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Effects of ridge and conventional tillage systems on soil properties and cotton growth

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Abstract

Cotton (*Gossypium hirsutum* L.) seeds are susceptible to low temperature and excess moisture in soil during seed emergence in years with high rainfall and low temperature in spring. Therefore, a two-year field experiment was carried out to evaluate effects of ridge tillage formed in autumn (RT-I), ridge tillage formed about a month before planting (RT-II) and flat conventional tillage (CT) cultivation systems on physical properties of soil and cotton growth. The RT-I and RT-II resulted in higher soil temperature and lower soil penetration resistance than CT at all depths. The RT-II gave highest emergence, earliest maturity and greatest seed cotton yield. In conclusion, ridge tillage formed a month before planting may be considered a good agronomic practice because it can provide favorable physical conditions in soil, while also improving growth and yield of cotton under weather conditions in spring in South East Anatolia Region of Turkey.

Keywords: Cotton; Emergence; Ridge tillage; Yield; Soil properties.

Introduction

Ridge tillage is a cultural practice widely used throughout the world with many different modifications but with the same goal; to prepare a seedbed that is elevated above the mean land surface of field. It changes soil temperature, compaction and water patterns compared to conventional tillage. These changes lead to an improved soil environment for crop emergence and early growth because of warmer soil temperatures and better water relations in both poorly drained and moderately well-drained soils during the early growing period (Benjamin et al., 1990; Lal, 1990; Hatfield et al., 1998; Mert et al., 2006).

The temperature, moisture and compaction of soil in the seedbed zone are very important parameters in promoting or delaying seed germination and plant emergence.

Therefore, healthy plant growth and development require soil conditions that have adequate soil moisture and temperature, and minimal root penetration resistance. Effective tillage systems create an ideal seedbed condition (i.e., soil moisture, temperature and penetration resistance) for seed germination, plant development, and unimpeded root growth (Tisdall and Hodgson, 1990; Taylor and Brar, 1991; Materechera and Mloza-Banda, 1997; Theodore and Gemtos, 2002; Atkinson et al., 2007; Krause et al., 2009).

Penetration resistance is a common measure of soil strength. The soil compaction increases penetration resistance and restricts root growth. Therefore, a reduction of crop growth and yield is attributed to penetration resistance (Raper et al., 2000; Raza et al., 2007).

The earliness is of great importance to cotton production in South East Anatolia Region of Turkey due to detrimental effects of autumn rainfall on lint quality. The preliminary earliness indicators of cotton are the first flowering date, node number of the first fruiting branch and the first picking percentage (Kerby et al., 1990; Panhwar et al., 2002). There are reports that ridge tillage systems could help yield increase and earliness by improving soil water and temperature regimes in root zone during the early growing period (Benjamin et al., 1990; Lal, 1990; Mobley and Albers, 1993; Hatfield et al., 1998; Stathakos et al., 2006). Previous researches have shown that crop yield was higher under ridge tillage than conventional tillage (Tisdall and Hodgson, 1990; Constable et al., 1992; Mert et al., 2006; Stathakos et al., 2006; Krause et al., 2009). Researches have also reported contradictory results on yield responses of cotton to ridge tillage due to climate, topography, soil properties and ridge formation procedures (Kennedy and Hutchinson, 2001; Özpinar and Isik, 2004; Yalçın et al., 2005).

In irrigated areas of South East Anatolia Region of Turkey, production systems are dominated by cotton and maize, in rotation with mainly wheat. Cotton planting system in this region is characterized by conventional tillage including mouldboard plough, cultivator and scrubber. In this planting system, plant emergence and growth are retarded due to low soil temperatures and excess moisture in years with high rainfall and low temperature in spring. Therefore, ridge tillage system, where crops are planted on ridges formed by using special equipment, is used in many countries. The ridges formed by using a ridge lister in autumn after primary tillage with moldboard or chisel plough are reformed and pressed with a ridge scrubber before planting. The ridges usually differ in shape, height and spacing, and moreover time of ridge forming.

The objective of this study was to evaluate short-term effects of ridge and conventional tillage systems on soil physical properties [soil temperature, penetration resistance, water content], seed emergence rate, some earliness parameters (first flowering date, number of first fruiting branch and first picking percentage) and yield of cotton after wheat in irrigated areas of South-East Anatolia Region of Turkey.

