EFFECTS OF DIFFERENT TILLAGE METHODS ON SOIL COMPACTION AND SOME PROPERTIES IN WHEAT

SAGLAM, R. – BULUT, B. – KUP, F.*

Department of Agricultural Machineries and Technologies Engineering, Faculty of Agriculture, Harran University, Sanliurfa, Turkey
(phone: +90-414-318-3474)

**Corresponding author*
e-mail: ferkup63@harran.edu.tr

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Abstract. This study focuses on the effects of different tillage methods on plant and soil properties in wheat after the second product corn. Conventional tillage (CT), reduced tillage (RT) and zero tillage (ZT) were used as soil tillage methods. In terms of average moisture values, ZT (24.5%) had the highest value while CT had the lowest (21.9%). Values close to each other were obtained for plant heights (CT (85.6 cm), RT (84.6 cm), ZT (83.6 cm)). In terms of yield characteristics, higher values were obtained for the number of grains per spike ZT (50) and for the weight of 1000 grains ZT (48 g). Penetration resistances were measured at a depth of 0-50 cm in the soil at 5 cm gaps in the sprouting of the wheat, stem forming and the post-harvest periods. Overall, it was observed that the penetration resistance increased with increasing depth. However, it was also observed that the resistance in CT was lower in the upper part of the soil and the penetration resistance increased mainly after 40 cm due to the formation of the plow base. Taking into account all the results obtained, the study showed that conservation tillage should be adopted and applied by farmers due to its eco-friendliness, economic efficiency, positive effects on the soil, and so on.

Keywords: *penetration resistance, physical properties, soil properties, soil tillage systems, yield*

Introduction

Grown in almost all parts of the world, including Turkey, wheat is a very important product concerning a very large number of mass producers, mostly due to the fact that it is the raw material for bread, which is the basic staple of humanity. According to USDA data 2020/2021, the top 5 regions with regard to world wheat production are the EU, China, India, Russia, and the US, with Turkey ranking 10th (USDA, 2021). According to 2017 data, the 4 provinces with the highest level of wheat production in Turkey are Konya, Diyarbakır, Ankara and Şanlıurfa (ZMO, 2021). It is a matter of meeting the increasing demand for wheat on the back of a rising population, both quantitatively and qualitatively. There are many factors affecting the quantity and quality of wheat production. These factors include seed quality, soil characteristics, climatic characteristics, soil tillage methods, irrigation systems etc. In particular, tillage methods have effects on both product characteristics and ecology as a sustainable system. Tillage methods are classified as conventional tillage, reduced tillage, conservation tillage and zero tillage. With traditional tillage, intensive tillage comes into question by burning the stubble. Therefore, conventional tillage harms ecology in the long term and causes the deterioration of soil properties. Improper soil management practices may increase greenhouse gas emissions, reduce the soil's organic carbon sequestration, compromise ecosystem services and affect climate change (Zhang et al., 2016). Therefore, global interest in reduced tillage methods as an alternative to traditional tillage is increasing. Our long-term field experiment points out the beneficial effects of reduced tillage that,

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in addition to preserving both soil fertility and biological activity, could increase wheat yield over a short term period and exhibit a comparable yield over a long-term period as in conventional plough (Carcer et al., 2019). Zero tillage has positive environmental effects (reduction of greenhouse emissions, fossil fuel gas saving, water saving) and agricultural and economic advantages compared to conventional tillage. The concept of zero tillage has become a very common practice in many countries of the world, because it is ecologically, agronomically, economically and environmentally beneficial (Ali et al., 2016). Papu et al. (2012) argued that zero tillage was much more economical (76%) compared to traditional tillage. Conventional tillage requires higher inputs in terms of machinery investment, maintenance and repair, and labor compared to conservation tillage, and especially zero tillage (Yalcin et al., 2003). Adoption of protective soil tillage systems and their application for the purpose can increase the quantity and quality of soil organic matter so that the chemical and physical properties of the soil can be improved and preserved (Polat, 2020). Many studies have been carried out for different products on the use of different tillage methods in agricultural production. Altuntaş et al. (2019) studied the effects of different tillage methods on energy for wheat production carried out in dry soil in the province of Sivas. They concluded that direct sowing, conservation tillage and reduced tillage could be preferred to traditional tillage methods in terms of energy rate, specific energy, energy efficiency and energy profitability. In a study in which different tillage systems for wheat were analyzed, Aykanat et al. (2019) argued that the most viable tillage method for wheat is reduced tillage. There are many reasons for which farmers do not prefer conservation tillage methods. In a study conducted by Kucukcongar et al. (2014) 19.3% of farmers in the province of Konya reported that they did not prefer the direct sowing method due to lower yields; 14.04% said that it was not a common practice in the field; 12.28% said that very few farmers used the method; 12.28% said that they would have to till the soil more than once before seeding, and 10.53% stated that they did not prefer the method due to excessive weeds. ZT and RT with viable and optimum use of herbicide have been suggested as a possible solution. However, a shift from an intensive tillage system to ZT/RT system can cause major changes in soil microclimates due to different tillage systems (Usman et al., 2009).

