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Full Length Research Paper

Effects of tillage on bulk density and soil moisture content in wheat-fallow rotation under dry conditions

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In the arid and semi arid region of Iran, conventional tillage is mainly used (Moldboard plowing followed by two disc harrowing) for wheat production. Such a tillage system requires a high energy input and may also cause water loss and long-term soil physical degradation. This field study was conducted under dry conditions to determine whether or not the reduced tillage systems altered the bulk density and soil moisture content. Thus, five tillage treatments (T_1-moldboard plow + disc harrow as the conventional method, T_2- chisel plow + disc harrow, T_3- moldboard plow without inversion page + disk harrow, T_4- power harrow, and T_5- sweep plow + disk harrow) were studied during the three year period (2004 to 2007) in soils with silty clay loam texture. Soil moisture in four depths (0-10, 10-20, 20-30 and 30-40 cm) was measured at the flowering and grain filling stages. Generally, the lowest soil bulk density was obtained by T_1 treatment. There were significant differences among tillage methods for soil moisture at the flowering stage ($P < 0.05$) and T_1 treatment had the highest value. There were no significant differences among soil tillage methods for soil moisture at the grain filling stage. Overall, chisel plow + disc harrow treatment was recognized as the best tillage method due to the remains of stored soils at the grain filling stage.

Key words: Bulk density, dry conditions, soil moisture, tillage.

INTRODUCTION

Due to the fact that wheat crop has a vital role in the national economy and an acceptable performance in dry conditions, it is seen as the most vital food crop in Southwestern Iran, especially in Gachsaran region. However, drought stress is an important limiting factor, especially in sensitive stages, such as grain filling stage, which can cause major loss in wheat productivity in arid and semi arid regions of Iran (Ahmadi et al., 2009). Therefore, keeping of soil moisture at critical stages, such as grain filling stage, under dry conditions is very important. Different factors, such as mulch (Yang et al., 2006; Hadrian et al., 2006), organic matter (Hudson, 1994; Igwa, 2005; Sultani et al., 2007) and polymer (Rifat and Safdar, 2004; Bai et al., 2010), and different soil tillage applications (Mrabet, 2000; De Vita et al., 2007; Erenstein et al., 2008) used to decrease the water loss from soil were extensively studied.

Under dry farming conditions, among the applications used to maintain soil moisture, the suitable choice of the tillage methods is very important, because soil characteristics and climate of various regions are different; therefore, the effect of tillage methods on soil properties from region to region varies (Mujdeci et al., 2010). On the other hand, proper tillage practices used to reduce surface runoff and increase infiltration rates can lead to more stored soil moisture. Conventional tillage practices modify soil structure by changing its physical properties, such as soil bulk density, soil penetration resistance and soil moisture content. Annual disturbance and pulverizing caused by conventional tillage produce a finer and loose soil structure as compared to conservation and no-tillage method which leaves the soil intact (Rashidi, 2007). Alternatively, conservational tillage methods often result to decreased pore space (Hill, 1990), increased soil strength (Bauder et al., 1981) and

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Table 1. Soil physical and chemical characteristics of the study area.

Soil characteristics	Values
Texture	Silty clay loam
Bulk density (mg kg^{-1})	1.59
Organic carbon (%)	0.875
SP (%)	34.9
pH	7.54
EC (dS m^{-1})	1.6
Available P (mg kg^{-1})	7
Available K (mg kg^{-1})	322
Available Fe (mg kg^{-1})	8.3
Available Mn (mg kg^{-1})	18.14
Available Zn (mg kg^{-1})	1.3
Available Cu (mg kg^{-1})	1.7

stable aggregates (Horne et al., 1992). However, many researches reported that the ability to hold water in low and no-tillage methods in comparison with conventional methods increases (Chaudhary et al., 1992; Rasmussen, 1999; Mrabet, 2000; Martinez et al., 2008; Erenstein et al., 2008). Despite the importance of choosing appropriate tillage methods, especially to prevent waste of water in dry conditions, most tillage operations in Gachsaran region were done traditionally (Moldboard plowing, followed by two disc harrowing). Such a tillage system requires a high energy input and may also cause water loss and long-term soil physical degradation (Barzegar et al., 2004). Therefore, appropriate tillage methods, in addition to reducing fuel costs and water loss, can cause the prevention of soil physical degradation. However, the result of different tillage practices under dry conditions depends on soil characteristics, climate conditions and cultivation equipment, and even the plant material used may be different for different regions. Thus, the objective of this study is to find the effects of different soil tillage methods on bulk density and soil moisture content under dry farming conditions and if possible choose the best tillage method.