Materials and Methods

A two-year field experiment was carried out during 2004 and 2005 growing season at the research station of South East Anatolia Research Institute in Diyarbakir, Turkey. The experimental station is located 37º55'36" N, 40º13'49" E at 670 m above sea level. The South East Anatolia region of Turkey is characterized by a semi-arid climate (humid winters and dry summers). The long-term average of precipitation was 488.4 mm, about 80% of which occurs from November to May. The cotton is planted from late April to early

May in region. Monthly rainfall during the experimental years and the monthly average rainfall over the long term (62 years) are shown in Figure 1. In April, rainfall was higher in 2004 than that in 2005. In May, rainfall was higher in 2004 than long-term average and in 2005. Temperature records are summarized in Figure 2. There were no considerable differences in temperature between the growing seasons in 2004, 2005 and long-term averages. But, April and May had lower mean temperature in 2004 than in 2005. The soil (0-20 cm) of the experimental field was clay loam, with pH of 7.6, organic matter content of 15.3 g kg^{-1}, ECe of 1.92 dS m^{-1}, $CaCo_3$ of 95 g kg^{-1} and extractable P of 40 kg P ha^{-1}.

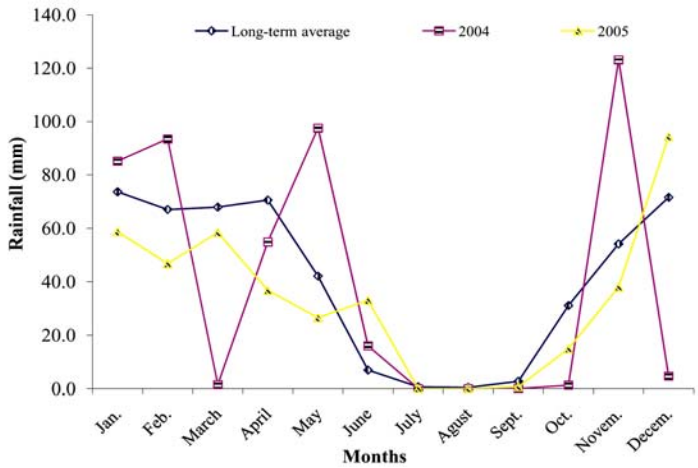

Figure 1. Long-term average monthly rainfall at Diyarbakir and monthly rainfall during two years.

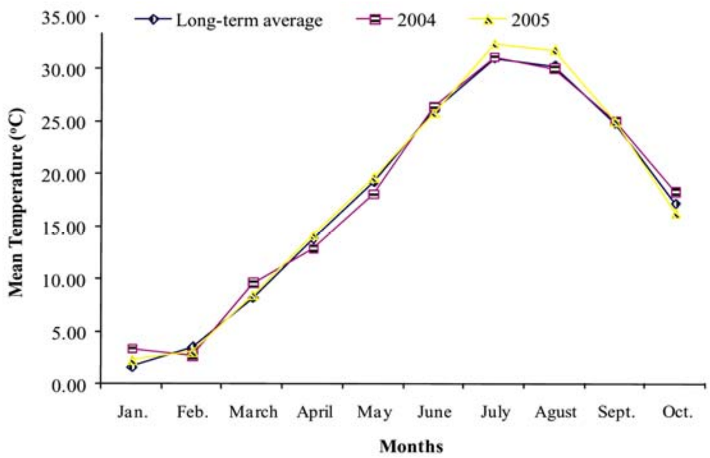

Figure 2. Long term average monthly temperature at Diyarbakir and average monthly temperature during two years.

Wheat was the previous crop at the experimental site in both years. Wheat as a winter crop was harvested in late June to early July. The residue after wheat harvest was collected for livestock. Moldboard plowing to 25 cm depth was used as primary tillage in November in both years. Conventional tillage (CT) corresponded to typical practices in the South-East Anatolia of Turkey. This system included an autumn moldboard plowing followed by cultivator to 10 cm depth in April, and then pressing with a scrubber. The ridge tillage (RT) consisted of a modified lister and scrubber. The combination of modified lister and scrubber was used to form and press the ridges. The ridges had approximately 12 cm height and 31 cm width at the base. Two different ridge tillage systems [ridge tillage formed in autumn (RT-I) and ridge tillage formed a month before planting (RT-II)] were used in the experiment. In the RT-I, ridges were formed in autumn by using combination of modified lister and scrubber after moldboard plowing. In the RT-II, moldboard plowing was used in autumn and ridges were formed by using combination of modified lister and scrubber about a month before planting.

