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THE EFFECTS OF REDUCED TILLAGE AND COMPACTION LEVEL ON THE RED LENTIL YIELD

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Abstract

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A two year - field experiment was conducted to investigate the effects of three tillage treatments and three intra-row compaction levels on sowing performance, weed population, red lentil yield and yield components. The tillage treatments were: (1) conventional tillage (moldboard plow + disk harrow + float - CT); (2) reduced tillage 1 (horizontal axis rotary tiller - RT1); (3) reduced tillage 2 (vertical axis rotary tiller with roller - RT2). Intra-row compaction levels were: (1) no compaction (C0), (2) 60 kPa compaction (C1) and (3) 90 kPa compaction (C2).

Results concluded that reduced tillage systems provided the best results of sowing performance and weed density. However, the highest crop yield was observed at the plot with tilled conventional tillage systems. Additionally, the increase in the intra-row compaction level improved sowing performance and crop yields.

Key words: yield component, conventional tillage, sowing performance, weed density, penetration resistance

Abbreviations: T - Tillage; C – Compaction; CT - Conventional Tillage; RT1 -Horizontal axis rotary tiller; RT2 - Vertical axis rotary tiller; C0 - 0 kPa intra-row compaction level; C1 - 60 kPa intra-row compaction level; C2 - 90 kPa intra-row compaction level; SY - Seed yield; NPP - Number of pods plant^{-1}; PH - Plant height (cm); SW - 1000 seeds weight (g); FPH - First pod height (cm)

Introduction

Lentils are a cool-season annual cash crop, classified as a grain legume or pulse. Turkey is the largest red lentil exporter alongside Canada, Syria, Australia and China (Bicer, 2009).

The traditional farming practice involves a series of tillage operations that break up the soil into smaller chunks to provide weed-free seedbeds during sowing. This system increases erosion, as well as the risk of soil structural degradation, and results in marked losses of soil moisture (Govaerts et al., 2009).

Reduced tillage combined with crop residue retention on the soil surface can increase moisture infiltration (Azooz and Arshad, 1996; Shaver et al., 2002), greatly reduce erosion, and increase water use efficiency, compared to conventional tillage. Results of field research are increased moisture levels, decreased soil temperatures, and more stable soil aggregates in case of less tillage (Limon-Ortega et al., 2002).

Soil must be compacted at appropriate levels using a press wheel or roller in order to decrease moisture loss, and provide enough soil-seed contact. Altikat and Celik (2011) and Altikat et al. (2006) reported that moderate compaction could improve seed germination and seedling establishment.

Rapid and complete emergence of seeds improves the odds for obtaining good yields (Nasr and Selles, 1995). Gan et al. (1992) reported that even though there are other limitations, like frost or pest cycles, early seed emergence would contribute more to utilise the yield potential of a crop at the site than a delayed seed emergence. Thus, a seed with an environment that encourages early germination and emergence is required to achieve desirable crop yields.

Altikat et al. (2006) stated that intra-row compaction levels increased wheat seed germination and soil moisture content but had no effect on the seedbed temperature. A higher percentage of emergence and soil moisture content was obtained at an intra-row compaction level of 60 kPa. In anoth-

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er study, reduced tillage systems and intra-row compaction levels enhanced the percentage of seedling emergence, and physical properties of soil (Altikat and Celik, 2011).

The aim of this study was to determine the effects of reduced tillage and intra-row compaction on the, sowing performance, weed population, red lentil yield, and yield components.

Materials and Methods

Site Description

The experiment was conducted at the research farm of Ataturk University Erzurum, Turkey during 2006 and 2007 growing seasons. The region shows characteristics of the continental climate. The classification of the soil texture of the experimental field was loam. The experimental field was flat with a slope less than 1%. Some physical properties of the experimental field soil are illustrated in Table 1.

Experimental Design and Treatment Applications

The layout of the experiment was a randomised complete block design, with a factorial arrangement of treatments consisting of three soil tillage systems and three intra-row compaction levels with three replications. The experimental plots were 30 m long and 3 m wide. The soil tillage systems were; (1) conventional tillage (CT); (2) reduced tillage 1 (RT1), and (3) reduced tillage 2 (RT2). The tillage equipments used in tillage systems were; mouldboard plow + disk harrow + float in CT; horizontal axis rotary tiller in RT1 and vertical axis rotary tiller with roller in RT2.