MATERIALS AND METHODS

A field experiment was conducted as factorial based on completely randomized block design with four replications to evaluate different tillage methods in wheat-fallow rotation under dry conditions in the semi tropical region at Gachsaran Dry Land Agricultural Research Station (GDARS), Iran (30° 17_ N and 50° 50_ E, 710 m asl) for 3 years (2004-2007). Five tillage treatments and four sampling depths were considered as experiment factors. The tillage treatment includes:

T_1: Moldboard plow+disc harrow as the conventional method.
T_2: Chisel plow+disc harrow.
T_3: Moldboard plow without inversion page+disk harrow.
T_4: Power harrow.
T_5: Sweep plow+disk harrow.

Soil moisture was measured at four depths (0-10, 10-20, 20-30 and 30-40 cm) at the flowering and grain filling stages. Seeds were sown in plots at a seed density of 300 per seed m^2 from 15th November to late December after the rains, and this condition was good for soil cultivation in every three years. Plot size was thirteen rows, 20 m long, 9 m wide, with 17.5 cm between rows. Interval between treatments was considered to be 1.5 m. Before planting, 120 kg ha^{-1} phosphate ammonium and 75 kg ha^{-1} urea was added to the soil in case of fertilizer necessity. In this experiment, koohdasht cultivar, as a major bread wheat cultivar for cultivation in the area, was used as a material. No disease was shown during growth season, and weed control was made by hand. Physical and chemical characteristics of the soil experiment are shown in Table 1, while the regional climatic data during the growth season (December to May) are shown in Figure 1.

Soil moisture samples were collected at four depth ranges: 0-10, 10-20, 20-30 and 30-40 cm, using a hand-held soil probe. The soil cans and soil samples were weighted and dried at 105°C for 24 h. The moisture content (MC %) of each sample was calculated on a percent dry weight basis by the following formula:

$$MC(\%) = \frac{W_{wet} - W_{dry}}{W_{dry}} \times 100$$

Where: Wwet = the weight of the wet soil sample (g), and Wdry = the weight of the dried soil sample (g).

Soil samples from different locations of the test area were also obtained to study the physical and chemical properties of the soil layers that affect the formation of the hardpan layer. Soil bulk density was calculated by using the following formula:

$$BD = \frac{W_{dry}}{V}$$

Where: BD = the dry bulk density (g cm^3), Wdry = the weight of the dried soil sample (g) and V = the total volume of the soil sample (cm3).

Statistical analysis and mean comparison of the treatments'

