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Soil compaction variation during corn growing season under conservation tillage

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ABSTRACT

Area cultivated using conservation tillage methods has recently increased in Iran and soil compaction increment is one of the most challenging issues in this new technology. In addition to the soil compaction status at the end of growing season, soil compaction variation during the growing season is also important because of its potential effect on the crop growth and yield. Therefore, soil compaction variation during the corn growing season under different tillage methods and its effect on the crop yield was investigated in this study. The research was conducted in the form of a split plot experimental design with nine treatments and six replications. Main plots were tillage methods including: (1) conventional tillage method (CT); (2) reduced tillage (RT); and (3) zero tillage or direct drilling (ZT). Soil depth ranges of 0–0.10, 0.10–0.20, and 0.20–0.30 m were considered as sub plots. Soil bulk density (BD) and soil cone index (CI) were measured during corn growth season (eight measurements for bulk density and five measurements for cone index) as indices of soil compaction. Corn silage yield, thousand kernels weight, and grain yield were also determined in this research. Collected data were analyzed using SAS statistics software and Duncan's multiple range tests were used to compare the treatments means. Results indicated that tillage methods and soil depth had a significant effect on the soil bulk density so that the maximum soil bulk density was obtained from ZT method and soil depth range of 0.10–0.20 m. The difference between soil bulk densities in different tillage methods was statistically significant from the beginning of growth season to two month after the first irrigation (sixth measurement); while, this difference was not significant from the sixth measurement to the end of growth season. Soil cone index was also significantly affected by tillage methods and soil depth in such a way that ZT method and 0.20–0.30 m soil depth range had the maximum cone index. Although, the difference between tillage methods for corn yield and yield components was not statistically different, ZT method decreased corn thousand kernels weight, silage yield, and grain yield compared to the CT method for 11.1, 2.4, and 18.2%, respectively.

1. Introduction

Conservation tillage is a tillage method in which at least 30% of soil surface remains covered by crop residues. Soil compaction enhancement in this rapidly growing technology is one of the most challenging issues in Iran as well as in the world. Soil compaction is affected by tillage methods and degree of soil disturbance during tillage operations. Soil compaction is normally evaluated by measuring soil bulk density and cone index. Soil bulk density and cone index are also used to predict the depth of soil hardpan (Mehari et al., 2005). However, the amount of soil bulk density and cone index may be close together in different tillage methods at the end of growing season, variation trend of these parameters under different tillage methods cannot be identical during the crop growing season because of difference in soil disturbance intensity in different tillage operations. Therefore, investigating on soil bulk density and cone index variation under different tillage operations during the crop growing season enables researchers to have more accurate judgment and interpretation regarding crop yield under different tillage methods. However, no research work was found in the literature regarding soil compaction variation during growing season, results of some studies conducted on effect of tillage methods on the soil compaction is reported here. There are some contradictory results of research work conducted on the effect of conservation tillage on the soil bulk density and cone index. Results of some studies show that conservation tillage methods

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(zero and reduced tillage) increase the soil bulk density and cone index compared to the conventional tillage (Afzalinia et al., 2012; Fabrizzi et al., 2005; Liu et al., 2005; Taser and Metinoglu, 2005). There are also some research results showing no significant effect of conservation tillage on the soil bulk density and cone index (Afzalinia et al., 2011; Logsdon and Karlen, 2004; Rasouli et al., 2012; Touchton et al., 1984). Soil bulk density and cone index are also affected by soil depth. Results of a research work in a Rhodic Ferrasol in Parana, Brazil revealed that soil bulk density had the highest value at the soil depth range of 0.20–0.30 m in a zero tillage system (Cavalieri et al., 2009). According to the results of a study conducted in Argentina, no-till increased soil resistance compared to the conventional tillage and soil resistance increment was greater in the shallow layers compared to the deep layers (Ferreras et al., 2000). Results of a research performed in Kimberly, Idaho showed that soil bulk density was 16–18% greater in disk and no-till treatments compared to paratill in the soil depth range of 0.15–0.20 mm (Aase et al., 2001). Results of this study also indicated that there was a linear relationship between soil bulk density and soil cone index. Objective of this study was to determine the effect of conservation tillage and soil depth on the soil compaction indicators such as bulk density and cone index, crop yield, and some yield components.