The tractor forward speed was kept constant at 1.5 ms^{-1} in all tillage treatments. Rotor rotational speed was set at 270 rpm for reduced tillage systems (RT1, RT2). A DJRVS II speed radar and a DJCMS 100 monitor made by Dickey-John was used to achieve the tractor forward speed.

The intra-row compaction levels were: (1) no compaction (C0), (2) 60 kPa compaction (C1), and (3) 90 kPa compaction (C2). Rubber press wheels, with additional iron plate weights attached to each unit of a seed drill (Figure 1). The red lentil seed (Cv: Malazgirt 89) was planted in the second week of May in both 2006 and 2007, at a rate of 120 $kgha^{-1}$.

Table 1
Some physical properties of the experimental area

Characteristics	Description (0-0.15m depth range)
Sand, %	32.3
Silt, %	44.1
Clay, %	23.57
Texture class	Loam
Bulk density, mg m^{-3}	1.11
Penetration resistance, MPa	1.2
Moisture content, %	19.4

Measurements

After tillage, an Eijkelkamp analog penetrometer (Eijkelkamp Agrisearch Equipment, Giesbeek, The Netherlands), with a depth of 0-20 cm and 5 cm increments, was used to measure the penetration resistance.

Approximately six weeks after the emergence of seed, ten seedlings in each marked row were distracted to determine the uniformity of sowing depth of seeders. The chlorophyll-free stem and coleoptiles' length of seedlings were measured by accepting them to be effective seeding depth (Tessier et al., 1991). Uniformity of inter and intra–row seed distribution was checked using the distances of emerged plants randomly selected at 1–m distance in each plot. Theoretical inter–and intra-row distances were used to calculate standard deviation, variation coefficient and means.

First hand weeding was applied when the lentil reached a lenght of 11-13 cm on 30 May 2006 and 30 May 2007, respectively on 1 m^2. Second hand weeding was done at flowering state on 28 June 2006 and 28 June 2007 on 1m^2. Weeds were taken to the laboratuary to be dried in an oven at 65^0C for 24 h for determining dry weights (Elkoca et al. 2005).

Observations on plant height (cm), first pod height (cm), number of pods per plant, number of seeds per plant and seed weight per plant (g) were randomly taken from 10 plants. Thousand seed weight was determined for each plot from a sample of the seed harvested (Bicer, 2009).

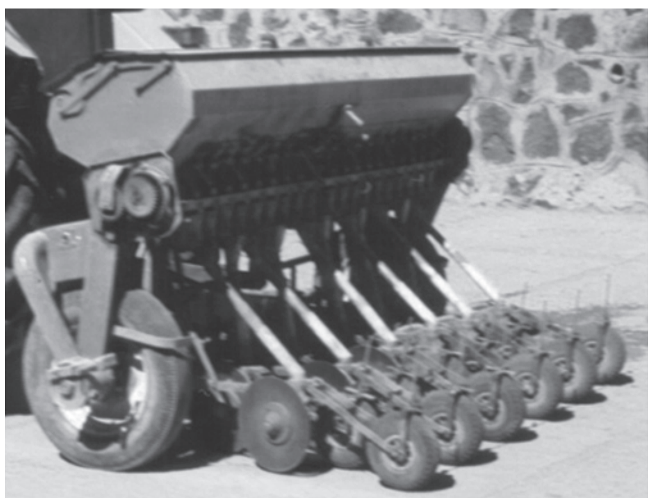


Fig. 1. Seed drill used in the experiment with rubber press wheels

Statistical Analyses

The ANOVA procedure, appropriate for randomised complete block design, was the procedure used to analyse the variance of obtained data. Means were compared using Duncan's multiple range tests.