A randomized complete block design with four replications was used in this study. Plot size was 84 m^2 (30 m × 2.8 m). The space between rows was 0.7 m. Maraş-92, standard cotton cultivar for the region, was planted at seed rate of 60 kg ha^{-1} by using a mechanical seed drill on 11 May 2004 and 28 April 2005. The sowing depth was adjusted approximately 5 cm in all plots. The plots were thinned to 25 cm at the third and fourth true leaf stage in both years. A compound (20-20-0%; N-P_2O_5-K_2O) fertilizer to supply 60 kg N plus 60 kg P_2O_5 ha^{-1} was applied as basal fertilizer at planting, and 100 kg N ha^{-1} as ammonium nitrate (33% N) was applied before first irrigation. One hand hoeing, and three machine hoeings with cultivator, rotary hoe and lister were made to loose, aerate the soil and control the weeds. Experimental plots were irrigated by furrow irrigation method 7 times at approximately 13 days intervals during the growing seasons each year. For a given irrigation, all plots received the same amount of water.

Soil temperatures were determined by using mechanical soil thermometer at 0-5, 5-10, 10-15 cm soil depths 4 days after planting in both years. Penetration resistance was measured by using hand penetrometer, on which the scale ranged from 0 up to 1.0 kN, the conical point was 1 cm^2 in area and point angle was 60°, at 0-10, 10-20, and 20-30 cm soil depths. At the same time when soil temperature and penetration resistance were measured, soil samples were taken to determine gravimetric moisture content at 0-10, 10-20, and 20-30 cm soil depth. In all plots, measurements were made on rows.

Seed emergence rate was calculated as the ratio of plants emerged about 7 days after planting to seeds sown on 2 m of two center rows. The first flowering date was determined as the number of days from planting to 50% of plants with the first opening flower. Node number of first fruiting branch was determined by counting nodes from the cotyledonary node to the first fruiting branch. To determine seed cotton yield, the middle two rows of each plot were harvested by hand two times in both years. The first harvest was performed when approximately 80% of cotton bolls were opened and the second harvest was 20 days after the first harvest. The first picking percentage was calculated by dividing the first harvested seed cotton to total seed cotton in two harvests.

The data on all variables were subjected to analysis of variance (ANOVA) using SAS, and mean comparison was made using Fisher's unprotected LSD at $P \leq 0.05$ (SAS, 2002). Homogeneity of variance tests was done before combining across years in the combined ANOVA.

Results and Discussion

Soil temperature

The effect of tillage treatments on soil temperature in different depths is presented in Table 1. Combined analysis across years indicated that tillage treatments had significant effect on soil temperature at all depths. While year influenced soil temperature at 0 to 5 cm and 10 to 15 cm depths, it had no significant effect at 5 to 10 cm depth. Among tillage treatments, RT-I and RT-II had higher soil temperature than CT. Soil temperature was approximately 1 ºC higher in treatments where cotton was planted under RT than under CT. These treatment differences are most likely the result of enlarged soil surface in RT because it has likely advanced absorption of incident heat radition, due to the more favourable angle of incident for sun rays at ridge legs under RT compared to flat soil under CT, Our results support the view of Potter et al. (1985), Benjamin et al. (1990), Stathakos et al. (2006), Krause et al. (2009), who reported that RT accelerated warming of seed zone.

Table 1. Effect of tillage treatments on soil temperature in different depths.