2. Materials and methods

This research was conducted in a farm in Fars province, Iran with the soil specifications shown in Table 1. The research was performed in the form of a split plot experimental design with the base of randomized complete block design with two factors (tillage methods and soil depth) and six replications. Tillage methods (TM) as main plots were including: (1) conventional tillage method (CT); (2) reduced tillage (RT); and (3) zero tillage (ZT), and subplots were soil depth (SD) ranges of 0–0.10 (SD_1), 0.10–0.20 (SD_2), and 0.20–0.30 m (SD_3). In the conventional tillage method, primary tillage was performed using a moldboard plow and secondary tillage operation was done using a disk harrow and land leveler. Seed bed was prepared in the reduced tillage method using a tine and disk cultivator which was able to complete the primary and secondary tillage operations simultaneously. Corn seed was directly planted using Bertini pneumatic direct planter (Rosario, Santa Fe, Argentina) without any seed bed preparation in the zero tillage method. Corn (*Zea mays* L.) variety used in this research was 704 single cross at the seed rate of 25 kg ha^{-1} with the row space of 0.75 m in the 20 m $\times$ 6 m plots. Experimental plots were irrigated using sprinkle irrigation for all treatments. Tillage treatments were applied to the farm for two years (2009–2011) in irrigated corn–wheat rotation and soil bulk density and soil cone index (CI) were measured during corn growing season in 2011 (from July to October) according to Table 2. Corn silage yield, thousand kernels weight, and grain yield was also determined at the end of corn growing season in this research. Collected data were analyzed using SAS statistics software (SAS Institute, Cary, NC) and Duncan's multiple range tests were used to compare the treatments means. Soil bulk density was measured in the soil depth ranges of 0–0.10, 0.10–0.20, and 0.20–0.30 m using core samplers from three different locations of each plot and drying samples at 105 °C for 24 h in the oven. The following equation was used to calculate the soil bulk density:

$$BD = \frac{W_d}{V} \quad (1)$$

where BD is soil bulk density (g cm^{-3}), W_d is sample dry weight (g), and V is sample total volume (cm^3).

Soil cone index was measured using a cone soil penetrometer (Eijkelkamp 6.15) up to the soil depth of 0.30 m with 0.10 m depth interval at the moisture content of 22% w.b. Average cone index of 10 penetrations at each soil depth range was considered as the soil cone index of each plot in corresponding soil depth. Corn yield and yield components were also determined by taking samples from the experimental plots at the end of corn growing season.

Table 1
Soil specifications of the farm.

pH	EC	Silt (%)	Clay (%)	Sand (%)	Soil texture
8.4	0.79	54.73	40.94	4.33	Silty clay loam

3. Results and discussion

Results of soil bulk density data analysis indicated that difference between tillage methods was significant ($P < 0.01$) from the growth season beginning (BD_1) to corn sixth irrigation time (BD_5) or fifth measurement stage (Table 3). After fifth measurement or sixth irrigation time (from BD_6 to BD_8) no significant difference was observed between tillage methods from the soil bulk density point of view. Since soil disturbance level in tillage methods is different and it takes time for the soil to reach its undisturbed status (its situation before disturbance), significant difference between soil bulk densities in different tillage methods until fifth measurement is expected. It takes about two month for the soil bulk density in CT and RT methods to get close to its undisturbed status; therefore, there is no significant difference between tillage methods for the soil bulk density from the sixth measurement (BD_6) to the end of growing season (BD_8). There was also statistically significant difference ($P < 0.01$) between soil depths for the soil bulk density from the beginning to the end of corn growing season (Table 3). Interaction between tillage methods and soil depth showed a significant effect on the soil bulk density only for two measurements at the beginning of the growing season (BD_1 and BD_2).

Results of means comparison of soil bulk density in different tillage methods during corn growing season showed that there was a significant difference between soil bulk density of ZT method and those of CT and RT methods from the first measurement (BD_1) to the fifth one (BD_5) so that ZT had the highest soil bulk density and CT had the lowest one (Table 4). There was no significant difference between tillage methods for soil bulk density from sixth measurement (BD6) to the end of corn growing season (BD_8); however, ZT had a greater bulk density compared to the CT and RT methods. Means comparison of average soil bulk density of whole growing season (average of eight measurements) also revealed that ZT had the highest soil bulk density which was significantly different from those of CT and RT methods (Table 4). The higher soil bulk density in zero tillage compared to the conventional tillage method was also reported by Liu et al. (2005), Taser and Metinoglu (2005), Fabrizzi et al. (2005), and Afzalinia et al. (2012). Results of this study indicated that soil disturbance effect on the soil bulk density and soil compaction resists for two months during corn growing season and after that there is no significant difference between CT with high soil disturbance and ZT with zero soil disturbance.

Means comparison of soil bulk density at different soil depth ranges revealed that soil bulk density increased with increasing soil depth range from 0–0.10 m to 0.10–0.20 m then decreased when soil depth range increased from 0.10–0.20 m to 0.20–0.30 m during entire corn growing season (Table 5). Therefore, soil depth range of 0.10–0.20 m had the highest soil bulk density during the corn growing season which was significantly different from the soil bulk density of 0–0.10 and 0.20–0.30 m. This was probably because