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Evaluation of Conventional and Conservation Tillage Systems for Maize

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Abstract: In this study, different tillage systems were compared in terms of their effects on physical properties of soil, task time, fuel consumption and crop yield. In the research, the seedbeds were prepared by four different tillage systems including minimum tillage with stubble (MTR), minimum tillage non-stubble (MT), conventional tillage with stubble (CTS) and conventional tillage non-stubble (CT). The crop sown into seedbed was maize (*Zea mays* L.). The result of study was shown that tillage systems with crop residue improved physical properties of the soil such as porosity, bulk density and compaction. Soil compaction was under 3.5 MPa in the all experiment plots. A clear difference in bulk density and porosity was detected in 0-10 cm depth. Bulk density was under 1.35 g cm^{-3}, whereas porosity was over 50% in this depth for all treatments. The effect of tillage systems on crop yield was found statistically significant. The highest grain yield was 8719 kg ha^{-1} on CT, because of intensive plant population. Among the systems, the lowest task time and fuel consumption were 4.0 h ha^{-1} and 28.8 l ha^{-1}, respectively on MT.

Key words: Tillage system, soil property, fuel consumption, task time yield

INTRODUCTION

Conservation tillage is an ecological approach including many different soil management systems (no-tillage, strip tillage, ridge tillage, mulch tillage, reduced/minimum tillage etc.) aimed at minimising the effects on soil structure and reducing erosion and degradation. Conversely, conventional tillage, mainly characterised by intensive tillage, straw burning and energetic/chemical inputs, has contributed to soil degradation through loss of organic matter, soil erosion and compaction[1]. Many comparative studies between conventional and conservation tillage systems have been performed in terms of effects on soil quality[2-5], crop production[6-8] and environment[9-11].

Bulk density is used to evaluate tillage and crop management effects on soil quality and vital information to assess seedbed properties[12]. Penetration resistance (MPa) of the soil can be regarded as other factor determining the quality of its structure[13]. Soil porosity plays a critical role in the sustaining soil quality of agricultural soils[14], crop production and environmental quality[15].

While stubble burning can be important in assisting normal tillage operations, it reduces or removes vegetative cover at the soil surface[16,17]. The burning stubble damages micro orgamisms, useful fungus and bacterium and causes water and wind erosion. In spite of this, residue left on the soil eliminates soil loss by preventing water and wind erosion and improves chemical, physical and biological properties of soil. Ghuman and Sur[18] investigated the effects of three different tillage systems (reduced tillage with residue, reduced tillage without residue and conventional tillage) on the soil quality and grain yield in maize and wheat for 5 years. The researcher indicated that reduced tillage with residue improves soil quality and yield. Conservation tillage system that are low in labour, time, energy and production cost have been considered important as time goes by. Some researches showed that conventional tillage and planting systems weren't economical because of high production cost in spite of reaching the highest yield. As operation number used tillage systems diminish, task time and fuel consumption reduces too. In this context, task time and fuel consumption in conventional tillage systems that have more operation number, is higher than in other tillage

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systems[19]. In addition, CO_2 emission rates could be minimum 15-29% by minimum tillage crop systems as a consequence of fuel savings[9].

A single tillage system is not suitable for all soils and climatic conditions. Therefore, the choice of the best suited tillage system must be harmonious to the particular agro-ecological environment. In this study, conventional tillage and conservation tillage systems were compared in terms of their effects on some physical properties of soil, task time, fuel consumption and grain yield for maize in southern Turkey.

MATERIALS AND METHODS

The study was carried out on trial plots of 300 m^2 with 29% sand, 25% silt and 46% clay on experimental field of Çukurova University located near Adana (37° latitude N, 35° longitude E, 23 m above sea level) between the years 1999-2000. Tillage equipment consist of three mouldboard plough, a 2.0 m wide rotary tiller with knife, a 2.1 m wide chisel plough, a 2.25 m wide disc harrow with 20 discs and a 3.5 m wide scraper. Maize (*Zea mays* L.) seed (ISADORA - AG9241) of 269 g 1000^{-1} seeds was sown by pneumatic single seed drill with four rows for all treatments.