The aim of this study is to assess the effects of different tillage methods (conventional tillage (CT), reduced tillage (RT) and zero tillage (ZT)) on soil properties, product yield, and product development in wheat production.

Materials and methods

Determination of the trial area

The study was carried out in 2016-2017 in the ecological conditions of the Artuklu District in the province of Mardin, in order to determine and compare the yield, plant characteristics and soil characteristics in the production of durum wheat using conventional tillage, reduced tillage and zero tillage methods. The research was carried out on irrigated farmlands. However, due to the rainy season, the crops were irrigated only once during the stem formation period.

This study was carried out in a total of 9 areas with 3 replications according to the randomized blocks experimental design. Trial areas were created 90 m long and 10 m wide. There is a gap of 5 m between the blocks and 3 m between the areas (*Table 1*).

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***Table 1.** Trial area*

Trial area (m)						
Length (m)		40				
		10		10		10
		1. area		2. area		3. area
276						3
	90	CT	5	RT	5	ZT
						3
	90	CT	5	RT	5	ZT
						3
	90	CT	5	RT	5	ZT

Plant material

Fırat-93 durum wheat was used in the study. Fırat-93 durum wheat has the following characteristics: Spike structure: white spiked with black awn. Stem and leaf characteristics: full, hard and vitreous grain, medium plant height, very waxy and robust stem; narrow, long and erect leaves. One thousand grains weigh between 45 and 50 g. Agricultural characteristics: summer crop, mid-early and drought-resistant, with good tillering properties. In favorable conditions, the average yield is up to 450 kg/da. The yield value in the region can go up to 700 kg/da.

Soil tillage methods

In the study, trials were performed on a field of approximately 11 decares, located in Çubuktepe village in the Artuklu district of Mardin. The trial area was divided up into 3 plots in a randomized trial pattern with 3 replications. A total of 9 plots were created with 3 replications. The trial plots were 90 m long and 10 m wide. Gaps of 5 meters between the blocks and 3 meters between the plots were allocated.

With the conventional tillage (CT) method, a plow, a goblet disc harrow, a PTO powered harrow and a seeder were used.

With the reduced tillage (RT) method, a PTO powered harrow and a seeder were used.

With the zero tillage (ZT) method, a seeder was used.

Machines used in the trial

In the study, a tractor, a plow, a goblet disc harrow, a PTO powered harrow, a seeder, a mounted sprayer, a mounted fertilizer spreader and a harvester were used (*Table 2*).

***Table 2.** Properties of machines used in trial*

Machine name	**Number of units (piece)**	**Working width (cm)**	**Working depth (cm)**	**Working speed (km/h)**
Plough	5	175	25	5.8
Goble disc harrow	24	275	10	7.75
PTO driven harrow	22	300	15	4.5
Grain sowing machine	22	300	10	4.55
Sprayer	32	1600	-	9.2

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Statistical analysis

Using descriptive statistics, the study gives the mean and the standard deviation. The assumption of normal distribution was taken into account in the determination of the comparison analyzes to be performed with parametric or non-parametric tests. The Shapiro Wilk Test was chosen to determine the normal distribution due to the small sample size. Non-parametric analysis methods were preferred since the assumption of normal distribution was not provided according to the Shapiro Wilk test results. Furthermore, the Kruskal Wallis test was used to compare penetrometer measurements according to the methods, while the Mann Whitney U test was applied to find different groups. The Friedman test was used to examine whether the methods were different during the sprouting of wheat, harvest and stem formation, while the Wilcoxon test was used to determine the point at which the difference originated. The analyses were finalized using the SPSS 25.0 package program.

