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Comparison of Strip Tillage Systems for Sillage Maize Production in Middle Anatolia

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ABSRACT

Strip tillage might offer an option to produce high silage maize yields at lower costs and improved erosion control compared to full width tillage practices. However, the strip tillage is not included in the agricultural production practice of the farmers in our country. In this study, three different strips tillage application have been used as a alternative to traditional practices (CT). While the machine made by the Maschio Gaspardo (OST) is used in one of the applications of the strip tillage, the other two machines (horizontal (MHST) and vertical shaft rotary tillers (MVST) have been modified and used in strip tillage. The width of the strips of applications varied between 25-28cm. As a depending on strip tillage applications, 35-40 % of soil surface was tilled. While the penetration resistance of the strip tillage applications ranged from 0.45-1.91 MPa, the surface roughness of the strips was found to be about 11 %. Results of fuel consumption were 4.92, 1.82, 1.3 and 0.73 l da^{-1} for the full width tillage, OST, MVST and MHST respectively. Seedling emergence degree was approximately 6 % higher for MVST and OST compared to CT. An average increasing of 12 % plant emergence rate index (ERI) under MVST compared with other applications was found.

1. Introduction

Strip-tillage implements create a narrow, residue-free strip, of soil about 20-30cm wide, 10 to 20cm deep. The soil surface between tilled strips is left undisturbed, as in no-till. Strip-tillage creates an environment favorable for rapid seed germination and seedling growth. The strip-tillage operation can be completed after harvest, or in early spring before seeding. The tilled soil strips with less surface residue are dark, so excess moisture dries and the soil is quicker to warm for timely spring seeding (Morrison, 2002).

Strip tillage is a conservative technique widespread overseas with recognized environmental, agronomical and economic benefits. In Europe it has been proposed only recently and is almost unknown by farmers of Italy and other Mediterranean countries (Trevini et al., 2013). They found that strip tillage moved less soil and left higher ground residue cover than minimum tillage, while the seedbed prepared by the two techniques did not differ for suitability to drilling, root exploration and crop growth.

Conservation tillage is a method in which at least 30% of the field area is left to be covered with plant residues after the cultivation and the sowing is performed together with soil tillage. This method anticipates preventing erosion and conserving the soil moisture content. In strip tillage technique, only up to 25 - 30% of the total field surface is tilled in strips (Wysocki 1986; Çelik and Altıkat 2010). Cultivators, subsoilers, soil rotary tillers, and special tools and machines which are designed for this purpose are used in strip tillage (Morrison and Sanabria 2002; Lee et al., 2003). Çelik and Altıkat (2010) found that, while seedling emergence and silage yield increased as the strip width increased, the average emergence time decreased. In widely tilled strips, there occurred a reduction in the average germination time and an increase in the germination percentage.

Sarauskis et al., (2015) researched that, the strip width depends on the technical parameters of the strip tillage machine working parts. When the row cleaner disc attack angles are switched from 10^{o} to 22.5^{o} and the gaps between the disc centres are increased from

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105 mm to 135 mm, the strip width increased from 192 to 290 mm. Row cleaner disc attack angles and the gaps between the disc centres have a strong impact on the distance of the cleaned off crop residues falling from the centre of the strip. Strip tillage technology is important for growing wide row crops, the row cleaner disc attack angle should not be greater than 15^{o}, and the distance between the disc centres should not exceed 120 mm.

Laufer and Koch (2017) studied on strip tillage affects the early growth of sugar beet on high yielding silt loam sites of Central Europe. As a result, plant dry matter yield and white sugar yield were approximately 7 % higher for conventional tillage and reduced tillage compared to strip tillage. Plant nitrogen uptake revealed a similar pattern, thus, nitrogen use efficiency was not affected by tillage systems.

Tillage practices are critical for sustaining soil quality necessary for successful crop growth and productivity (Leskovar et al., 2016). They carried out to evaluate the influence of strip and conventional tillage practices and three water status on plant morphology, physiology, yield and quality of seedless watermelon. Watermelon yield and sugar content in strip tillage was higher than conventional tillage across the three growing seasons. This yield increase could be attributed to the fact that strip tillage also improved soil quality (biological and chemical) by increasing the soil microbial populations.

