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Soil moisture dynamics during intervening period in rice-wheat sequence as affected by different tillage methods at Ludhiana, Punjab, India

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Abstract

The objective of this study was to evaluate the residual effect of conventional (CT) and zero tillage (ZT) methods after wheat 2013-14 on moisture dynamics after three consecutive seasons under rice- wheat cropping system at the research farm of Punjab Agricultural University, Ludhiana, India. Soil matric suction (SMT) and water content were measured by using Tensiometer and Time Domain Reflectrometer, respectively at 10, 20 and 30 cm and 7.5 cm soil depths. Soil temperature (by using digital soil thermometer) at 5 cm depth. Evaporation was measured by using Mini-lysimetrs. Outcome of study clearly depicted that conventionally tilled wheat plots followed by conventionally tilled direct seeded rice followed by conventionally tilled wheat (CTW-DSRCT-CTW) plots conserved more moisture than the zero tilled wheat followed by zero tilled direct seeded rice followed by zero tilled wheat (ZT-DSRZT-ZTW) plots. On an average, during the intervening period after wheat, SMT was 21, 16 and 17% more in ZT plots than CT plots at 10, 20 and 30 cm soil depths, respectively while soil temperature was 2.1% more in the ZT plots. Recorded water depths upto 7.5 cm of soil surface was 9.5% more in CT plots than ZT treatments. Evaporation losses were higher (12.9%) in ZT plots, due to higher surface temperature and continuity of soil pores. It was concluded from the data that CT treatment retained prolonged and higher contents of soil moisture during intervening period which might be useful for cultivating short intervening crop viz. moong.

Keywords: Intervening soil moisture, time domain reflectrometer, tensiometer, lysimeter, soil thermometer

Introduction

The intensive rice-wheat cultivation in central Punjab, India has resulted in sharp decline in underground water levels during the last few decades (Bhatt and Kukal, 2013). The ground water in north India has been reported to decline by 1 ft year^{-1}, which resulted in the loss of 4 cm raw ground water (Soni, 2012). The environmental pollution on the other hand due to burning of rice residues (to the tune of more than 13 million tonnes every year) has prompted the scientists to find alternate ways of managing natural resources of soil, water and atmosphere. The conservation tillage in the form of direct drilling of wheat in standing rice stubble (zero tillage) is an important resource conservation technology being propagated in the rice-wheat regions of South Asia (Beff *et al.*, 2013; Singh *et al*., 2014). Zero tillage (ZT) improves the soil physical environment (Bhaduri and Purakayastha, 2014; Paccard *et al*., 2015) because of the residue retention at the fields resulting in increased infiltration rate, water retention, hydraulic conductivity, lower soil compaction (Bhaduri and Purakayastha, 2014; Palese *et al*., 2014; Zheng *et al.*, 2015) while conventional tillage breaks macro-aggregates into the micro-aggregates which adversely affect the soil properties (Roper *et al.*, 2013; Das *et al*., 2014; Kuotsu *et al*., 2014) apart from greater losses in soil organic carbon.

The positive benefits of zero tillage (ZT) systems on crop production (Paccard *et al*., 2015), water use efficiency (Guan *et al.*, 2015), carbon sequestration (Zhangliu *et al.*, 2015) and economic performance (Tripathi *et al*., 2013) are well recognized. For better irrigation water management, understanding of soil water dynamics during the intervening periods as affected by residual effect of conservation tillage in comparison to conventional system is important (Bhatt and Kukal, 2014 and 2015).

Bhatt and Kukal (2014) reported that after rice, ZT plots (with 8.1% higher straw load) retained higher soil moisture than CT plots during intervening period. They further reported 3.3 and 4.7% higher diurnal soil temperature in zero tilled than that of conventionally tilled plots at 5 and 10 cm soil depths during wheat 2013-14 (Bhatt and Kukal, 2015). The soil water dynamics during the intervening periods may be affected by conservation tillage and needs to be understood for better management of water productivity of the cropping system as a whole. Studies on soil moisture dynamics during the longer

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intervening period after wheat harvest till sowing of rice, as influenced by conservation tillage are not adequately reported in literature. The present study aims to understand the soil moisture dynamics during the intervening period after wheat harvest in a wheat-rice cropping system in a sandy loam soil of Indian Punjab.

Materials and Methods

Field experiments were conducted at the research farm of Punjab Agricultural University, Ludhiana (30°54′N, 75°98′E) and 247 m above sea level during 2012-14 starting from wheat crop. The experimental site was under puddle transplanted rice for the last 20 years except that the field was under direct dry-seeded rice (DSR-CT) sown under tilled conditions during the immediate previous year (2012). The long-term average annual rainfall is 734 mm, 85% of which occurs during a short period of July-September. The studies on intervening period were conducted during the period after wheat harvest till sowing of rice in 2014. The study soil was sandy loam, calcareous, mixed, hyperthermic Typic Ustochrept with subtropical climate. About 26.5 mm rain was recorded during the intervening period under study (Figure 1).