Results and discussion

Soil moisture properties

In order to determine the soil moisture in the experiments, a total of 9 soil samples were taken from 3 different points and from 0-30 cm depth from each area. These samples were dried at 105 °C for 24 h to determine the soil moisture content (%) and the average was taken. The values derived from measurements made 14 days after sowing in order to determine the effect of the tillage methods on the changes in soil moisture are given in *Table 3*.

Table 3. *Average soil moisture contents (%)*

Soil depth (cm)	Moisture content of soil tillage methods (%)		
	CT	RT	ZT
0-10	21.0	21.4	23.7
10-20	21.9	22.8	24.8
20-30	22.9	22.3	25.1
Mean	21.9	22.1	24.5

According to the values in *Table 3*, ZT had the highest value in terms of average moisture content with 24.5%, followed by RT with 22.1%, while the lowest moisture content was that of CT with 21.9%. Other studies reported similar results. In a study examining the effects of different tillage methods on moisture and yield in wheat, Capar and Kenan (2015) stated that the highest moisture levels of the soil at depths of 30-60 cm and 60-90 cm were caused by direct sowing, reduced sowing and conventional sowing methods, respectively. The highest moisture content value was found in stubble sowing system for 0-15 cm and 15-30 cm soil depths than the other conventional tillage systems (Bulut and Altuntaş, 2015). Capar and Kenan (2015) found that the moisture content of soil at a depth of 0-30 cm toward harvest was 15.6% in direct sowing, 15.4% in reduced sowing and 15.3% in conventional sowing. With conventional tillage, evaporation increases while the moisture level decreases due to over-cultivation of the soil. For this reason, reduced or zero tillage methods should be preferred for non-

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irrigated lands or for plants that rely on rain, especially in warmer regions. Previous studies have shown that reduced tillage performs better, especially in dryland areas that rely on rainfall, as it retains more soil moisture (Baiamonte et al., 2019).

Plant root depth and height

The averages were determined by taking 3 samples from each of the 3 area determined in different soil tillages for plant root depth and plant height. Measurements were made during the phenological maturation period to determine the effects of different tillage methods on plant root depth.

The values from the measurements of plant root depth are given in *Table 4*.

Table 4. *The effect of tillage methods on root depth*

Methods	Plant root depth (m)			Mean	SD
	1. repetition	2. repetition	3. repetition		
CT	1.4	1.5	1.6	1.5	0.10
RT	1.2	1.3	1.3	1.27	0.06
ZT	1.2	1.1	1.1	1.13	0.06

According to the values in *Table 4*, CT had the highest root depth, with 1.5 m, followed by RT (1.27 m) and ZT (1.13 m). A study by Qin et al. (2006), which examined the effect of different tillage methods on the roots of corn in Switzerland, found that traditional tillage resulted in longer root lengths and smaller root diameters. In conventional tillage, oxygen uptake from the atmosphere decreases due to excessive soil compaction and a very humid environment, so oxygen concentration in the plant root decreases while carbon dioxide concentration increases. If this situation persists, an anaerobic environment forms in the roots, causing root development to slow down (Sahin and Aybek, 2020). The size of soil particles and compaction status, which vary according to the tillage tool used and the plowing of the soil, affect soil aeration, its contact with the seed, water-holding capacity, germination, and plant root development (Kus and Yildirim, 2017).

Pre-harvest measurements were conducted to determine the effects of different tillage methods on plant height.

The values from the measurements of plant height are given in *Table 5*.