Results

Penetration Resistance

Figure 2 illustrates the soil penetration resistance in response to tillage systems and intra-row compaction levels

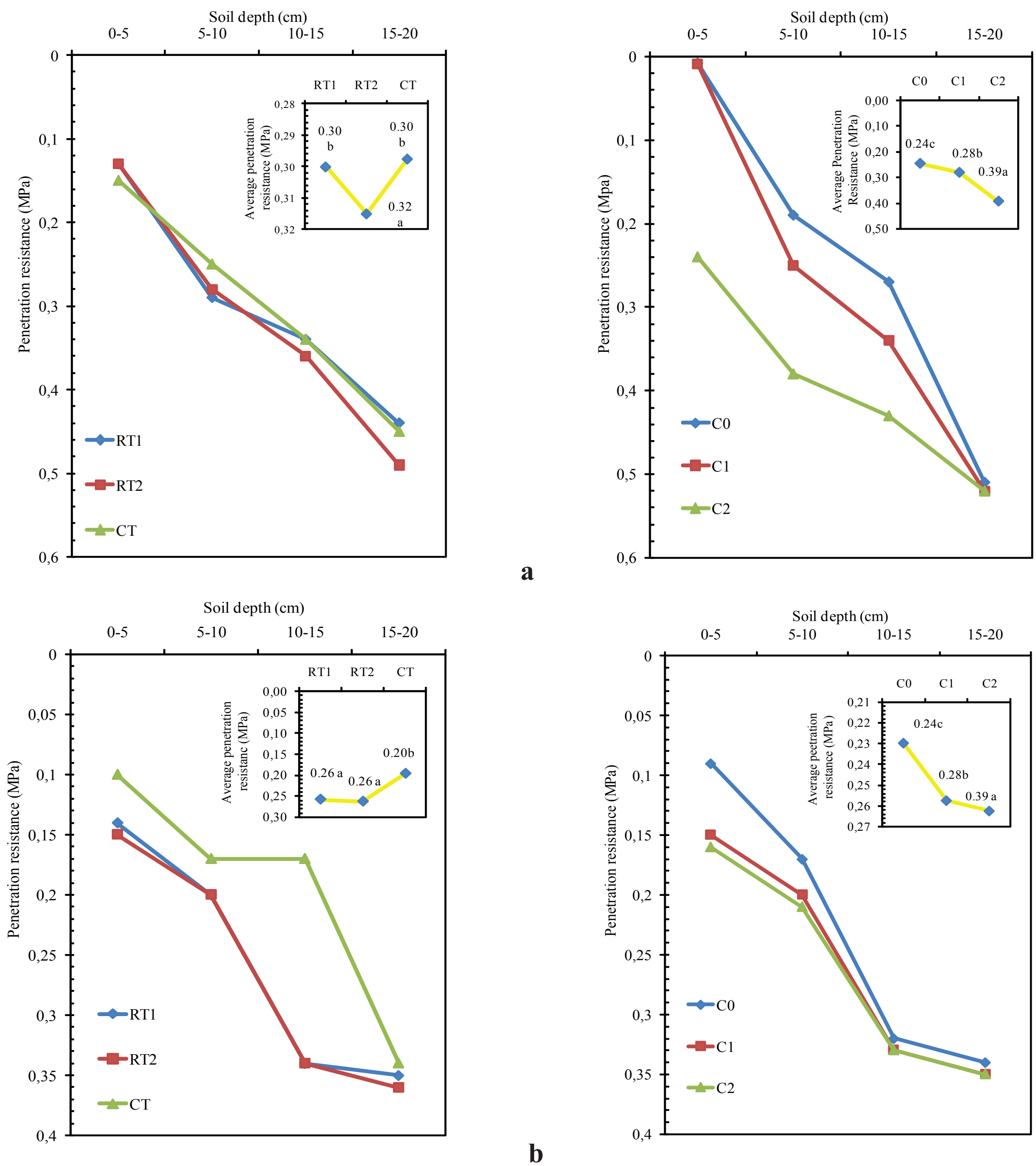


Fig. 2. The effects of tillage and intra-row compaction on the penetration resistance
a) 2006 and b) 2007

during 2006 and 2007 growing seasons. The soil penetration resistance was increased with increase in soil depth for all of the treatments. In 2006, at a depth of 20 cm the highest penetration resistance values were recorded using the RT2 system (0.49 MPa), and the lowest values were obtained using RT1 (0.44 MPa) and CT system (0.45 MPa). RT1 and RT2 tillage systems broke soil into small pieces, and caused lower penetration resistance than the CT system (Figure 2). The RT2 system caused highest penetration resistance under tillage depth in both years because of the roller attached to this system, and the lowest with the CT tillage system at all measuring depths.

In both years, the effects of intra-row compaction on the penetration resistance were statistically significant. C2 intra-row compaction level, caused the highest penetration resistance values, whereas C0 level caused the lowest penetration resistance (Figure 2).

