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The influence of different tillage practices on water content of soil and crop yield in vetch–winter wheat rotation compared to fallow–winter wheat rotation in a high altitude and cool climate

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ABSTRACT

Fallow–winter wheat crop rotation under conventional tillage conditions is an agricultural system widely used in semi-arid regions. Water content of soil required for seed germination and plant growth can be improved performing tillage practices. Moreover, a crop rotation allowing sustainable and continuous production can be created. Therefore, the effect of four different tillage practices in a Hungarian vetch–winter wheat crop rotation (CR1) compared to fallow–winter wheat crop rotation (CR2) for water use efficiency was investigated in a semi-arid region with a high altitude (~1750 m a.s.l.) for three years (2011–12, 2012–13 and 2013–14). Tillage practices consisted of; TS1: Conventional tillage (moldboard plough + cultivator + combined harrows + precision seeder); TS2: Reduced tillage-1 (cultivator + combined harrows + precision seeder); TS3: Reduced tillage-2 (rotary power harrow + precision seeder) and TS4: No-tillage (no-till seeder). Experiment was conducted applying randomized complete block design based on split-plot trial plan. The water content of soil in the CR1 was higher than the contents in the CR2. The TS4 practice significantly increased ($P < 0.01$) the water content of soil in all measurement periods (sowing, winter, spring, harvesting and the whole year) and in soil layers (0–30 cm, 30–60 cm and 60–90 cm) compared to the other tillage practices. Water contents of soil were the lowest in the TS1. For the 0–30-cm depth, compared to the TS1 practice, the TS4 practice provided higher water contents of soil by 21.3, 22.1, 14.4, 15.7 and 17.4% in sowing, winter, spring, harvesting and the whole year periods, respectively. Water contents in 30–60 and 60–90 cm soil layers in the TS4 practice also were higher than the TS1 practice values. Higher water contents of soil of the sowing period in TS4 provided higher stand density. Although the amount of weeds in winter wheat plots was the highest in the TS4 practice (67.4 kg ha^{-1}) when considering three-year average values, grain yield in TS4 was also high (2652 kg ha^{-1}) and statistically similar to TS1 (2762 kg ha^{-1}). There was no clear effect on water use efficiency of winter wheat of the no-tillage practice compared to conventional tillage practice. Stand density and fodder yield of vetch were the highest in TS4. Our results indicated that the no-till vetch–winter wheat rotation could be more suitable than the conventional tilled fallow–winter wheat rotation due to the opportunity of high crop production in semi-arid regions.

1. Introduction

The retention of the precipitation water reaching into the soil and the conservation of current water content of soil are particularly important in water scarce arid and semi-arid agricultural regions. Tillage is considered as one of the most important agricultural practices in the crop production because it facilitates seed germination, controls weeds and soil erosion, causes suppression of evaporation and improves water infiltration and aeration of soil for the best production conditions (Mohammed, 2013).

Ma et al. (2015) concluded that soil moisture content, winter wheat grain yield and water use efficiency were influenced by tillage regimes. Reduced tillage is considered as one of the main applications for water conservation in dry agriculture (Anderson

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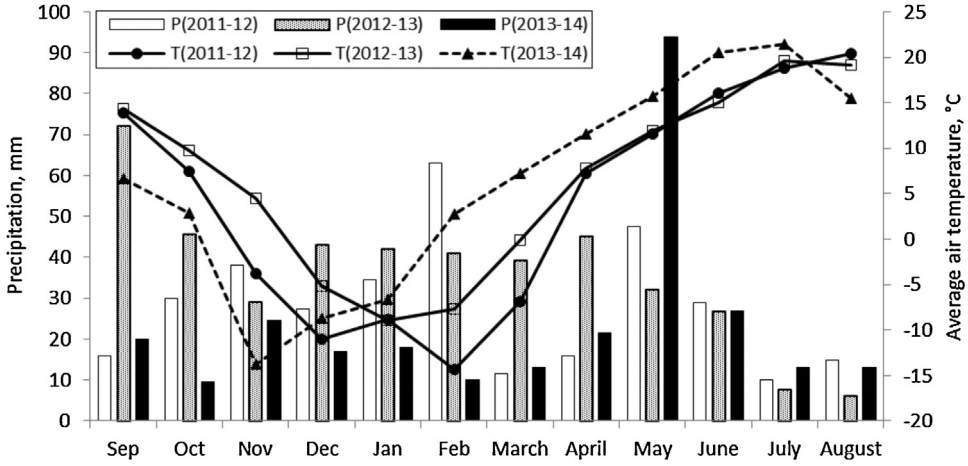

Fig. 1. Monthly precipitation (*P*) and average air temperature (*T*) values in experimental region in trial years (2011–12, 2012–13 and 2013–14).