Table 5. *The effect of tillage methods on plant height*

Methods	Plant height (cm)			Mean	SD
	1. repetition	2. repetition	3. repetition		
CT	86	85	86	85.6	0.58
RT	85	84	85	84.6	0.58
ZT	84	83	84	83.6	0.58

According to the values in *Table 5*, CT had the highest plant height at 85.6 cm, followed by RT (84.6 cm) and ZT (83.6 cm). However, the values were somewhat similar. Other studies reported different results. Different results indicate that not only

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tillage, but also factors such as type of product, soil characteristics and atmospheric changes also affect plant height. In their study, Ali et al. (2016) stated that zero tillage significantly increases wheat height, tillers per square meter, 1000 grain weight and yield compared to conventional tillage. A study by Papu et al. (2012) reported that the average wheat plant height was (86.3 cm) in other tillage methods while wheat plant height was (89.9 cm) in zero tillage. Bulut and Altuntaş (2015) stated that plant height was 96.68 cm in direct seeding in stubble and 105.75 cm in conventional tillage for wheat. Aykanat et al. (2019) emphasized that with a height of 101.7 cm, wheat plant height was the highest with the direct sowing method followed by reduced tillage, 3 rows of planting and 2 rows of planting (98.5, 97.8, 97.75), respectively.

Yield properties

In order to determine the yield characteristics, samples were taken from a total of 9 plants, 3 plants in each area. In terms of yield characteristics, the number of grains per spike, the yield per decare (kg), the 1000 grain weight and the number of spikes per square meter were all examined. The results are given in *Table 6*.

Table 6. *The effect of tillage methods on yield*

Methods	**Number of grains in spike (grain/spike)**			**Mean**	**SD**	**Yield per decare (kg/da^{-1})**			**Mean**	**SD**	**Thousand grain weight (g)**			**Mean**	**SD**
CT	37	28	45	45	8.50	633	634	632	633	1.00	43	44	43	43	0.58
RT	39	45	49	49	5.03	593	589	593	592	2.31	45	45	45	45	0.00
ZT	46	54	50	50	4.00	549	548	536	544	7.23	48	48	48	48	0.00
Count of spikes per square meter (spike/m^2)															
CT	514	489	483	495	16.44										
RT	454	462	453	456	4.93										
ZT	352	337	353	347	8.96										

According to the values obtained from *Table 6*, ZT (50) had the highest value in terms of the number of grains per spike, followed by RT (49 cm) and ZT (45 cm). ZT (48) had the highest value in terms of 1000 grain weight, followed by RT (45) and CT (43), respectively. However, there is an inverse relationship for the yield per decare. The highest value in yield per decare was claimed by CT (632 kg/da), RT (593 kg/da) and ZT (536 kg/da), respectively. This is because the number of spikes per square meter was the highest in CT (495), followed by RT (456) and ZT (347). Bulut and Altuntaş (2015) stated that the number of spikes per square meter was higher in conventional tillage (485) compared to direct seeding in stubble (398). Aykanat et al. (2019) stated that the highest weight (g) for 1000 grains with different tillage methods was achieved by 2 rows of sowing, 3 rows of sowing, direct sowing and reduced tillage (36.9, 35.8, 35.7, 33.9), ranked from top to bottom. In their article comparing direct seeding in stubble and conventional tillage methods in wheat, Bulut and Altuntaş (2015) stated that conventional tillage (330 kg/da) had a higher wheat yield than direct seeding in stubble (293 kg/da). Other studies, meanwhile, reported different results. The grain yield received with zero-till ferti drill machine was about 44.55 q/ha that was slightly higher

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than convectional system in which it was about 43.98 q/ha (Papu et al., 2012). Usman et al. (2009) reported that the highest wheat yield (5584 kg/ha) was obtained with reduced tillage (RT) followed by zero tillage (ZT) (5575 kg/ha) while conventional tillage (CT) (5479 kg/ha) had the lowest yield of all. In durum wheat-based farming systems in Mediterranean areas, the adoption of CA (conservation agriculture) seems to be an optimal choice to combine high quality yields with improved soil fertility (Pagnani et al., 2019). Verma et al. (2018) stated that the product yield for HD 1563 wheat was 34.1 q/ha in conventional tillage and 36.6 q/ha in zero tillage.