Sowing Performance

In measurements conducted in order to determine the sowing depth uniformity, deviation of the measured amounts from the target sowing depth was determined. When the results related to these deviation values expressed as variation coefficient were examined, it was seen that RT1 had the lowest variation coefficient of sowing depth with 11.52 % and this system was followed by RT2 with 10.99 % and CT with 14.86 % in 2006 (Table 2).In this year the increase in intra-row compaction level decreased the variation coefficient of sowing depth. The variation coefficient of sowing depth, 13.09 % at C0 compaction level, decreased to 11.52 % at C2 compaction level (Table 2). Similar results were observed during the 2007 growing season. In this year, the highest variation coefficient of sowing depth was for the CT system (13.97 %), followed by RT2 (11.78 %) and RT1 (12.01 %). However, the increase in intra-row compaction level also decreased the

Table 2
Means comparisons of sowing performance

Treatments	2006	
	Sowing depth (% CV)	Intra-row sowing uniformity (%CV)
Tillage Systems (T)	11.52 b√	10.38 ns
RT1	10.99 b	10.87 ns
RT2	14.86 a	10.24 ns
CT		
Intra-row compaction (C		
C0 (0 kPa)	13.09 a	10.79 a
C1 (60 kPa)	12.75 a	10.88 a
C2 (90 kPa)	11.52 b	9.82 b
Analysis of Variance	P	P
T	0.001**	0.139
C	0.001**	0.006**
TxC	0.959	0.972
Treatments	2007	
Tillage Systems (T)		
RT1	12.01 b	10.65 ns
RT2	11.78 b	11.29 ns
CT	13.97 a	11.58 ns
Intra-row compaction (C		
C0 (0 kPa)	13.17 a	11.5 a
C1 (60 kPa)	12.96 a	11.51 a
C2 (90 kPa)	11.63 b	10.51 b
Analysis of Variance	P	P
T	0.004**	0.100
C	0.001**	0.040*
TxC	0.980	0.993

variation coefficient of sowing depth during the 2007 growing season (Table 2).

The effects of soil tillage systems and compaction levels on the variation coefficient in inter-row sowing uniformity were statistically insignificant for both 2006 and 2007. However, effects of soil tillage systems on the variation coefficient in intra-row sowing uniformity were statistically insignificant all of the experiment years.

Intra-row compaction levels were affected statistically significant on the variation coefficient in intra-row sowing uniformity in 2006 and 2007 growing seasons. The lowest variation coefficient of intra-row sowing uniformity was observed at C2 compaction level with 9.82 % and 10.51 % for 2006 and 2007, respectively (Table 2). Minimum values were determined at the plot with compacted C0.

Weed Density

The effects of soil tillage systems and intra-row compaction levels on weed densities are illustrated in Table 3. According to variance analysis, soil tillage systems had a statistically significant effect on weed densities during in both 2006 and 2007 growing seasons, but this effect was not observed for intra-row compaction levels. In the research, the most weed population values were at the plot with tilled reduced tillage systems, and the minimum values were obtained at the CT system (Table 3).

Crop yield and yield components

Variance analysis results for yield and yield components are illustrated in Table 4. The tillage systems, significantly affected the seed yield (SY), plant height (PH), first pod height (FPH), and number of pods plant $^{-1}$ (NPP) during both 2006 and 2007 growing seasons (Table 4).

The effect of tillage systems on the seed yield is illustrated in Figure 3a. According to the obtained results, the highest seed yield was obtained from CT systems as 588 kgha^{-1} and 591 kgha^{-1}, whereas RT1 gave the lowest seed yield as 483 kgha^{-1} and 454 kgha^{-1} in the first and second year, respectively. Plant heights of red lentil for each tillage systems in years 2006–2007 are illustrated in Figure 3b. The best results for plant height were obtained in CT in both years (27.02 cm in 2006 and 26.53 cm in 2007) in comparison with other tillage systems. This was due to the increased rooting depth in CT system.

Number of pods plant^{-1} was higher at the CT system in comparison to RT1 and RT2 (Figure 3c). The number of pods plant^{-1} in CT system was calculated as 24.85 in 2006 growing season and 20.67 in 2007 growing season. These values at the RT1 were determined as 17.17 and 15.15 for 2066 and 2007, respectively.