The study was planned in a split plot design with three replications for two years. The main plot treatments were minimum tillage with stubble (MTR), minimum tillage without stubble (MT), conventional tillage with stubble (CTS) and conventional tillage without stubble (CT). The tillage systems consisted of as follows:

1. Minimum tillage with stubble (MTS) including tillage with a rotary tiller at a depth of 15 cm and final preparation with a scraper in twice.
2. Minimum tillage without stubble (MT) including tillage with a rotary tiller at a depth of 15 cm and final preparation with a scraper in twice.
3. Conventional tillage with stubble (CTS) including tillage with a plough at a depth of 25 cm, tillage with a disk harrow at a depth of 7-8 cm and final preparation with a scraper in three times.
4. Conventional tillage without stubble (CT), including tillage with a chisel at a depth of 35 cm, tillage with a disk harrow at a depth of 7-8 cm and final preparation with a scraper in twice.

The tillage implements were operated with the standard tractor of 70 kW whereas sowing and cultivation operations were performed with the tractor of 56 kW. After wheat harvesting, residues left on the field surface were burned for plots with non-stubble while they were mixed into soil with tillage equipment for plots with stubble. The amount of stubble mixed into soil for plots with residue was 3380 kg ha^{-1}.

All experiment area was irrigated after burning of non-stubble plots. The fertilizer was spread 500 kg ha^{-1} by spinning disc distributor and then tillage was applied. Sowing distance was adjusted as 21 cm on row and 70 cm between rows. Maize was sown in July and harvested in November of the same year. After plant emergence, the operations such as cultivation, fertilization, pesticide application and irrigation were performed at the same time and same dose on all plots with regard to the trial.

The penetration resistance, porosity and bulk density of the soil was found to reveal the effect on physical properties of soil of tillage equipment used in tillage. For determination of the penetration resistance, a soil penetrometer was used. Measurement range of penetrometer, is up to 380 N cm^{-2} and measurement accuracy is 0.01 N cm^{-2}. Soil strength was measured from the soil surface to a depth of 52.5 cm at 35 mm depth increments from ten points of each plot, with three replications after seedbed preparation. In order to determine moisture content, bulk density and porosity, soil samples were taken from depths of 0-10, 10-20 and 20-30 cm. Soil samples were tested in the laboratory for bulk density and total porosity using methods described by Blake and Hartge[20], Danielson and Sutherland[21], respectively. One part of soil samples taken from each plot was dried in the oven at 105°C to determine soil gravimetric moisture content. Soil organic carbon content was determined using the Walkley-Black method[22]. All soil samples were taken before sowing.

The task times for the tillage systems were measured by using a chronometer in order to obtain management data of farm machineries used seedbed preparation for maize. Fuel tank of tractor at the beginning of each application was filled fully to determined fuel consumption. At the end of each application, the measured fuel was added up to fill in the fuel tank of the tractor. The added fuel was consumed fuel based on area for plots of 300 m^2[23]. In November, cobs of plants on three rows of 10 m selected randomized from each trial plots, were harvested by hand. Thereby, harvesting area was 7 m^2 in related to 70 cm row distance. Then, the cobs were threshed by a maize sheller driven by hand.

The experiment data was analyzed by a statistics programme. Therefore, variance analysis and LSD (Least Significance Difference) test were performed to prove that the results statistically significant.

RESULTS AND DISCUSSION

The results of the soil samples analyses in terms of total porosity and bulk density are presented for different tillage treatments in Fig. 1. Moisture contents of soil in the plots varied between 23 and 28% while taking soil samples.