Soil penetration resistance

Within the scope of the methodology, penetration resistance measurements were taken during sprouting, with these measurements done every 5 cm down the soil for depths of up to 50 cm. Three measurements were conducted at each plot and the average values were taken. Penetration resistance measurements were taken during wheat sprouting, stem formation and post-harvest periods.

Statistical analyses were done using the penetration resistances obtained from different soil depths during wheat flowering. The results are given in *Table 7*.

Table 7. *Investigation of wheat emergence period penetrometer measurements*

Measuring depth (cm)	**Penetrometer measurements (MPa)***			**p**
	CT X ± s.s.	**RT X ± s.s.**	**ZT X ± s.s.**	
0-5	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	-
5-10	0.00 ± 0.00 ^{a}	0.21 ± 0.09 ^{b}	0.41 ± 0.17 ^{c}	0.01*
10-15	0.06 ± 0.02 ^{a}	0.51 ± 0.21 ^{b}	0.81 ± 0.33 ^{c}	0.01*
15-20	0.43 ± 0.18 ^{a}	0.84 ± 0.34 ^{b}	1.51 ± 0.62 ^{c}	0.01*
20-25	0.73 ± 0.3 ^{a}	1.45 ± 0.59 ^{b}	2.04 ± 0.84 ^{b}	0.01*
25-30	1.55 ± 0.64 ^{a}	1.96 ± 0.80 ^{ab}	2.55 ± 1.05 ^{b}	0.04*
30-35	2.13 ± 0.87	2.48 ± 1.02	2.86 ± 1.17	0.08
35-40	2.85 ± 1.17	2.94 ± 1.21	3.25 ± 1.33	0.09
40-45	3.23 ± 1.32	3.23 ± 1.32	3.54 ± 1.45	0.29
45-50	3.44 ± 1.41	3.36 ± 1.38	3.75 ± 1.54	0.13

**Kruskal Wallis test conducted a < b < c, *significant difference at 0.05 level

According to the values obtained in *Table 7*, the penetrometer measurements were different across the groups during wheat sprouting at soil depths of 5-10 cm. The reason for this difference is that the penetrometer measurements of the ZT group were higher than the RT and CT groups, and the RT group had higher levels than the CT group (p = 0.01).

It was observed that penetrometer measurements at depths of 10-15 cm were different across the groups. The reason for this difference is that the penetrometer measurements of the ZT group were higher than the RT and CT groups, and the RT group had higher levels than the CT group (p = 0.01).

It was observed that penetrometer measurements at depths of 15-20 cm were different across the groups. The reason for this difference is that the penetrometer

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measurements of the ZT group were higher than the RT and CT groups, and the RT group had higher levels than the CT group ($p = 0.01$).

It was observed that penetrometer measurements at depths of 20-25 cm were different across the groups. The reason for this difference is that the penetrometer measurements of the RT and ZT groups were higher than the CT group ($p = 0.01$).

It was observed that penetrometer measurements at depths of 25-30 cm were different across the groups. The reason for this difference is that the penetrometer measurements of the ZT group were higher than the CT group ($p = 0.04$).

It was observed that penetrometer measurements at depths of 30-35, 35-40, 40-45 and 45-50 cm did not show any variation between groups. At these depths, the measurements of the CT, RT and ZT groups were similar ($p > 0.05$).

Statistical analyses were done using penetration resistances obtained from different soil depths during the wheat's stem formation stage. The results are given in *Table 8*.

Table 8. *Investigation of stem elongation period penetrometer measurements*

Measuring depth (cm)	**Penetrometer measurements (MPa)***			**p**
	CT (X ± s.s.)	**RT (X ± s.s.)**	**ZT (X ± s.s.)**	
0-5	0.76 + 0.33	0.79 + 0.34	0.62 + 0.27	0.29
5-10	1.46 + 0.63	1.29 + 0.55	1.29 + 0.55	0.15
10-15	1.77 + 0.76	1.62 + 0.7	1.66 + 0.71	0.33
15-20	2.41 + 1.04	2.25 + 0.97	2.31 + 0.99	0.38
20-25	2.80 + 1.20	2.63 + 1.13	2.82 + 1.21	0.26
25-30	3.40 + 1.46	3.29 + 1.41	3.30 + 1.42	0.21
30-35	3.74 + 1.61	3.53 + 1.52	3.34 + 1.44	0.12
35-40	4.13 + 1.78	3.86 + 1.66	3.18 + 1.37	0.08
40-45	4.59 + 1.97 ^{a}	4.27 + 1.84 ^{ab}	3.56 + 1.53 ^{b}	0.01*
45-50	4.93 + 2.12 ^{a}	4.74 + 2.04 ^{ab}	4.26 + 1.83 ^{b}	0.03*