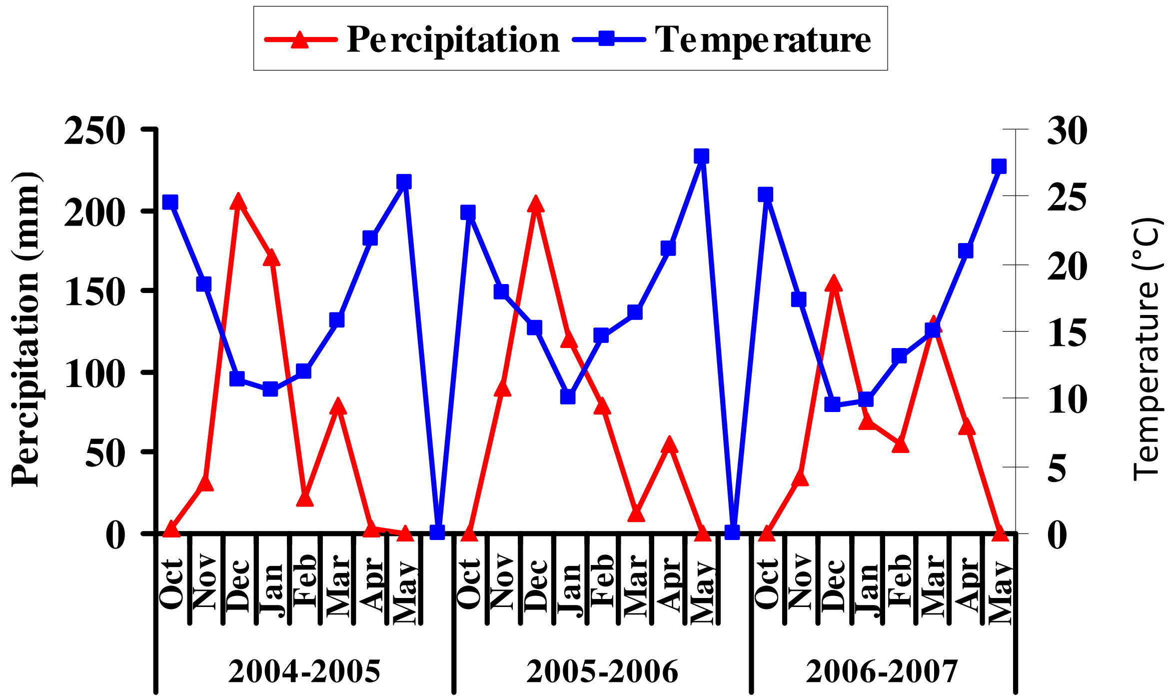

Figure 1. Metrological data of the experimental site during the three years of study.

Table 2. Combined analysis of variance of soil bulk density and moisture content.

Source of variation	D.F	Bulk density	Moisture content	
			Grain filling stage	Flowering stage
Year (Y)	2	0.002	671.038**	2610.687**
Year×replication	9	0.025	4.597	2.684
Depth (D)	3	0.234**	74.672**	4.225*
Y×D	6	0.021**	9.715**	0.726
Treatment (T)	4	0.047**	2.501	4.358*
Y×T	8	0.013*	0.409	2.220
D×T	12	0.021**	1.439	4.344**
Y×D×T	14	0.007	0.850	0.614
Error	171	0.005	1.156	1.471
C.V%		4.86	12.77	8.32

** and * are significant at 0.01 and 0.05 levels, respectively.

values, as Duncan multiple-range test, were performed using statistical software SAS 9.1 (2003) at 5% probability level.

RESULTS AND DISCUSSION

Soil bulk density

With analysis of the soil bulk density, significant difference (P < 0.01) was observed for the depth and tillage method as indicated in Table 2. This significant difference indicates different effects of tillage treatments on soil bulk density. Reduction of the soil bulk density, after tillage treatments were applied (1.52) as compared to the initial soil bulk density (1.59), was expected due to the looseness and hollowness of the dense soil by tillage equipment. The effect of year in this study was non-significant; despite the difference between years in terms of rainfall amount and distribution (Figure 1), these environmental factors could not affect the soil bulk density value (Table 2). Results of the mean comparison indicated that the highest and lowest soil bulk density values were related to T_3 (1.59) and T_1-T_4 (1.46) treatments in the third year, respectively (Table 3).

Table 3. Mean of soil bulk density in three years.

Treatment	growth season			Mean
	2004-2005	2005-2006	2006-2007	
T_1	1.47	1.48	1.46	1.47
T_2	1.49	1.53	1.55	1.53
T_3	1.51	1.55	1.59	1.55
T_4	1.57	1.56	1.55	1.56
T_5	1.53	1.49	1.46	1.49
LSD (5%)	0.0743	0.0596	0.0596	0.0376

