et al*., 2001). Options for maintaining or improving soil quality in dry lands are to simultaneously increase cropping intensity and reduce or eliminate tillage. Soils in the low precipitation region (less than 12 inch annual) of the Columbia Plateau are particularly susceptible to wind erosion under intensive tillage, weak aggregation, limited vegetative cover and high wind speed. Wind erosion can be severe on cropland under winter wheat-summer fallow where only one crop is produced in two years. Wind erosion is also a concern on irrigated cropland in the fall after harvest of crops such as potatoes and in the spring before new crops can provide ground cover. The key for controlling wind erosion and dust pollution in downwind areas is to maintain year round vegetable cover and surface roughness. The use of spring cropping in combination with no-till sowing would appear to offer a better approach for increasing cropping intensity, improving soil quality and controlling erosion in the conventional fall farming (Papendick, 1998).

According to Benjamin *et al.* (2003) findings, the least limiting water range is a good indicator of plant productivity when the full potential of available water can be realized, such as with wheat grown in a no-till system when the wheat followed a fallow period. The least

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limiting water range was a poorer indicator of plant productivity when conditions such as low total water availability limited the expression of the soil status on crop production. The least limiting water range combines limitations to root growth caused by water holding capacity, soil strength and soil aeration into a single number that can be used the determine soil physical improvement or degradation. No-till practices increase soil organic matter contents to the extent that reductions are generally observed in run off and soil loss. This was demonstrated by Rhaton and Shigltalo (2000) who reported that runoff was 275.6 and 164.3 mg ha$^{-1}$ for conventional and reduced tillage systems, respectively. Chassot *et al*. (2001) reported that maize crop growth and shoot development were slower in no tillage than conventional tillage. Root length and weight were reduced in no tillage compared to conventional tillage. Mean root diameter was smaller at 0.15 m depth in conventional tillage than in no tillage. Vertical and horizontal distributions of roots did not differ between the tillage systems (Chasso *et al*., 2001). Kanwar (1989) investigated the effects of four different tillage systems on the variability of soil- water tension, soil water content and yield. The first tillage was a conventional tillage using a moldboard plough in the fall and a disc harrow or cultivator in the spring. The second tillage used a chisel in the fall and a disc harrow or cultivator in the spring, the third used a paraplow in the fall and the last used a no till method. He reported that more water accumulated above the 90 cm depth in the no tillage system compared to the other three systems. Soil-water tension did not affect yield and the highest yield was obtained using conventional tillage. Erbach *et al*. (1992) conducted an experiment to determine the effect of four different tillage systems (chisel, moldboard, paraplow and no tillage) on maize growth. The most rapid emergence was obtained using a moldboard plough while better emergence was observed using the paraplow method than in no till. No-till spring barley sowed (2160-4670 lb acre$^{-1}$) into undisturbed soil produced grain yields equal to or exceeding those under conventional tillage and provide environmental and potential soil quality benefits for low-precipitation dry land farming in the inland Pacific Northwest (Schillinger *et al*., 1999).

There is no single soil tillage system appropriate for all soil conditions. Use of a direct stubble drill, reduced tillage system and seedbed combination implements that are widely used in developed countries have been practiced for a decade in the dry-land regions in Turkey. Interests in conservation tillage have been recently, increasing; however there have been few studies reported investigating the suitability of alternative tillage systems for the dry-land soil conditions of Turkey. The objective of this study was to investigate the effects of conventional, reduced and no-tillage systems on penetration resistance, emergence time, emergence degree and yield.

## MATERIALS AND METHODS

**Description of study area:** The experiment was conducted at Gökhöyük Agricultural Institute, Turkey in 2003. The study area (Field of Gökhöyük Agricultural Institute) is located 22 km West of Amasya Province center in the Central Black Sea Region of Turkey. Long-term average precipitation is 390 mm and air temperature is 13.9°C (State Water Work, 1974). A total of 297.2 mm annual precipitation was observed during the year that the experiment was conducted. The water and temperature regime of the study area are semi arid. Higher precipitation usually occurs during spring while the least rain falls in the summer. At 3 acre wheat stubble field was selected from 6200 acres of the institute's land. The field has been cropped with conventional tillage using a moldboard plough (about 20 cm depth) and a disc harrow (about 10 cm depths) for more than 10 years.