**Kruskal Wallis test conducted a < b < c, *significant difference at 0.05 level

According to the values obtained in *Table 8*, the penetrometer measurements were not different across the groups during the stem formation of wheat at soil depths of 10-15, 15-20, 20-25, 25-30, 30-35 and 35-40 cm. At these depths, the measurements of the CT, RT and ZT groups were similar ($p > 0.05$).

It was observed that the penetrometer measurements at depths of 0-45 and 45-50 cm were different between groups. The reason for this difference is that the penetrometer measurements of the ZT group were lower than the CT group ($p < 0.05$).

Statistical analyses were done using penetration resistances obtained from different soil depths during the post-harvest period. The results are given in *Table 9*.

According to the values obtained in *Table 9*, the penetrometer measurements did not differ across groups during the post-harvest period at soil depths of 10-15, 15-20, 20-25, 25-30, 30-35 and 35-40 cm. At these depths, the measurements of the CT, RT and ZT groups were similar ($p > 0.05$).

It was observed that the penetrometer measurements at depths of 0-5, 5-10, 40-45 and 45-50 cm were different between groups. The reason for this difference is that the penetrometer measurements of the ZT group were lower than the CT group ($p < 0.05$). This is because the traffic density on the soil is less in zero tillage.

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Table 9. *Investigation of postharvest period penetrometer measurements*

Measuring depth (cm)	Penetrometer measurements (MPa)*			p
	CT (X ± s.s.)	RT (X ± s.s.)	ZT (X ± s.s.)	
0-5	0.50 + 0.22 ^{b}	0.32 + 0.14 ^{a}	0.28 + 0.12 ^{a}	0.01*
5-10	0.93 + 0.40 ^{b}	0.76 + 0.33 ^{a}	0.69 + 0.30 ^{a}	0.043*
10-15	1.51 + 0.65	1.30 + 0.56	1.25 + 0.54	0.13
15-20	1.87 + 0.80	1.66 + 0.71	1.59 + 0.68	0.08
20-25	2.29 + 0.98	2.00 + 0.86	1.79 + 0.77	0.06
25-30	2.61 + 1.12	2.51 + 1.08	2.29 + 0.98	0.23
30-35	3.02 + 1.30	2.9 + 1.25	2.7 + 1.16	0.10
35-40	3.33 + 1.43	3.25 + 1.4	3.07 + 1.32	0.12
40-45	3.71 + 1.60 ^{b}	3.58 + 1.54 ^{ab}	3.28 + 1.41 ^{a}	0.04*
45-50	4.13 + 2.22 ^{b}	3.86 + 2.24 ^{ab}	3.49 + 2.11 ^{a}	0.04*

**Kruskal Wallis test conducted a < b < c, *significant difference at 0.05 level

Similar results were reported by studies on the effect of different tillage methods on penetration resistance. Barut et al. (2010) stated that the penetration resistance was higher in protective tillage methods compared to conventional tillage, causing soil compaction. Bulut and Altuntaş (2015) stated that after wheat harvesting for direct seeding in stubble, penetration resistance at the depth of 0-15 cm was 1.36 MPa and 2.19 MPa at 15-30 cm. That of conventional sowing, meanwhile, was 0.81 MPa and 1.67 MPa, respectively. They reported that soil penetration resistance with direct seeding in stubble was higher than that of conventional tillage.

Depending on the soil depth, the penetration resistance also increased. However, there were variations in the effects of tillage. Overall, since the soil is tilled more intensively with CT, the penetration resistance in the upper parts of the soil was lower compared to with other methods. However, the penetration resistance was higher in CT after soil depths of 35-40 cm. This is because the traffic density on the ground is higher in CT (*Fig. 1*).