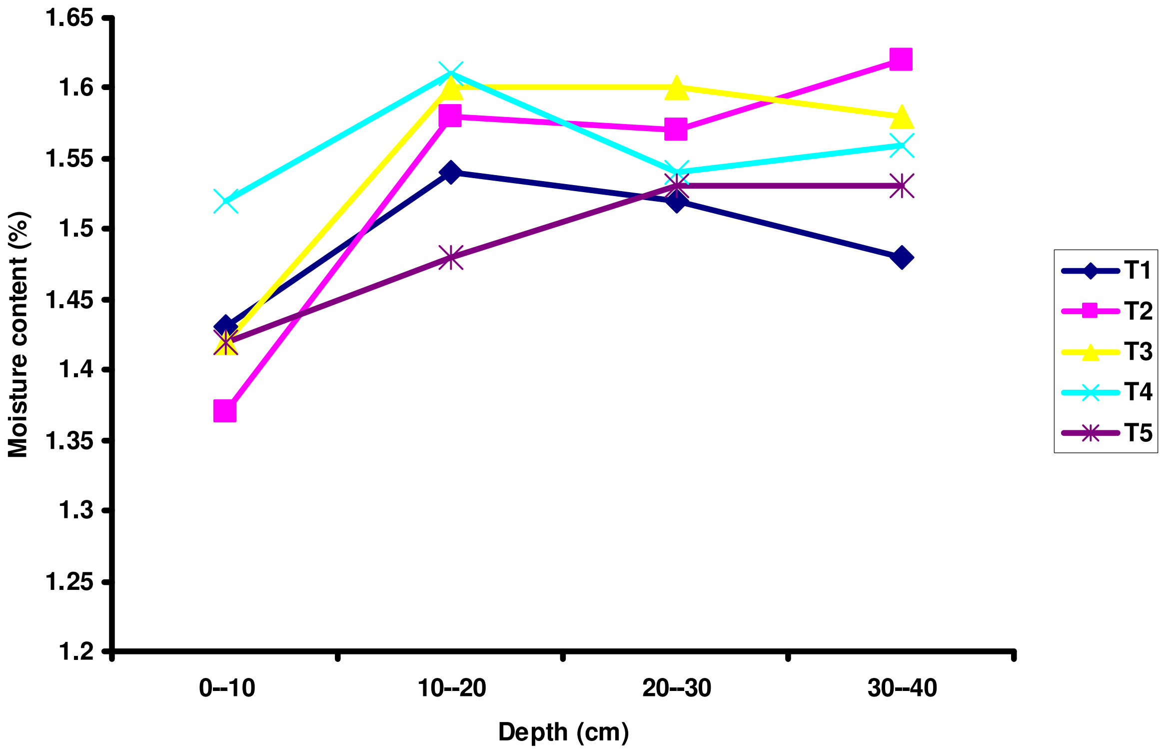

Figure 2. Mean of bulk density in sampling depths.

However, based on the three-year average, T_1 and T_4 treatments had the lowest and highest value, respectively. Many researchers (Azim Zadeh et al., 2002; Safadust et al., 2004; Mc-Vaya et al., 2006; Tripathi et al., 2007; Mohammadi et al., 2009) also showed that soil bulk density, using a moldboard, significantly decreased when compared with other tillage treatments. Considering the different impacts of tillage treatments on soil compaction and porosity, the differences in soil bulk density reduction depend on tillage equipment and operations (Mohammadi et al., 2009). The effect of tillage treatments on soil bulk density at different depths showed that the lowest (1.37) and highest (1.52) bulk density value, which was in the depth range of 0-10 cm was related to T_2 and T_4 treatments, respectively (Figure 2). T_5 treatment in 20-10 cm depth and T_1 treatment in 30-20 and 40-30 cm depth had the lowest bulk density. Although T_2 treatment in terms of soil bulk density at all depths samples was not the most appropriate treatment, this treatment in the 0-10 cm depth when compared with other tillage treatments had the minimum soil bulk density. Mahboubi et al. (1993) reported that the highest soil porosity in the 0-15 cm layer was shown with chisel and minimum porosity in no tillage system. Roozbeh and Poskani (2003) also found that bulk density in the 0-10 cm depth further reduce in the chisel plow when compared with the moldboard plow.

Soil moisture content

With analysis of variance, significant difference was observed for the depth and tillage method ($P < 0.05$), as

Table 4. Mean of soil moisture content at flowering and grain filling stages.

Treatment	Moisture content (%)		Mean
	Flowering stage	Grain filling stage	
T1	14.9	8.2	11.6
T2	14.6	8.8	11.7
T3	14.7	8.4	11.6
T4	14.7	8.4	11.6
T5	14.6	8.8	11.7
LSD (5%)	0.4887	0.4332	