Tillage[a]	Soil temperature (°C)								
	0-5 cm			5-10 cm			10-15 cm		
	2004	2005	Mean	2004	2005	Mean	2004	2005	Mean
RT-I	19.75	19.00	19.37[ab]	16.75	16.87	16.81[a]	13.37	13.87	13.62[a]
RT-II	20.00	19.25	19.62[a]	16.87	16.87	16.87[a]	13.37	14.37	13.87[a]
CT	18.75	18.00	18.43[b]	15.25	15.50	15.37[b]	11.75	13.12	12.43[b]
Mean	19.4[ab]	18.65[b]		16.13	16.41		12.8[b]	13.8[a]	
Analysis of variance, mean square									
Year, 1 df[c]			3.76[nsd]			0.09[ns]			5.51[ns]
Tillage, 2 df			3.13[**e]			5.76[**]			4.71[**]
Year x tillage, 2 df			0.01[ns]			0.03[ns]			0.38[ns]
Error, 12 df			0.39			0.52			0.49
C.V.[f]			3.27			4.41			5.29

[a]RT-I, ridge tillage formed in autumn; RT-II, ridge tillage formed a month before planting; CT, conventional tillage; [b]Values within a column for the three treatments, or values in the row for the two year means, followed by the same or no letter (s) are not significantly different at the 5% level of the LSD test; [c]df, degree of freedom; [dns], not significant; [e**], significant at the 0.05 probability; [f], Coefficient of variation.

Soil penetration resistance

The ANOVA showed that soil penetration resistance was significantly affected by tillage systems. The RT systems had lower soil penetration resistance than CT at 0 to 10 cm and 10 to 20 cm depths. While there was no significant difference between RT-I and CT, the RT-II had the lowest soil penetration resistance at 20 to 30 cm depth (Table 2). Similarly, László and Gyuricza (2004) reported that RT resulted in lower penetration resistance in the upper 20 cm soil than CT. In all tillage systems, penetration resistance increased with soil depth reaching a maximum at about 20 to 30 cm depth. At this soil depth, penetration resistance was higher than 2.0 MPa, the resistance at which cotton taproot penetration was about 40% compared with that on where root penetration was not impeded (Taylor and Gardner, 1963). The threshold value was reached at 10 to 20 soil depth in both RT-I and CT systems.

Table 2. Effect of tillage treatments on soil penetration resistance in different depths.

Tillage[a]	Soil penetration resistance (MPa)								
	0-10 cm			10-20 cm			20-30 cm		
	2004	2005	Mean	2004	2005	Mean	2004	2005	Mean
RT-I	1.344	1.463	1.404[bb]	1.922	2.186	2.054[b]	2.854	2.952	2.903[a]
RT-II	1.210	1.169	1.189[b]	1.819	1.797	1.808[b]	2.630	2.371	2.500[b]
CT	1.595	2.033	1.814[a]	2.189	2.677	2.433[a]	3.103	3.267	3.185[a]
Mean	1.417	1.555		2.014	2.220		2.912	2.863	
Analysis of variance, mean square									
Year, 1 df[c]			0.177[nsd]			0.354[ns]			0.007[ns]
Tillage, 2 df			0.805[**f]			0.793[**]			0.947[*e]
Year x tillage, 2 df			0.119[ns]			0.130[ns]			0.103[ns]
Error, 12 df			0.068			0.080			0.090
C.V.[g]			17.8			13.48			10.51

[a]RT-I, ridge tillage formed in autumn; RT-II, ridge tillage formed a month before planting; CT, conventional tillage; [b]Values within a column for the three treatments, or values in the row for the two year means, followed by the same or no letter (s) are not significantly different at the 5% level of the LSD test; [c]df, degree of freedom; [dns], not significant; [e*], significant at the 0.05 probability; [f**], significant at the 0.01 probability; [g], Coefficient of variation.

Soil moisture content

The ANOVA over two years indicated that while tillage system had significant effect on soil moisture content at 0 to 10 cm and 10 to 20 cm depths, there was no difference among tillage systems at 20 to 30 cm soil depth. The soil moisture content at 0 to 10 cm and 10 to 20 cm depths was higher in 2004 which had higher rainfall during April and May than in 2005. But, at 20 to 30 cm soil depth, it was lower in 2004 because of excessively low rainfall during March (Table 3, Figure 1). While RT systems had lower soil moisture content than CT at 0 to 10 cm and 10 to 20 cm depths, there was no significant difference among tillage systems at 20 to 30 cm soil depth. The greater surface area of RT most probably resulted in reduced soil moisture content. Our results support the view of Potter et al. (1985), Benjamin et al. (1990), Stathakos et al. (2006), Krause et al. (2009) who confirmed that RT accelerated drying of seed zone.