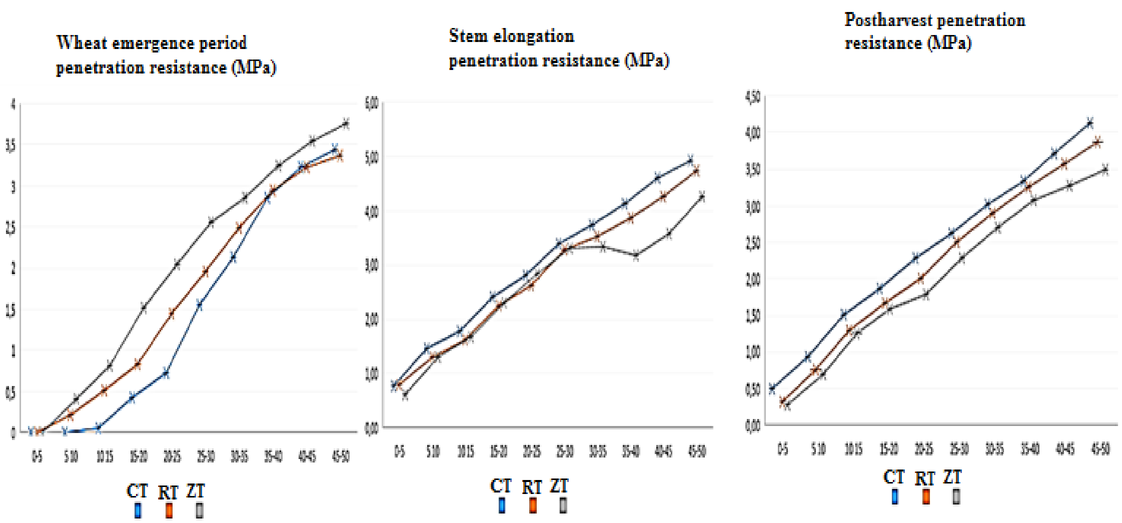

Figure 2. *Penetration resistance values of the different soil tillage systems*

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Figure 1 shows that the penetration resistances increase overall in parallel with the increase in soil depth across all three periods. However, the plow base formed after an average depth of 35-40 cm increases the penetration resistance. Barut et al. (2010) state that increased resistance to penetration occurs primarily at soil depths of 25-30 cm, especially with conventional tillage, but there is increased penetration resistance due to the presence of a lower plow base at this depth. Altuntas and Dede (2007) found in their study examining different tillage methods for second-crop silage corn that the penetration resistance increases with depth, overall within the 0-40 cm range. Cetin et al. (2005) stated that the penetration resistance (Mpa) was (0.723, 0.468, 0.467, respectively) at a depth of 0-10 cm and (2.278, 2.823, 3.405, respectively) at a depth of 10-20 cm in their study examining the effects of different tillage methods S1 (Mouldboard plow + disc harrow), S2 (Chisel + disc harrow), S3 (Rotary Tiller).

Conclusions

The following conclusions were drawn from this study:

- It was observed that the soil's average moisture content (%) increased as the depth increased. However, the moisture content was lower in CT because soil is cultivated more intensely and at a greater scale with this method compared to others. Therefore, reduced tillage methods are more preferable, especially in arid regions where irrigation is dependent on rain water.
- The CT had the highest plant root depth. The reason for this is that soil compaction is higher with other tillage methods, resulting in a decrease in root lengths.
- In terms of plant height, each method had similar values. This result shows that not only tillage, but also other factors, affect plant height.
- ZT had higher values with respect to the number of grains per spike and its 1000 grain weight. However, CT had higher values in yield per decare. This is because the number of spikes per square meter is higher in CT.
- The penetration resistance values increase overall with increasing soil depth. However, penetration resistance was lower in CT, especially in the upper part of the soil, until it gets down to 40 cm. After an average depth of 40 cm, the penetration resistance for CT increased. The reason for this is that the conventional tillage method has more traffic density than the reduced tillage method.

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