Soil moisture and soil temperature conditions in the seedbed zone (top 5 cm) can promote or delay seed germination and plant emergence (Kaspar et al., 1990; Licht and Al-Kaisi, 2005). Therefore, healthy plant growth and development require soil conditions that have adequate soil moisture and minimal root penetration resistance

Soil compaction management in the southeastern U.S. relies heavily on the use of annual deep tillage. The conventional cotton production systems require a minimum of three and often five field operations at a cost of approximately 12.4$ per ha. Strip tillage systems have shown considerable promise for reducing the energy and labor requirement, equipment cost, soil erosion and cotton plant damage from blowing sand. Cost savings of approximately 8$ per ha could be achieved by strip tillage compared to conventional methods (Khalilian et al, 2004).

In recent years, farmers have been using drip irrigation systems to save water in the production of maize in the middle Anatolian region. After the plant emergence was completed, they have done herbicide apply. When the plants reach about 15-20 cm high after planting, the farmers put drip irrigation systems in the field. Therefore they do not do the hoeing.

The objectives of this study were to evaluate the performance of three different strip tillage systems compared to conventional methods in terms of effects on soil parameters, seed placement, crop responses and fuel consumption.

2. Materials and Methods

Experimental studies were conducted on clay-loam soils in a randomized complete block design at the Universitiy of Selcuk, Faculty of Agriculture in Research and Education Center during the years of 2018. It is 30 km away from Konya province, which is located in the Middle Anatolia region of Turkey.

Some of the important physical properties of the experiment field soils are given in Table 1.

Table 1
Some of the important physical properties of the experiment field soils

Soil properties	
Soil texture class (clay: 43%, sand:29%, silt:28%)	Clay loam
Soil moisture content, % d.b.	15.5
Penetrasyon resistance, MPa	2.64
Organic matter, %	0.95
Residue amount (g m^{-2})	324

In order to determine the penetration resistance, an Eijkelkamp analog penetrometer with 60° cone angle was used. Measurements were made at the depth of 20 cm in 5 cm increments with five replications in each plot before and after soil tillage.

Surface relief was measured using surface profilemeter. This consisted of a set of vertical rods, spaced at 2.5 cm intervals, sliding through an iron bar of 100 cm length. The soil surface roughness was calculated by using the Kuipers equation;

$$R = 100log_{10}S_d$$

Where R is the surface roughness (%) and S_d is the standard deviation (mm). The standard deviation was estimated by measuring the distance between a constant horizontal surface and the soil surface over a set of 100 cm.

Soil moisture content and seedbed temperature at depths of 0-10cm in each plot until the seedling emergence is completed after seeding, were measured. A time domain reflect meter (TDR 300) that has 12 cm rods was used for soil moisture content. Seedbed temperature was measured using a thr251 model digital soil thermometer. 10 measurements were taken randomly in daily in each plot. The data were saved into the data logger and then transferred to a computer. The average monthly temperature and rainfall values in the experiment area in sowing month (May) were 18.2 ^{o}C and 59.6mm respectively.

4 units were placed on the frame in the strip tillage. The distance between the units is set to 70cm. In the first of the applications, the original Maschio Gaspardo-made striped soil tillage equipment (Figure 1) was used whereas the other two applications were modified machines. Conventional and three strip tillage treatments were performed on May, 3rd. The treatments included:

1. Conventional tillage (plough + Cultivator – float (2 times) (CT)
2. Original strip-till system (OST)
3. Modified Vertical shaft strip-till system (MVST)
4.Modified Horizontal shaft strip-till system (MHST)

The specifications of the tools used in the experiment are given Table 3. New Holland TD90 tractor was used in the experiments.

Figure 1
Original strip-tiller (OST)

While the originally vertical shaft tiller was having 10 units, we removed 6 units in modified machine (Figure 2).