**Experimental design:** Experimental design included three soil tillage systems with four replications. Therefore, 12 different plots were used. The tests were conducted using a randomized complete block design. In the investigation, three tillage systems: namely, conventional tillage, reduced tillage and no-tillage were applied as the soil tillage method. Conventional Tillage (CT) used a moldboard plough (19 cm working depth and 4.4 kmh$^{-1}$ operation speed) followed by a spring tine cultivator and spike tooth harrow combination (11 cm working depth and 8 km h$^{-1}$ operation speed). Reduced Tillage (RT) included only a spring tine cultivator and spike tooth harrow combination (11 cm working depth and 8 km h$^{-1}$ operation speed). No-Tillage (NT) was accomplished by direct stubble drilling (5.6 cm sowing depth and 3.5 km h$^{-1}$ sowing speed). A precision drill was used to sow the plots (5.3 cm sowing depth and 10 km h$^{-1}$ sowing speed) where the CT system was applied whereas the RT and NT systems were planted by a direct (stubble) drill.

Penetration resistances for each treatment were measured after each successive field cultivation of a particular tillage treatment, accordingly; for example, post moldboard plough, post spring tine cultivator + spike tooth harrow combination and post drilling for CT system. Emergence shoots were counted in 1 m$^2$ area in every plot by randomly choosing three bands consisting of doublesuccessive lines (row) during emergence period.

Average emergence time (1), emergence ratio index (2) and emergence degree (3) were calculated using following equations (Zeren *et al.*, 1986).

$$ET = \frac{\sum NiDi}{\sum Ni} \quad (1)$$

$$ERI = \frac{n}{ET} \quad (2)$$

$$ED = n/TS.100 \quad (3)$$

Where;

ET: Average emergence time (day)

$N_i$: Number of seed emergence at ith count,

$D_i$: ith day after sowing (day)

ERI: Emergence ratio index (number m day)

n: Number of seed emergence at 1 m in a row.

ED: Emergence degree (%)

TS: Number of total seed sown at 1 m.

For yield comparisons between treatments, five randomly selected locations (each location is a 1 $m^2$ area) for each plot were harvested, manually. An electronic balance was used to measure harvested grain. Yield values for each plot were calculated in kg $ha^{-1}$. Yield of a particular treatment was average of four plots (replications).

Statistical analyses (ANOVA and LSD) by using SPSS 10.0 packet program were performed to determine the significance of the effect of the different soil tillage systems on penetration resistance, emergence time, emergence degree and yield.

**Equipment:** The power source was a tractor with 105 KW. The tractor has three point free link attachment for hitching equipment. The plough was 6 bodies and 240 cm working width. The wide-blade cultivator and spike toothed harrow combination (280 cm of working width) had 9 tines. The precision drill (32 rows spacing at 12.5 cm) had a seed hopper with a capacity of 500 L and a fertilizer hopper with a capacity of 750 L. Drill coulter had trailing shoe coulter. The stubble drill (working width of 225 cm and a row spacing of 25 cm) used in the tests had hoe coulter. The feed mechanism was a force-feed roller type with 9 feed mechanisms. The seed hopper capacity was 226 kg and fertilizer hopper capacity was 60 kg. Seri-82 variety wheat seed having 38-42 g thousand grain weight, 95% germination (tested seed) and 98% purity degree was used with 20 kg $da^{-1}$ of sowing norm. Di-ammonium phosphate ($(NH_4)_2HPO_4$) fertilizer with 15 kg $da^{-1}$ of fertilization norm was applied during drilling. In addition, Ammonium nitrate ($NH_4NO_3$) fertilizer with 15 kg $da^{-1}$ of fertilization norm was applied two times in 20 days interval at post emergence.