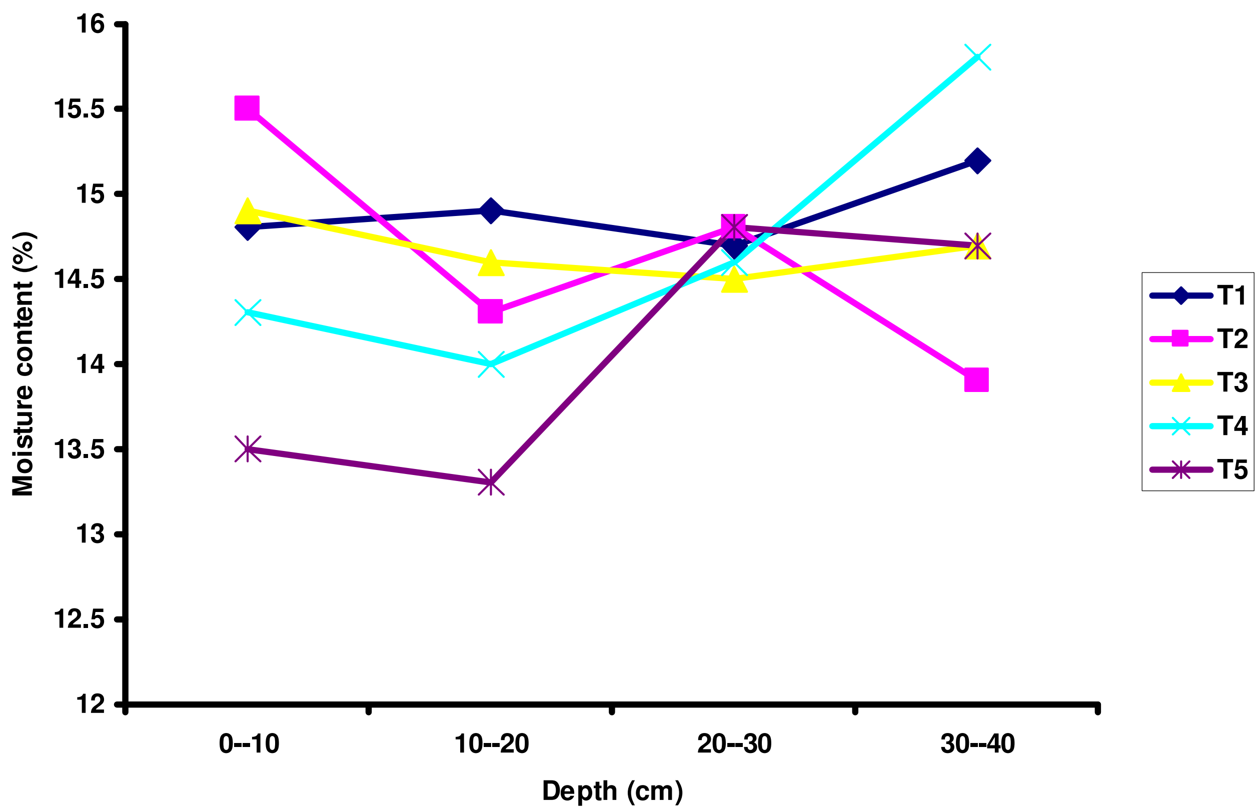

Figure 3. Mean of moisture content (%) in sampling depths at flowering stage.

well as for year and depth × tillage interaction ($P < 0.01$) at the flowering stage as indicated in Table 2. At the grain filling stage, the effect of year, depth and year × depth interaction was also observed to be significant ($P < 0.01$). Due to the difference in the amount of rainfall and distribution during the years studied, these results were expected. Soil moisture amounts at the flowering and grain filling stages were mostly affected by rainfall in the months of March, April and May. So, soil moisture amount in the third year was more due to more rainfall in the aforementioned months when compared with the first and second years. Based on the calculated average moisture at the flowering stage, T_1 and T_4 treatments had the highest (14.9%) and lowest (14.1%) moisture amount (Table 4). However, T_1 treatment at the flowering stage with T_2, T_3 and T_5 treatments did not show significant difference ($P < 0.05$). Overall, the conventional treatment as compared to other tillage treatments could be used to save more moisture in the soil at the flowering stage. Due to the increased porosity and permeability of soil by moldboard and no temperature rise during flowering stage, increased soil moisture in conventional tillage treatment at the flowering stage can be expected. Quincke et al. (2007) also found that the permeability of water into the soil, using moldboard, increases. Mean comparison of soil moisture content for tillage ×depth interaction at the flowering stage is given in Figure 3. Based on the three-year average, the maximum moisture