Table 3. Effect of tillage treatments on soil moisture content in different depths.

Tillage[a]	Soil moisture content (%)								
	0-10 cm			10-20 cm			20-30 cm		
	2004	2005	Mean	2004	2005	Mean	2004	2005	Mean
RT-I	24.97	21.40	23.18[bb]	26.55	22.86	24.70[b]	26.70	26.93	26.82
RT-II	27.22	20.15	23.69[b]	28.15	23.41	25.78[b]	29.15	26.71	27.93
CT	27.69	23.71	25.70[a]	28.50	25.96	27.23[a]	26.06	28.66	27.36
Mean	26.3[ab]	21.7[b]		27.8[a]	24.1[b]		26.7	27.4	
Analysis of variance, mean square									
Year, 1 df[c]			142.41[**f]			80.121[**]			0.101[ns]
Tillage, 2 df			14.17[*e]			12.851[**]			2.486[ns]
Year x tillage, 2 df			7.33[nsd]			2.419[ns]			12.65[ns]
Error, 12 df			2.77			1.12			2.47
C.V.[g]			6.88			4.07			5.74

[a]RT-I, ridge tillage formed in autumn; RT-II, ridge tillage formed a month before planting; CT, conventional tillage; [b]Values within a column for the three treatments, or values in the row for the two year means, followed by the same or no letter (s) are not significantly different at the 5% level of the LSD test; [c]df, degree of freedom; [dns], not significant; [e*], significant at the 0.05 probability; [f**], significant at the 0.01 probability; [g], Coefficient of variation.

Seed emergence rate

The effect of tillage treatments on seed emergence rate is presented in Table 4. The RT-II increased seed emergence rate by 6.49% in 2004 and 3.94% in 2005 compared to CT. This difference between RT-II and CT according to years may have resulted from the variability of rainfall and temperature in 2004 and 2005 years. During May, rainfall was higher and temperature was lower in 2004 than in 2005 (Figure 1, Figure 2). The RT resulted in warmer top soil temperature under wet and cool conditions in 2004. The higher soil temperature probably increased the seed emergence rate. Similar results were presented by Licht and Al-Kaisi (2005) who found that the 1.2-1.4 °C increase in soil temperature at 0 to 5 cm depth contributed to an improvement in plant emergence rate index and corn growth. Also, Morrison and Gerik (1983) determined that higher soil water content caused lower soil temperatures and in turn reduced seed germination and emergence.

Table 4. Effect of year and tillage treatments on seed emergence rate (SER), the first flowering date (FFD) and number of the first fruiting branch (NFFB) of cotton.

Tillage[a]	SER (%)			FFD (day)			NFFB (node plant^{-1})		
	2004	2005	Mean	2004	2005	Mean	2004	2005	Mean
RT-I	87.50	84.19	85.84[abb]	72.50	75.75	74.12[a]	5.80	3.17	4.48[b]
RT-II	90.50	85.62	88.06[a]	67.75	74.75	71.25[b]	6.80	3.72	5.26[a]
CT	85.00	82.37	83.68[b]	71.25	76.25	73.75[a]	5.75	3.12	4.44[a]
Mean	87.66[ab]	84.06[b]		70.5[b]	75.5[a]		6.1[a]	3.3[b]	
Analysis of variance, mean square									
Year, 1 df[c]			77.83[*e]			155.04[**]			46.20[**]
Tillage, 2 df			32.28[**f]			19.54[**]			1.71[**]
Year x tillage, 2 df			2.66[nsd]			7.04[ns]			0.135[ns]
Error, 12 df			4.75			2.29			0.21
C.V.[g]			2.54			2.07			9.79

[a]RT-I, ridge tillage formed in autumn; RT-II, ridge tillage formed a month before planting; CT, conventional tillage; [b]Values within a column for the three treatments, or values in the row for the two year means, followed by the same or no letter (s) are not significantly different at the 5% level of the LSD test; [c]df, degree of freedom; [dns], not significant; [e*], significant at the 0.05 probability; [f**], significant at the 0.01 probability; [g], Coefficient of variation.