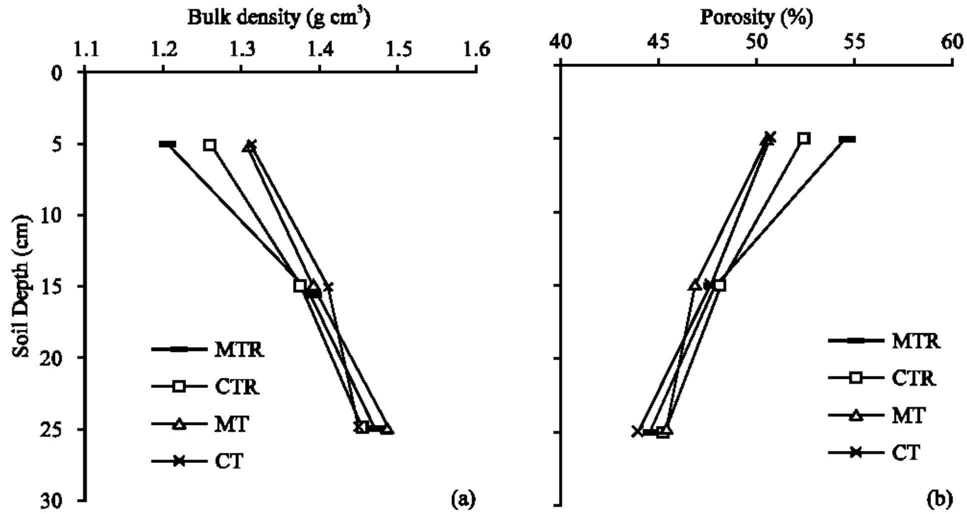

Fig. 1: Bulk density (a) and porosity (b) of the soil samples according to soil depth for tillage systems (MTR, minimum tillage with residue; CTS, conventional tillage with residue; MT, minimum tillage and CT, conventional tillage)

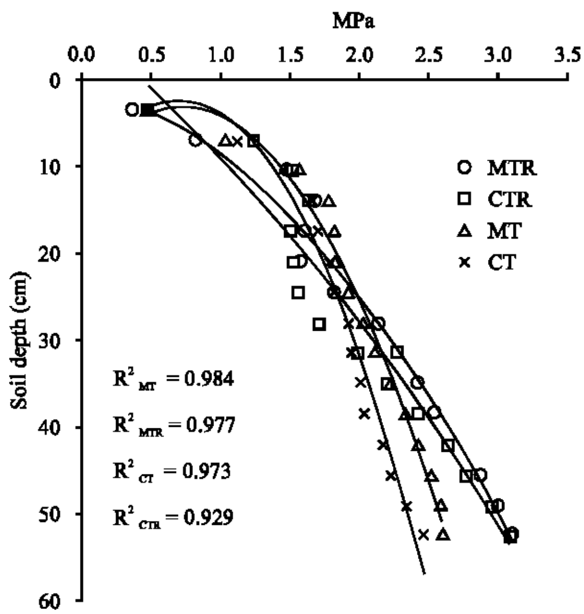

Fig. 2: Penetration resistance (MPa) of the tillage systems (MTR, minimum tillage with residue; CTS, conventional tillage with residue; MT, minimum tillage and CT, conventional tillage) according to soil depth (cm)

Soil bulk density: Soil bulk density of 0-10 cm layer in MTR was 1.21 g cm^{-3} and lower than in the other plots because tillage depth in MTR was shallow. Similarly, Logsdon and Karlen[12] showed significant temporal changes in near-surface incremental bulk density for tillage systems in a sub-humid climate. Bulk density was lower in the plots with stubble (MTR and CTR) than that in non-stubble plots (MT and CT) for 0-10 cm soil layer. Crop residue has been reported to improve soil bulk density and cause lower bulk density[17,18,24]. Bulk densities in the 0-10 cm depth were under 1.35 g cm^{-3} and lower than other both depths in the same tillage system. There was no a clear difference between 10-20 and 20-30 cm layers for the same tillage treatments. However, bulk densities of these depths were lower in CTS and CT compared to these layers of other two tillage systems. This situation shows that the deep tillage of chisel and plough in CTS and CT loosened soil texture. Also, in the non-stubble lands, soil bulk density of the CT was lower than that in MT. This was probably due to the tillage depth of chisel. Bulk density was under 1.5 g cm^{-3} in all plots.

Soil porosity: The porosity in 0-10 cm soil layer was over 50% for all tillage systems. The highest porosity was in MTR with 55%. But, there was no a clear difference among porosities of tillage systems in the 10-20 and 20-30 cm soil layers. Total porosity was under 50% for 10-20 and 20-30 cm soil layers. Porosity of these depths in CTS was higher than other tillage systems due to tillage depth of the plough and mixing stubble. Total porosity was over 43% for all treatments. Soil porosity was higher in the plots with stubble (MTR) than that in non-stubble plots (MT) for the same tillage equipment. This shows that crop residues in the soil are likely to increase soil porosity. However a study indicated that total porosity was not affected by conservation tillage compared with conventional tillage in the silt loam, distribution of pore sizes was affected[24]. Also, in the non-stubble lands, soil porosity of the CT was higher than that in MT. This was probably due to the deep tillage of the chisel.