The highest first pod height was observed at the CT system in both 2006 and 2007. The first pod height at the plots tilled by CT system was 9.13 cm and 9.23 cm in 2006 and

Table 3
Means comparisons of weed density of tillage systems and intra-row compaction levels, (g m^{-2})

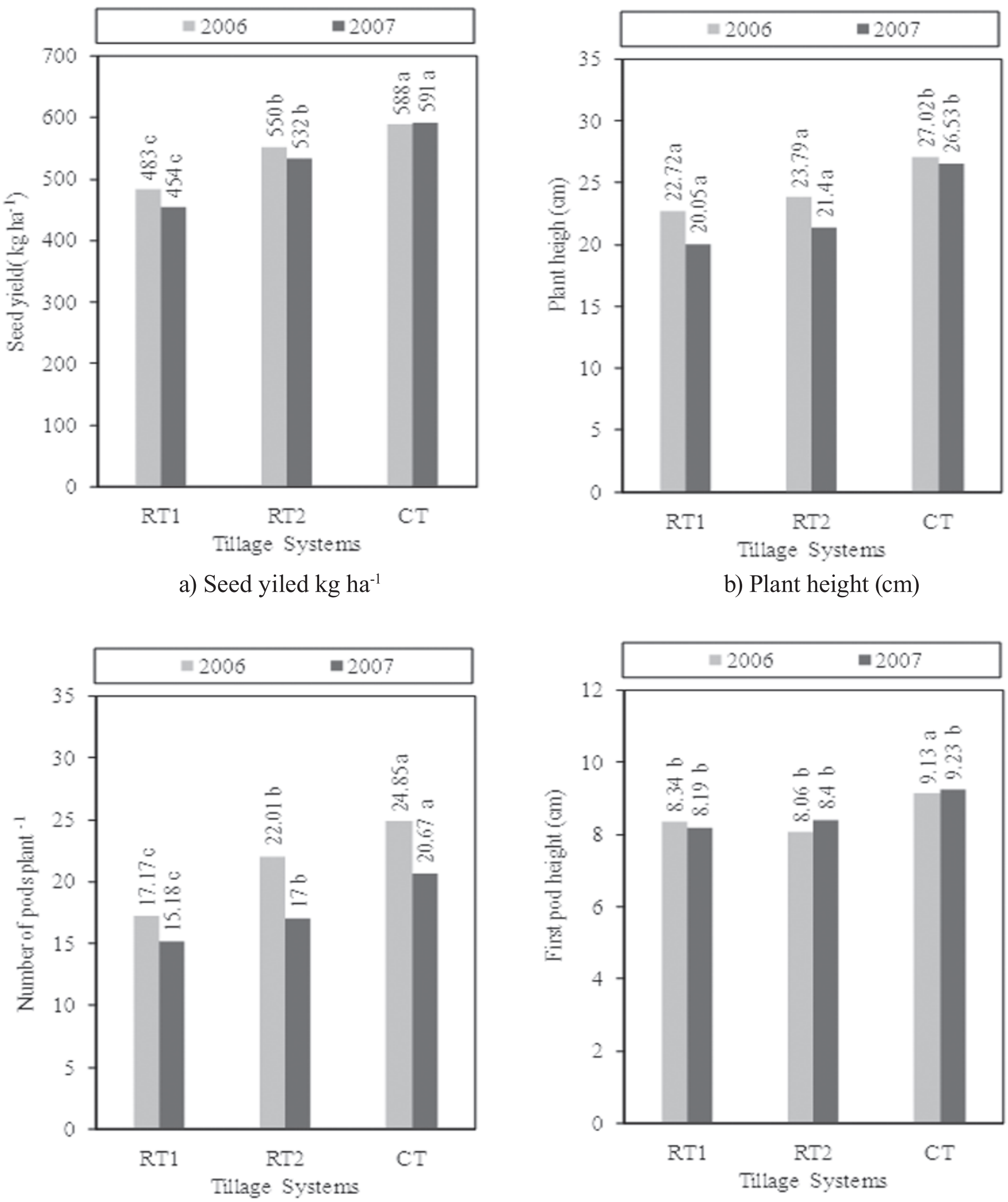
Treatments	2006		2007	
Tillage Systems (T)	30-May	28 June	30-May	28 June
RT1	50.5 a√	135.5 a	55.2 a	190.7 a
RT2	48.9 a	127 a	54.7 a	185.6 a
CT	31.2 b	90.9 b	30.3 b	98.2 b
Analysis of Variance	P	P	P	P
T	0.001**	0.001**	0.001**	0.001**
C	0.769	0.940	0.595	0.329
TxC	0.440	0.262	0.272	0.436