and Impiglia, 2002). Moreover, reduced tillage increases the soil water content compared to traditional tillage (Czyż and Dexter, 2008; Romaneckas et al., 2009). Similarly, Fernández-Ugalde et al. (2009), Ferreras et al. (2000) and Lenssen et al. (2007) determined that the water content under no-tillage conditions was higher than the contents in conventional tillage. Su et al. (2007) also indicated that no-tillage with mulching is the optimal tillage system for increasing water storage in winter wheat production. Generally, weed infestation is higher under reduced tillage and no-tillage conditions compared to conventional tillage. In no-tillage practice, farmers use chemicals to prevent existing weeds on their fields. The roots of weeds remained in the soil after chemical application created larger pores in the soil causing it to hold water better (Coleman, 2003). Furthermore, no-tillage practice causes low evaporation due to more surface cover (Lampurlanés and Cantero-Martínez, 2006). Additionally, higher bulk density values under no-tillage conditions increase the proportion of capillary pores supplying water to plants (Badalíkova, 2010). Hence, seeds may gain advantage from capillary rise of water in deeper layers. Gozubuyuk et al. (2014) determined that the germination is increased under no-tillage conditions, which obtained better water content of soil. On the contrary, some researchers determined lower water content of soil under no-tillage conditions (Aikins and Afuakwa, 2012; Kováč et al., 2005).

Low water content of soil is considered as the most important environmental risk for wheat production under rainfed conditions in the dry regions of the world. Therefore, fallow–winter wheat crop rotation under conventional tillage conditions is widely applied in water scarce semi-arid regions. Considering the continuously increasing food demand in the world, the importance of agricultural practices that provide sustainable and acceptable production is increasing. In this case, a well-planned crop-rotation system integrated with different tillage practices can help to avoid the risk of less water content in soil.

Water retention in soils is closely related to the soil structure. Although soil tillage is a main factor affecting soil structure, freezing and thawing process and soil organic matter content are also important factors affecting soil structure. The effects of these factors vary depending on regional climate. This study was conducted in a cool climate region at high altitude (~1750 m a.s.l.). Mean air temperatures between November and March are below zero degrees in this region (Fig. 1). Surface soil layers are exposed to freeze–thaw cycles, especially in the spring period. Freeze–thaw cycles in cooler climates may positively or negatively affect soil aggregation and the structure (Sahin et al., 2008). Moreover, decomposition rates of soil organic matter in cooler climates are slow (Várallyay, 2010). However, tillage practices may affect the organic matter decomposition. It was known that minimum tillage practices increase the soil organic matter. Bot and Benites (2005) have indicated that while a rapid decomposition in soil organic matter occurs under the traditional tillage conditions, no-tillage practice protects and increases the soil organic matter. Similarly, Olgun et al. (2004) found that no-tillage practice provided more organic matter under cool climate conditions.

The study area is located in the Eastern Anatolia Region in Turkey. In this region, fallow–wheat crop rotation is the most common cropping system under non-irrigated conditions due to low annual precipitation (<500 mm) and because it covers an area of 1.5 million ha (Kumlay et al., 2007). While the fallow area in the region covers 31.9% of the cultivable land, 17% of cultivable land and about 45% of uncultivable land have water erosion problem (SPO, 2000). Vetch is one of the most important fodder crops considering animal roughage needs of 15 million tons in this region which agricultural practices are based on animal production (SPO, 2000).

The influence of different tillage practices on water content of soil and wheat yield have not yet been sufficiently investigated under vetch–winter wheat crop rotation compared to fallow–winter wheat rotation under high altitude conditions with cool climate. The aim of this study was to evaluate the combined effects of four different soil tillage practices (conventional, reduced-1, reduced-2 and no-till) and two crop rotations (vetch–winter wheat and fallow–winter wheat) on water content of soil, water use efficiency, stand density, yield and weed development under non-irrigated conditions in a semi-arid region with a high altitude.

2. Materials and methods

Experiments were conducted in a field located approximately 30 km east of Erzurum, Turkey, at the Soil–Water Resources Research Station in Pasinler of East Anatolia Agricultural Research Institute (39.99°N, 41.57°E, 1721 m a.s.l.).

The region has a semi-arid climate with annual total precipitation of 417 mm considering 2001–2013 period. While winters are long, cold and snowy in the region, summers are short, cool and dry. Moreover, the average temperature and relative humidity values were 5.9 °C and 66.6%, respectively (DATAE, 2014). While the experiment started in 2010–11 (installation year of the research), the observations for analysis were made during 2011–12, 2012–13 and 2013–14. Monthly precipitation and average air temperature