**Preliminary field tests:** A wheat stubble field was established to carry out an experiment at Gökhöyük Agricultural Institute, Turkey. Preliminary tests were conducted to determine soil moisture content, penetration resistance, stubble height and stubble density for each plot. For soil moisture determination, ten soil samples for each plot were taken at 10 cm depth. Moisture content of each sample was determined, separately by using gravimetric method based on dry-weight. Moisture contents of 10 samples were averaged to represent each individual plot. In addition, soil physical properties of each plot were measured in the laboratory. Eight samples were taken from randomly selected locations for each plot and these samples were mixed together to represent the entire plot. Stubble height and density were measured, before the trials, manually at 5 locations that comprised 1 $m^2$ area for each plot in order to characterize field residue conditions that affect drill uniformity. Penetration resistances for each plot were determined by using a proctor type of penetrometer. Penetration resistance measurements were made pushing vertically the penetrometer to the soil at an approximated speed of 13 mm $sec^{-1}$. Ten values were taken randomly from each plot in 10 cm depth. Soil penetration resistances were obtained as lbf $in^{-2}$ (force values of penetrometer reading divided by a flat surface), than results were converted into kg $cm^{-2}$. Average values of 10 reading were calculated in kg $cm^{-2}$ to represent each plot assigned to a particular treatment.

Statistical analyses were done (using individual data) in order to discover field uniformity. ANOVA and LSD tests were performed using SPSS 10.0 packet program to determine whether there were significant differences in penetration resistance, moisture content, stubble density and height between the plots.

## RESULTS AND DISCUSSION

Preliminary tests were conducted to determine soil moisture content, penetration resistance, stubble height and density of the experimental plots. Soil properties of each plot were also determined in the laboratory. Analysis results showed that all plots were silty clay-loam, light alkali; light salty and with low of organic matter (Table 1).

Table 1: Soil texture, pH, salt and organic matter for each treatment

| Treatments | Soil type | pH | Salt (%) | Organic matter (%) |
|---|---|---|---|---|
| CT | Silty clay loam | 7.78 | 0.12 | 1.49 |
| RT | Silty clay loam | 7.83 | 0.12 | 1.45 |
| NT | Silty clay loam | 7.63 | 0.12 | 1.28 |

Table 2: Mean penetration resistance, moisture content, stubble height and density for Conventional Tillage (CT), Reduced Tillage (RT) and No-tillage (NT) systems

| | Mean | | | |
|---|---|---|---|---|
| Treatments | Penetration resistance (kg cm$^{-2}$) | Moisture content (%) | Stubble height (cm) | Stubble density (number m$^{-2}$) |
| CT | 40.49 | 15.67 | 23.5 | 592.50 |
| RT | 43.30 | 16.27 | 24.5 | 595.25 |
| NT | 43.94 | 15.61 | 23.0 | 601.75 |

Table 3: Mean penetration resistances (kg cm$^{-2}$) measured between successive soil tillage for Conventional Tillage (CT), Reduced Tillage (RT) and No-tillage (NT) systems

| Treatments | First reading | Post moldboard | Post spring tine cultivator+spike tooth harrow | Post drilling | Difference |
|---|---|---|---|---|---|
| CT | 40.49 | 40.14 | 41.13 | 44.92 | 4.43 |
| RT | 43.30 | - | 42.60 | 48.93 | 5.63 |
| NT | 43.94 | - | - | 53.71 | 9.77 |

Penetration resistance, moisture content, stubble density and stubble height were measured and mean values of these field parameters for each treatment are given in Table 2. The highest penetration resistance (43.94 kg cm$^{-2}$) was obtained for NT system after planting. Mean moisture contents were 15.67, 16.27 and 15.61% for CT, RT and NT, respectively. Mean stubble density were also measured as 592.5, 595.25, 601.75 number m$^2$ for CT, RT and NT, respectively.