Table 4
Analysis of variance of yield and yield component

Treatments	Years	SY	PH	FPH	NPP	SW
Soil tillage (T)	2006	0.001**	0.001**	0.001**	0.001**	0.669 ns
	2007	0.001**	0.001**	0.001**	0.001**	0.774 ns
Compaction C	2006	0.001**	0.518 ns	0.163 ns	0.004 **	0.001 **
	2007	0.001**	0.173 ns	0.298 ns	0.034*	0.001**
TxC	2006	0.827 ns	0.307 ns	0.061 ns	0.719 ns	0.326 ns
	2007	0.817 ns	0.889 ns	0.888 ns	0.993 ns	0.193 ns

2007, respectively. However, minimum values were obtained at RT1 and RT2 systems (Figure 3d). Soil tillage systems had no effect on 1000-seed weight.

Intra-row compaction levels, only significantly affected the seed yield (SY), number of pods plant $^{-1}$ (NPP), and 1000 seeds weight in both 2006 and 2007 growing seasons (Table 4). Seed yield, number of pods plant^{-1} and 1000-seed weight increased with an increase in intra-row compaction level. The highest seed yield was observed at the C2 compaction level (565 kg ha^{-1} in 2006 and 556 kg ha $^{-1}$ in 2007) while the lowest seed yield was at C0 compaction level (524 kg ha^{-1} in 2006 and 506 kg ha^{-1} in 2007) (Figure 4a).The number of pods plant^{-1}, applied C2 intra-



a) Seed yiled kg ha^{-1}

b) Plant height (cm)

c) Number of pods plant^{-1}

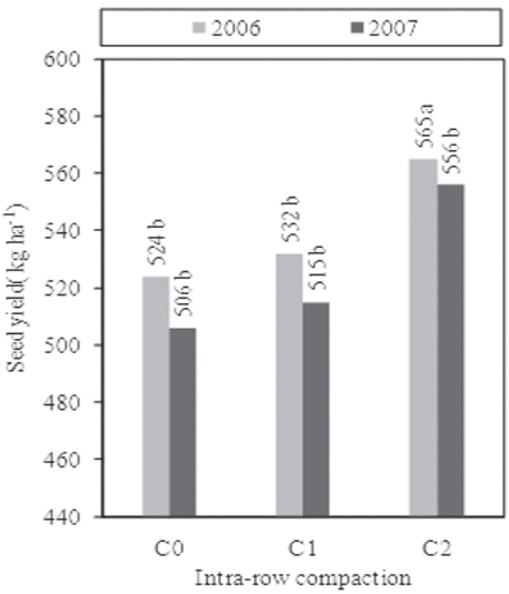
d) First pod height (cm)

Fig. 3. Effects of tillage systems on the yield and yield components

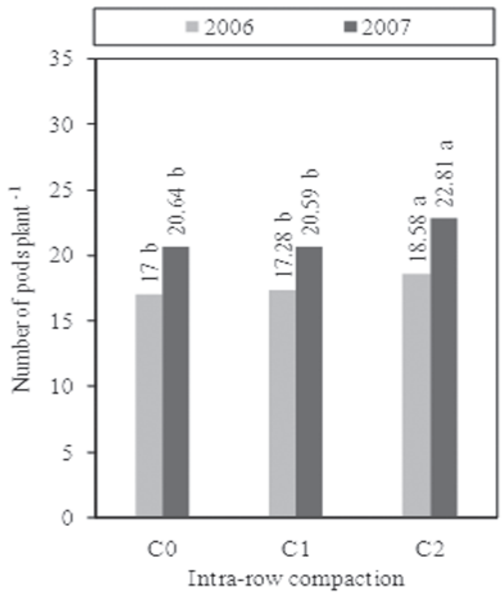
row compaction level, were 18.58 and 22.81 while these values were 17 and 20.64 for C0, 17.28 and 20.59 for C1 compaction level in 2006 and 2007, respectively (Figure 4b). In addition to these results, maximum 1000-seed weight was determined at the C2 intra-row compaction level (29.14 g in 2006 and 28.81g in 2007) and minimum value was observed at the C0 compaction level (27.05 in 2006 and 27.07 in 2007) (Figure 4c).