Earliness

First flowering date, node numbers of first fruiting branch and first picking percentage were considered as preliminary earliness indicators of cotton. According to the values obtained from two years, first flowering date was lower in RT-II than in RT-I and CT while the highest node numbers of first fruiting branch was obtained in RT-II. The RT-II had higher FPP than RT-I and CT (Table 4). The importance of earliness has been noted by many studies (Mert et al., 2006; Saleem et al., 2009). There are many components that can be managed to contribute earliness. Saleem et al. (2009) stated that earliness in cotton may be enhanced by decreasing the number of days taken for appearance of first flower or first boll splition or by lowering the node to the first fruiting branch. However, in our study, while first flowering date was lower, node numbers of first fruiting branch was higher. Many researchers used the first picking percentage as the earliness indicator of cotton. Mobley and Albers (1993), Yalçın and Uçucu (1999), and Mert et al. (2006) emphasised that ridge planting increased first picking percentage. In our study, first picking percentage was affected by year and tillage (Table 5). The RT-II improved earliness of harvesting by 16.35% in 2004 which had higher rainfall and lower temperature and by only 1.26% in 2005. These results indicated that RT-II planting system, especially in a wet season, may enhance earliness by improving soil water and temperature regimes in the root zone (Benjamin et al., 1990; Lal, 1990; Mobley and Albers, 1993; Hatfield et al., 1998; Stathakos et al., 2006).

Table 5. Effect of year and tillage treatments on the first picking percentage (FPP) and seed cotton yield.

Tillage[a]	FPP (%)			Seed cotton yield (kg ha^{-1})		
	2004	2005	Mean	2004	2005	Mean
RT-I	77.97^{cb}	90.35^{a}	84.16^{c}	4449.68	3728.27	4088.98^{ab}
RT-II	90.72^{a}	91.49^{a}	91.11^{a}	4861.56	3878.57	4370.06^{a}
CT	84.53^{b}	90.86^{a}	87.69^{b}	4244.37	3630.35	3937.36^{b}
Mean	84.4^{bb}	90.9^{a}		4518.54^{a}	3745.73^{b}	
Analysis of variance, mean square						
Year, 1 df[c]			253.17**[f]			35833.9**
Tillage, 2 df			96.493**			3866.45*[e]
Year x tillage, 2 df			67.53**			720.326ns[d]
Error, 12 df			9.62			787.31
C.V.[g]			3.53			6.97

[a]RT-I, ridge tillage formed in autumn; RT-II, ridge tillage formed a month before planting; CT, conventional tillage; [b]Values within a column for the three treatments, or values in the row for the two year means, followed by the same or no letter (s) are not significantly different at the 5% level of the LSD test; [c]df, degree of freedom; [d]ns, not significant; [e]*, significant at the 0.05 probability; [f]**, significant at the 0.01 probability; [g], Coefficient of variation.

Seed cotton yield

Seed cotton yield was affected by year and tillage. The highest seed cotton yield was obtained in the RT-II planting system (Table 5). While the RT-II planting system produced about 14.54% higher seed cotton yield than CT planting system in 2004, it had 6.83% higher seed cotton yield in 2005. This difference in seed cotton yield between RT-II and CT according to years may have resulted from the variability of rainfall and temperature in 2004 and 2005. The RT system probably resulted in warmer top soil temperature and plant growth under these wet conditions. Similar views were presented by Benjamin et al. (1990); Lal (1990); Mobley and Albers (1993); Hatfield et al. (1998); Stathakos et al. (2006) who reported that RT system could help increase yield and earliness by improving soil water and temperature regimes in root zone during the first growing period in wet season.

Conclusions

Sowing of cotton on ridges resulted in increased soil temperature at all depths, while it reduced penetration resistance and soil moisture content at 0 to 10 and 10 to 20 cm depths. At 20 to 30 cm depth, ridge tillage formed a month before planting had the lowest penetration resistance, and gave highest seed emergence rate, earliest maturity and greatest seed cotton yield. The findings suggest that ridge tillage formed a month before planting may be considered a good agronomic practice because it can provide favorable physical conditions in soil and improve cotton growth and yield under weather conditions in spring in South East Anatolia Region of Turkey.

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