Statistical analysis showed that there were no significant differences ($p>0.01$) in moisture content, stubble density and height between the treatments before planting. However, there was a significant difference ($p>0.01$) in penetration resistance between the treatments before planting. Based on LSD tests, RT and NT systems fall in the same group, while the CT system is in a different group. These preliminary trials showed similar soil moisture content, stubble density and height. These results provided basis for the investigations.

**The effects of tillage systems on penetration resistance:** Penetration resistances for each treatment were measured after successive field cultivation of a particular tillage treatment. Mean penetration resistances between successive soil tillage for each treatment were given in Table 3. Mean penetration resistance slightly decreased (from 40.49 to 40.14 kg cm$^{-2}$) after moldboard plough operation, increased, considerably (from 40.14 to 41.13 kg cm$^{-2}$) after spring tine cultivator+spike tooth harrow operation and increased from to 44.92 kg cm$^{-2}$ after drilling for CT system. For the RT system, mean penetration resistance was decreased to 42.6 kg cm$^{-2}$ after the spring tine cultivator + spike tooth harrow operation (first reading was 43.3 kg cm$^{-2}$) and increased to 48.93 kg cm$^{-2}$ after drilling. Similarly, mean penetration resistance increased from 43.94 (first reading) to 53.71 kg cm$^{-2}$ for NT system. For all the treatments, there was an increase in penetration resistance between before tillage operation and after drill. The differences in mean penetration resistance between pre-tillage and post drill were 4.43, 5.63 and 9.77 kg cm$^{-2}$ for CT, RT and NT systems, respectively. The highest difference in penetration resistance was measured for NT system.

The differences in penetration resistance were significant ($p>0.01$) between the treatments. Therefore, LSD tests were applied on resistance differences for all treatments. The difference of penetration resistance before soil tillage and after drilling for CT and RT treatments fell into the same group while NT is in different group.

Barut *et al.* (1996) investigated the effect of different tillage equipment (Moldboard plough, disc harrow, tandem disc harrow and scrubber) on penetration resistances in cotton farming. They reported that penetration resistances varied from 1.36 to 3.89 MPa before soil tillage while penetration resistances varied from 0.27 to 4.36 MPa after soil tillage. According to Barut's findings, penetration resistance difference between before and post conventional soil tillage was 4.7 kg cm$^{-2}$. In this study, penetration resistance difference for conventional treatment was the lowest among all treatments (4.43 kg cm$^{-2}$). For CT treatment, there was a lower difference in penetration resistance because of swelling of soil by turning over the furrow slice to bury surface vegetation and to leave the soil in a suitable condition for weathering. In addition, the light weight of the precision drill contributed to the lower penetration resistance. In contrast, the NT system had the highest penetration resistance difference. For the NT system, the furrow was lightly opened, seed dropped into the furrow and then the furrow was covered with soil by the press wheel. The highest penetration resistance difference for NT system was due to the heavy weight of the direct stubble drill and high pressure exerted by the press wheel onto the soil surface (furrow) and not having a soil till are operation before drilling .

**The Effects of the tillage system on crop growth and yield:** Emergence shoots were counted in 1 m$^2$ area in every plot by randomly choosing three bands consisting

Table 4: Mean Emergence Time (ET), Emergence Ratio Index (ERI), shooting degree (ED) and yield for Conventional Tillage (CT), Reduced Tillage (RT) and No-tillage (NT) systems

| Treatments | ET (Day) | ERI (number/m day) | ED (%) | Yield (kg ha)$^{-1}$ |
|---|---|---|---|---|
| CT | 20.25 | 2.38 | 52.25 | 2520 |
| RT | 22.50 | 2.61 | 63.50 | 2140 |
| NT | 17.00 | 3.62 | 66.50 | 1815 |