Soil penetration resistance: As can be seen from Fig. 2, up to 15 cm depth, soil compactions in MTR and CTR were under 1.5 MPa and lower than that in MT and CT. The same findings were observed for CTS in the 20-30 cm soil layer due to inverted soil and stubble by plough. The similar results have been reported that ploughing causes a decrease in soil compaction up to tillage depth[25]. There weren't a considerable difference among soil compactions of the tillage systems in soil layer of 20 and 30 cm. After 30 cm depth, soil compaction in CT was lower than other treatments. This situation can be explained that tillage depth of chisel is deeper than other tillage equipment used in the experiment. Deep tillage can get better soil compaction caused by movement of heavy machinery on the soil. After this depth, soil penetration resistance of tillage systems with stubble boost more than that of tillage systems with non-stubble. Soil strength was under 3.5 MPa in the all trial plots.

Grain yield: In the study, tillage systems statistically ($p<0.01$) affected the yield (Table 1). The greatest grain yield was in CT as 8719 kg ha^{-1} compared to other tillage treatments. The lowest grain yield was 7288 kg ha^{-1} in MTR. This result is pertinent to plant density. As the plant density increased, so did grain yield. However, Ghuman and Sur[18] reported that maize grain yield increased in the minimum tillage with residue after production period of first two years when compared with conventional tillage. While plant number per area on stubble plots was lower, weed number per area was higher. Even though expected that the yield on plots with stubble would be higher, this result had not materialized. Due to the fact that weeds share water, nutrients and light by competing with crops, weeds and low plant density on stubble plots can be considered a factor which has decreased grain yield[26].

The task time and fuel consumption: As can be seen from Table 2, for field operation, the lowest task time was found 4.0 h ha^{-1} in MT, whereas the highest time spent was 7.5 h ha^{-1} in CTS. Similar findings were observed for fuel consumption. This situation shows that task time for field tillage increases due to increasing the pass number. Owing to less the field traffic, the lowest fuel was consumed as 28.8 l ha^{-1} in MT. On contrary to this, the highest fuel consumption was detected as 55.4 l ha^{-1} in CTS because of increment of pass number on the field as it was observed by Koruyucu and Kirişci[19]. Generally tillage systems with rotary tiller had less task time and fuel consumption in comparison with other tillage systems with plough and chisel due to less pass number. Besides minimum fuel costs, the use of MT production systems lead minimum CO^2 emission[9].

Table 1: Yield (kg ha^{-1}) and plant density (plant ha^{-1}) values of tillage systems (MTR, minimum tillage with residue; CTS, conventional tillage with residue; MT, minimum tillage and CT, conventional tillage)

	MTR	CTS	MT	CT
kg ha^{-1} *	7288b	8179ab	8148ab	8719a
Average (kg ha^{-1})	7733.5#		8433.5‡	
Plants ha^{-1} **	59210.5	58055.5	61610.9	63698.7
Average (plants ha^{-1})	58633#		62654.8‡	

* Means followed by the same letter(s) within a group do not differ at 1% level according to LSD test, ** Non-significant

Table 2: Task time and fuel consumption for different tillage systems (MTR, minimum tillage with residue; CTS, conventional tillage with residue; MT, minimum tillage and CT, conventional tillage)

Tillage systems	Fuel consump.* (l ha^{-1})	Average (l ha^{-1})	Task time* (h ha^{-1})	Average (h ha^{-1})
MTR	29.1c		4.2ab	
CTS	55.4a	42.25#	7.5a	5.85#
MT	28.8c		4.0c	
CT	33.0b	30.9‡	4.7b	4.35‡

*Means followed by the same letter(s) within a group do not differ at 1% level according to LSD test

#Average of values of MTR and CTR in terms of task time and fuel consumption

‡Average of values of MT and CT in terms of task time and fuel consumption

In conclusion, result of the study indicated that tillage systems with crop residue improved physical properties of the soil such as bulk density, porosity and compaction. On the other hand, yield on non-stubble plots was more improved and task time and fuel consumption was lower. However, it is essential that conservation tillage systems should be used to preserve natural life and sustaining soil fertility. In this context selected tillage systems should be improved and new tillage systems functioning by mixing previous crop residue into soil should be investigated.

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