Figure 2
Modified vertical shaft-tiller (MVST)

While the originally horizontal shaft tiller was having 12 units, we removed 6 units in modified machine (Figure 3).

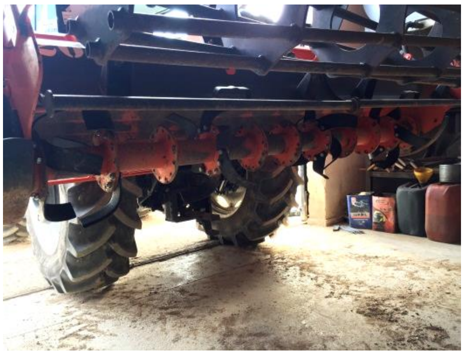

Figure 3
Modified horizontal shaft-tiller (MVST)

Table 3
The specifications of the tools used in experiment

	Average speed (km h^{-1})	Working depth (cm)	Working/strip width (cm)
Plough (5 bodies)	2.9	24	165
Cultivator-roller combination	6.15	18	220
Original strip tiller	5.21	22	28
Modified vertical shaft strip tiller	4.23	18	26
Modified horizontal shaft strip tiller	4.56	17	25

Silage maize variety TAREKS OSSK 644 was planted on May 7th. A pneumatic precision seeder with 4 rows was used for seeding. The seeder was a general-purpose Sakalak SK-PMB-4 seeder designed for row crops such as maize and soybean (Sakalak Company, Konya, Turkey). A seed plate operated in a vertical plane and required a vacuum of 3.5–8.0 kPa to select a seed. Air suction from the holes of the seed plate caused the seed to stick to holes 4.5 mm in diameter. Seed was released from the rotating plate by blocking air suction over the opener, which had no seed tube. Each seeding unit was independently mounted on a four-bar parallel linkage equipped with joint springs to apply downward force on the seeding unit and was composed of a furrow opener followed by a presswheel, which closed and compacted the seed furrow. The seed metering system was adjusted for a nominal seed spacing of 16 cm for maize in the row and a nominal depth of 5 cm. The seeder was calibrated in the laboratory before field operation. The seed metering system of planter was adjusted as 70 cm between rows.

In order to determine seedling emergence, the experiment field was observed throughout the emergence time and along with the beginning of the emergences, emergence counts were taken at two day intervals on spaces of 300 cm from each row. The values of average emergence day (MED),emergence rate index (ERI), and seedling emergence degree (PE) were calculated by using the values obtained from the counts in the equations given in Bilbro and Wanjura,1982:

$$MED = \frac{N1D1 + N2D2 + \cdots + NnDn}{N1 + N2 + \cdots Nn}$$

$$ERI = \frac{Total\ emerged\ seedling\ per\ meter}{MED}$$

$$PE = \frac{Total\ emerged\ seedling\ per\ meter}{Number\ of\ seeds\ planted\ per\ meter} x100$$

Where MED is mean emergence day; ERI is emergence rate index, seedlings day^{-1}m^{-1}; PE is percentage of emergence, %; N1…n is number of seedlings emerging since the time of previous count; D1…n is number of days after the seeding.

After approximately 45 days from seeding, the herbicide apply (Mustang, 100cc / da) was performed in all treatments.

3. Results and Discussion

The penetration resistance of tilled soil for conventional and three different strip tillage applications is given in Figure 4. As it is expected, the effect on penetration resistance of different applications was significantly (P<0.01). The greatest changes in penetration resistance occured for treatment CT, a decrease of 66.6 % compared with before tillage. Similar findings were reported by Erbach et al. (1992) and Çarman (1997). While there was not a difference between strip tiller on penetration resistance, there was a significant difference between conventional treatment to strip tiller. It was found that as the measurement depth increased, the penetration resistance also increased.