Table 5: Group categories of Emergence Time (ET), Emergence Ratio Index (ERI), Shooting Degree (ED) and Yield based on LSD tests for Conventional Tillage (CT), Reduced Tillage (RT) and No-Tillage (NT) systems

| Treatments | ET (day) | ERI (number/m day) | ED (%) | Yield (kg da)$^{-1}$ |
|---|---|---|---|---|
| CT | B | B | B | A |
| RT | A | A | A | B |
| NT | C | C | A | C |

of double successive lines (rows) during the emergence period, Average Emergence Time (ET), Emergence Rate Index (ERI) and Emergence Degree (ED) were calculated. Five randomly selected locations of 1 m$^2$ area for each plot were harvested manually and yield values for each plot were calculated in kg ha$^{-1}$.

Mean values of ET, ERI, ED and yield were given in Table 4 for each treatment. Although the earliest seed emergence and the highest ED were observed in NT system, yield was the lowest (1815 kg ha$^{-1}$). Mean ET were 20.25, 22.5 and 17 days for CT, RT and NT treatments, respectively. Mean ERI values were 2.38, 2.61 and 3.62 number/m day and mean ED were 52.25, 63.5 and 66.5% for CT, RT and NT, respectively. The highest yield was obtained for CT system (2520 kg ha$^{-1}$). Yields obtained for RT and NT were 2140 and 1815 kg ha$^{-1}$, respectively.

Statistical analyses showed that there were significant differences ($p>0.01$) in ET, ERI, ED and yield between the treatments. LSD test showed that all tillage systems fell into different groups in terms of ET, ERI and yield. RT and NT fell in the same group while CT in different group in terms of ED (Table 5).

Smika (1990) reported that the development of no tillage fallow to replace mechanical-tillage fallow improved water storage. This improvement is due to the capability of no-till to retain more crop residue on the soil surface and increase soil water accumulation (Latta and O'Leary, 2003). No till management increases water infiltration, reduce evaporation and keep the soil in the fallow fields moisture (Jones and Popham, 1997; Smika and Unger, 1986). In our experiment, the heavy weight of the direct stubble drill and high force impact on soil surface by the press wheel increased contact area between the seed and soil. More water storage and higher infiltration in soil for NT system were observed compare to RT and CT systems because of leaving more residue on the soil surface. This caused the earliest seed emergence (17 days) for the NT system. McMaster *et al.* (2002) reported that grain yield was always equal or greater in no tillage than on moldboard plowing plots and positively correlated with earlier/greater seedling emergence. This supports our findings of the earliest seed emergence (17 days) and the highest emergence degree (66.5%) in the NT plots (Table 4). However, lower grain yields in RT and NT system were obtained than the CT system. Lower tillage depth (11 cm) with RT prohibited root growth deeper into soil, while the swelling of soil by deeper cultivation to a depth of 19 cm for CT system permitted root growth, comfortably into deeper zone. These factors might be the reason for lower yield in RT and NT compare to CT system.

## CONCLUSIONS

The experimental field appeared to be uniform based on the results of soil analysis and the preliminary field test. The results of experiment showed that the highest penetration resistance was measured in the NT system after the drill while it was the lowest in CT. However, the lowest yield was obtained in NT system compared to the RT and CT systems although the earliest seed emergence and the highest emergence degree were obtained with NT. More water storage and higher infiltration in soil due to pressure exerted by the press wheel of direct stubble drill onto soil and reduction of evaporation from surface due to more field residue and soil coverage for NT system accelerated seed emergence and emergence degree. Root growth might be inhibited for the RT and NT due to shallow soil tillage (11 cm depth for RT), high mechanical impedance in root growth zone and direct stubble drilling (no soil tillage operation before drilling). These factors might be the reason for lower yield in RT and NT compare to CT system.

As a result of this study, reduced tillage and no tillage systems could be proposed for Gökhöyük region which has a semi-arid climate pattern if alternative solutions are found to prevent soil compaction and to reduce mechanical impedance in root growth zone. In addition, long-term investigations were suggested in order to better understand the effect of tillage systems on crop growth and yield for this region.

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