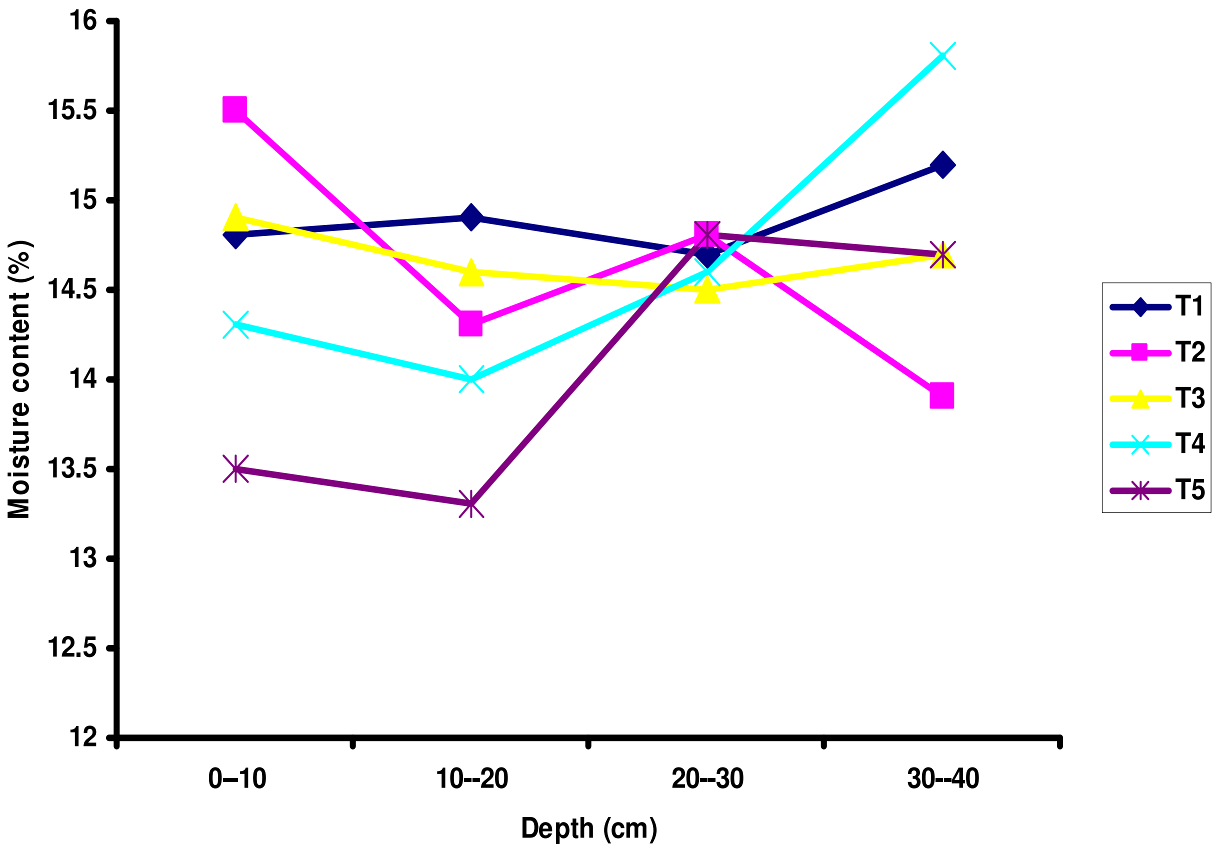

Figure 3. Mean of moisture content (%) in sampling depths at flowering stage.

content for the depth range of 0-10, 10-20, 20-30 and 30-40 cm was related to T_2, T_1, T_2-T_5 and T_4, respectively. Therefore, T_2 treatment when compared with other tillage treatments had the highest moisture in the depth range of 0-10 cm.

Although there were no significant differences among soil tillage methods for soil moisture at the grain filling stage (Table 2), the measured moisture at the grain filling stage showed that the highest and lowest moisture value was related to T_2 and T_1 treatments, respectively (Table 4). Therefore, T_2 treatment at the flowering stage in terms of moisture value with T_1 treatment located in the same statistical class, could store more moisture in the grain filling stage. So, soil moisture at different soil depths when compared with conventional tillage increased with 6.8%. On the other hand, the mean comparison of the soil moisture content for tillage × depth interaction in the grain filling stage showed that T_2 treatment for depths of 10-0, 20-10 and 40-30 cm and T_3 treatment for depth of 20-10 cm had the highest values (Figure 4). Many researchers (Azim Zadeh et al., 2002; Halvorson et al., 2000; Mohammadi et al., 2009) have reported that the use of moldboard increased soil moisture loss. Asghari-Meidani (2006), in a three-year study with different tillage treatments under dry conditions reported that the most soil moisture at tillage was obtained with chisel. Also, Shams Abadi (2007) and Mohammadi et al. (2009), in their study on the effect of different tillage methods on soil physical properties under dry conditions, reported total chisel efficiency due to the improvement of soil physical properties and an increase in the stored moisture. However, chisel + disk harrow treatment when compared with other tillage methods had the lowest bulk density value in the depth range of 0-10 cm. Also, this treatment transferred more of the stored soil moisture to the grain filling stage (as the critical stage to drought stress). Therefore, chisel + disk harrow treatment was recognized as the best tillage method in this study. Obviously, acceptance of this system requires the implementation of the project by on-farm conditions.

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