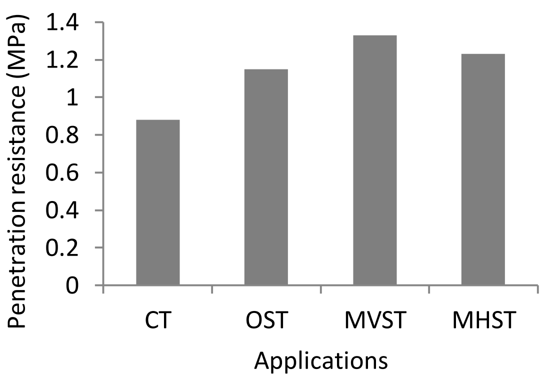

Figure 4

The effect of treatments on penetration resistance of soil.

Surface roughness of soil tillage is an impotant characteristic in assessing tillage performance. Figure 5 shows the effect of the tillage systems on the soil surface roughness. The effect of tillage systems on soil surface roughness was significantly (P<0.01). The soil surface after treatment CT had the greatest roughness (24.6 %). Çarman (1997) reported that the soil surface roughness was 55.1 % for conventional tillage. There was no significant difference between strip tiller.

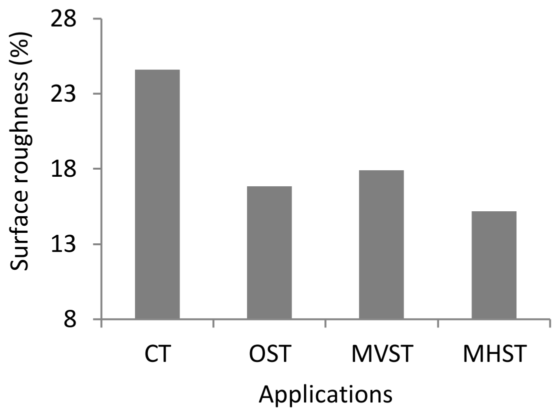

Figure 5

The effect of treatments on surface roughness of soil.

One of the important aims of strip tillage is to conserve soil moisture and to make the seedbed warm enough for germination. Until the seedling emergence is completed after seeding, soil moisture and temperature measurements were conducted periodically. The data obtained from measurement were given in Table 4. The results show that there was a significant differences in soil moisture status between the different tillage systems. In the study, soil moisture content in conventional tillage was determined to be lower compared strip tiller. As increasing the strip width, the moisture loss also increased with evaporation from the soil. As a consequence, soil moisture content was conserved in relatively narrower strips. Despite this, however, the difference between the stripping tillage practices was no significant. Licht and Al-Kaisi (2005) found that strip-tillage can be as effective as no-tillage in conserve soil moisture within the soil profile. As decreasing the strip width, it could be possible to reach the advantages of no-till (Çelik and Altıkat, 2010). Many studies have reported that by reduced soil tillage, plant residues left at the surface can conserve soil moisture.

Table 4
Soil moisture content and seedbed temperature

	Soil moisture content (%)	Seedbed temperature (°)
	0-10 cm	0-10 cm
CT	20.95[a]±0.823	19.30[a]±0.535
OST	22.55[b]±0.896	17.97[b]±0.359
MVST	23.42[b]±0.888	17.55[b]±0.331
MHST	23.95[b]±1.303	17.40[b]±0.632
LSD (0.05)	1.535	0.742

Changes in soil temperature magnitude due to strip tillage effects were highly dependent on air temperature throughout the day, when maximum air temperature often resulted in maximum soil temperature. As the soil is cultivated, the pass of air temperature to tillage layer gets easier. Temperature values measured in conventional tillage due to full width tillage were found to be 1-2°C more than in strip-tillage in Table 4. The results show that there was a significant differences in soil seedbed temperature status between the different tillage systems. As increasing strip width, the temperature at top soil layer (0-10cm) increased. This finding suggests that topsoil under conservation had lower heat capacity and greater thermal conductivity than strip-tillage due to lower moisture content. The change in soil temperature due to tillage effect was not reflected in improvement of plant emergence rate index.