Discussions

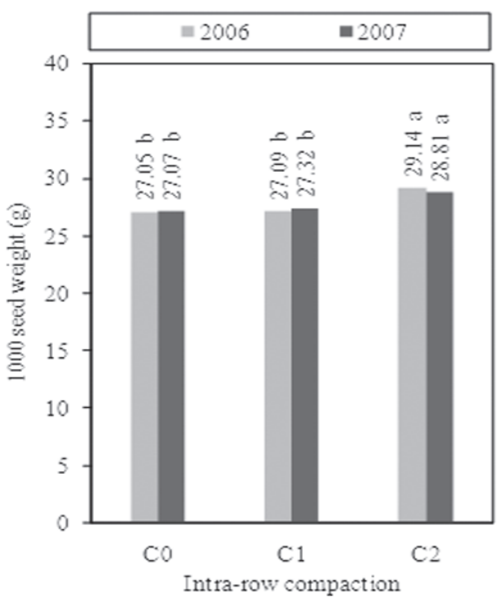
In the research, the penetration resistance values in all treatments at 0-20 cm depths were below the 2-3 MPa critical compaction level (Hakansson and Lipiec, 2000). Compaction above this level was accepted as slowing root growth (Vepraskas, 1994). Mosaddeghi et al. (2000) report-



a) Seed yield (kg ha^{-1})



b) Number of pods plant^{-1}



c) 1000 seed weight (g)

Fig. 4. Effects of intra-row compaction level on the yield and yield components

ed that soil compaction increases the soil penetration resistance values. Altikat et al. (2006) indicated that increasing intra-row compaction levels increased the penetration resistance.

Cultivation is still the primary method of weed control in the most crop production areas where annual mouldboard plough is used in production systems. Although herbicides have improved the viability of farmers and helped to reduce the risk of soil erosion, the weed control with cultivation is less expensive than herbicides, which may be seen as a potential ecological hazard (Felton and McCoy, 1992). In this research minimum weed population values were observed at conventional tillage system all of the experimental years. Ozpinar (2006) pointed out that the density of weed in reduced tillage was higher than that in CT. Similarly, Nakamoto et al. (2006) found that maximum weed population at the reduced tillage.

Compaction may significantly impair the production capacity of a soil. Compaction increases bulk density and penetrometer resistance while it reduces penetrability of roots to soil (Unger and Kaspar, 1994) and crop yield (Husnjak et al., 2002, Birkas et al., 2002). However, a limited degree of soil compaction under the seeding depth tends to increase the soil moisture content near planted seeds, encouraging capillary ascent of water from subsoil. Bicki and Siemens (1991) reported that a limited surface compaction is beneficial around the planted seeds because it provides a better seed-soil contact and rapid germination and reduces the rate of soil drying. Voorhees et al. (1986) and Swan et al. (1987) reported that limited soil compaction helped to increase the soybean yield. Altikat and Celik (2011) reported the maximum seed emergences were obtained at the 60 kPa intra-row compaction level.

Conclusions

In this study, we examined the effects of tillage and intra-row compaction on the sowing performance, weed population, red lentil yield, and yield components. According to obtained results, the penetration resistance increased with tillage depth and intra-row compaction. However, the penetration resistance values were below the critical level for root growth.

Reduced tillage systems had the lowest variation coefficient for sowing depth compared to CT. The increase of intra-row compaction level decreased the variation coefficient for sowing depth. The effects of soil tillage systems on the variation coefficient in intra and inter-row seed distribution uniformity were statistically insignificant for both 2006 and 2007. Soil tillage systems had a statistically significant effect on weed densities, but this effect was not observed for intra-row compaction levels. The most weed population values were observed at the plot with tilled reduced tillage systems and the minimum values were observed in the CT system.

The highest seed yield, numbers of pod plant^{-1}and first pod height were found in CT systems compared to reduced tillage systems. Intra-row compaction levels, significantly affected the seed yield (SY), number of pods plant^{-1} (NPP) and 1000 seeds weight. Increasing intra-row compaction level increased seed yield, number of pods plant^{-1} and 1000 seed weight during both 2006 and 2007 growing seasons.

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