The effects of different tillage systems on the emergence rate index and seedling emergence degree were summarized in Table 5. In all applications, seedling emergence degree values were found well above the limit value (>50 %) (Anonymous 1999). It can be concluded that the moisture content and temparature in the soil effects mean emergence time and percent emergence of seeds. MVST and OST applications performed better than the conventional tillage, according to the percent emergence and emergence rate index. The effect of the tillage systems on emergence rate index and seedling emergence degree was significant (P<0.01). The highest emergence rate index and seedling emergence degree were obtained from treatment MVST, and treatment MHST gave the lowest emergence rate index and seedling emergence degree. There was no significant difference between strip tillage treatment.

In the strip tillage used in corn production, while PE values were obtained lower as 61-76%, ERI values was higher than our results (Çelik and Altıkat, 2017). Seedling emergence degree of conventional tillage was found to be higher compared to strip tillage in sugar beet production by Laufer and Koch (2017).

Table 5
Emergence rate index (ERI)and seedling emergence (PE)

	ERI	PE
CT	0.745[a]±0.013	83.75[ab]±2.500
OST	0.770[a]±0.018	88.25[a]±3.947
MVST	0.835[b]±0.024	89.50[a]±5.259
MHST	0.700[c]±0.008	80.00[b]±4.082
LSD(0.05)	0.026	6.269

The fuel consumption of the applications is given in Figure 6. As it is expected, the effect on fuel consumption of different applications was significantly (P<0.01). Results indicated that the CT system was the greatest consumer of fuel with 4.92 l da^{-1}. The strip tillage system with OST, MVST and MHST consumed 63 %, 73.5 % and 85 % less than the CT system respectively. As shown in Figure 6, the fuel consumptions for the strip tilage methods were approximately 1/2.7 to 1/6.7 of that for the full width tillage method. This big difference in fuel consumption is due to the higher number of tractor trips and tilling operations associated with the full width tillage method. Although the difference between fuel consumption of the full width tillage and strip tillage systems is noticeable, the decision to use a strip tillage method will depend on other factors, too.

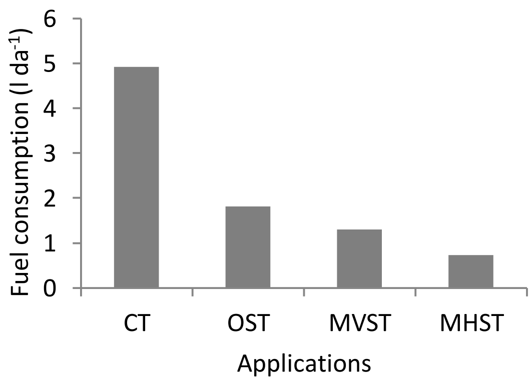

Figure 6
The effect of treatments on fuel consumption.

4. Conclusion

The possible impact of this research is that farmers can benefit from advantages of a strip tillage system by modifying the vertical or horizontal shaft rotatiller existing in farm. Modifying the conventional tillage equiment commonly used in Turkey may be a key factor in the shift to strip tillage. On the basis of this research we reached the following conclusions.

Strip tiller did not significantly affect soil penetration resistance and soil surface roughness. Residue between strips reduced water evaporation from the soil, and gave more time for the water to redistribute within the soil profile. Soil moisture content increased as strip width decreased and a 25 cm strip width (MHST) conserved more moisture at the 0–10 cm depth compared to the 28 cm strip width (OST). Soil temperatures at the top 10 cm soil layer for the strip tiller applications showed no significant differences during the seed emergence period. However, the soil temperature associated with the 25 cm strip width (MHST) was generally lower than other strip tillage.

The full width tillage operations (CT) have higher fuel consumption, due to an increased number of tractor trips and higher working depth.

The greatest total percentage of seed emergence was 89.50 % and occurred for the MVST while the smallest emergence was 80 % and occurred for the MHST application. In MVST application, the average seed emergence was found to be 6.8 % higher than the full width tillage (CT) application. Based on these results, Because of the highest seed germination percentage for the MVST application, this practice is recommended to the Middle Anatolia. Inaddition, considering the threat of wind erosion in the region, strip tillage applications is recommended.

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