The tillage treatments in wheat comprised of zero tillage, ZT (direct drilling of wheat in standing rice residues) and conventional tillage, CT (two passes of tractor-driven disk harrow followed by two passes of cultivator and planking) as main plot, rice establishment method viz. direct seeded rice (DSR) and mechanically transplanted rice (MTR) as sub-plot treatments and tillage in rice viz. puddle (PD), dry (DT) and zero (ZT) tillage as sub-sub plot treatments. First wheat crop was established with CT and ZT in 2012 followed by rice in 2013 with two establishment methods viz. DSR and MTR under PD, DT and ZT scenarios followed by wheat in 2013 with similar treatments.

The present study was conducted after wheat 2013-14, to delineate the soil moisture retention dynamics as affected by divergent tillage treatments by monitoring fluctuating behaviour of soil matric tension, volumetric water content, evaporation and surface soil temperature. The soil matric suction was determined by electronic Tensiometer (Kukal *et al*., 2005; Bhatt *et al*., 2013). Tensiometers were installed at 10, 20 and 30 cm depths to monitor the soil matric suction in the soil profile during the intervening period

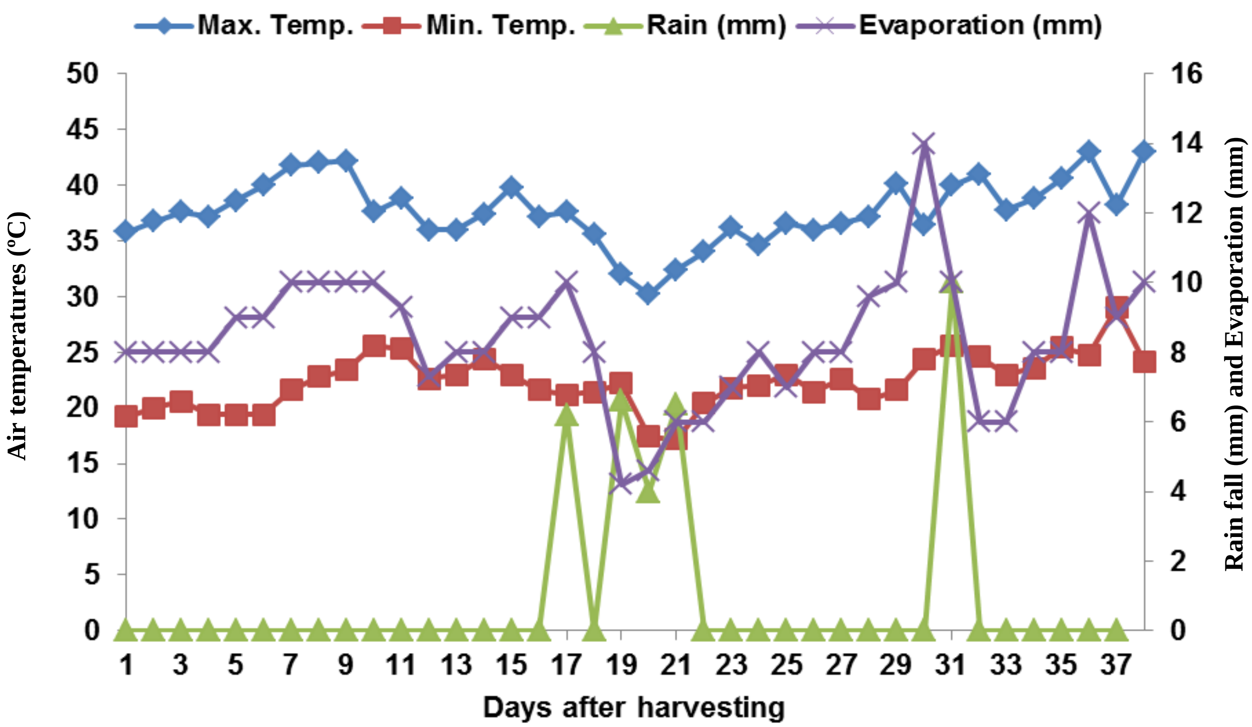

Figure 1: Different climatic parameters variation during the study period

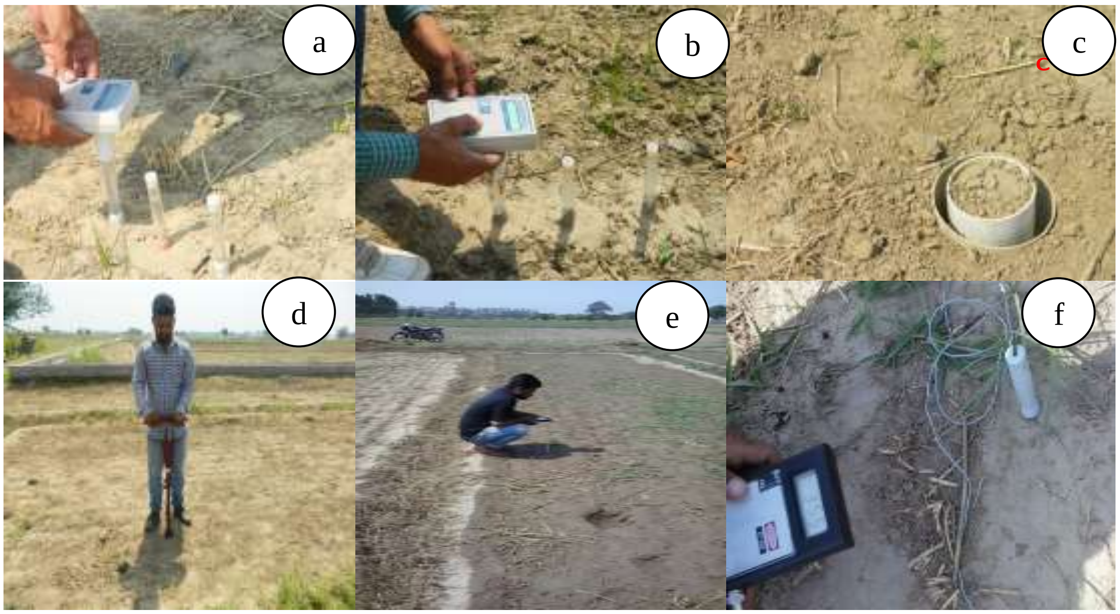

Figure 2: Demonstrating different instruments used to monitor moisture retention under different tillage treatments during intervening period viz. (a) & (b) soil suction with digital soil SPEC (c) capped and filled mini-lysimeter (d) time domain reflectrometer (e & f) measurement of soil temperature using digital soil thermometers

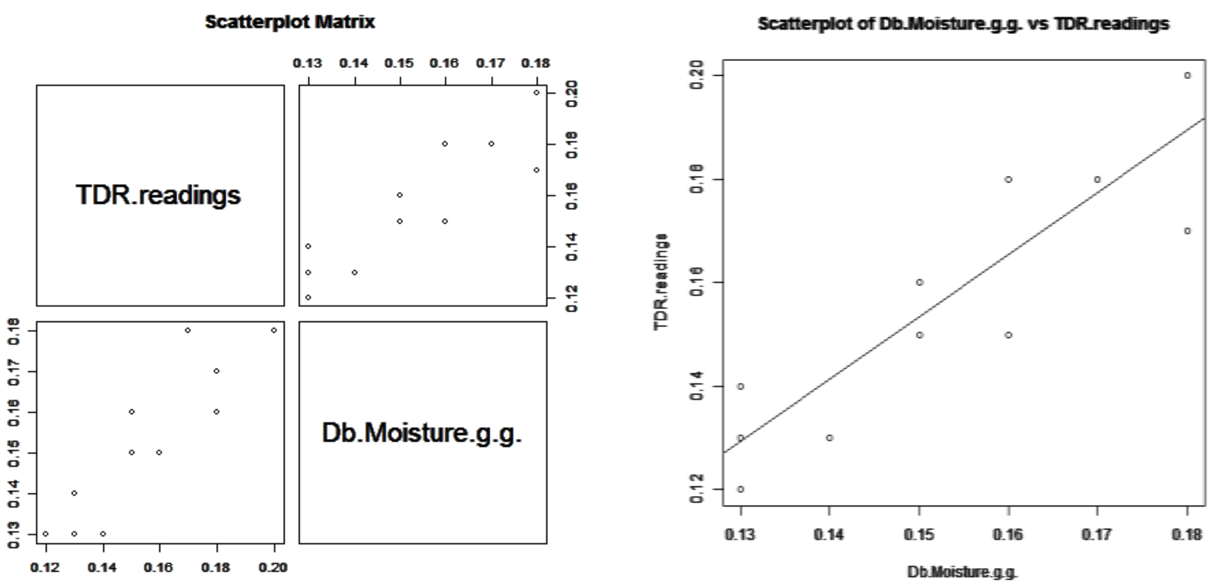

Figure 3: Calibration of time domain reflectrometer (TDR) (r^2 = 0.77) showed good relation between TDR readings and product of bulk density and gravimetric moisture content

(Figure 2). Daily SPEC readings were recorded to understand the fluctuating behaviour of soil matric tension. The fluctuating behaviour of evaporation under different treatments was determined by using Mini-lysimeters (Zhang *et al*., 2009; Carlos *et al*., 2013). These meters were prepared by using PVC pipes of 8 inch length and with 2.5 inches diameter. Mini-lysimeters were filled from a particular treatment with the help of chain pulley arrangem-

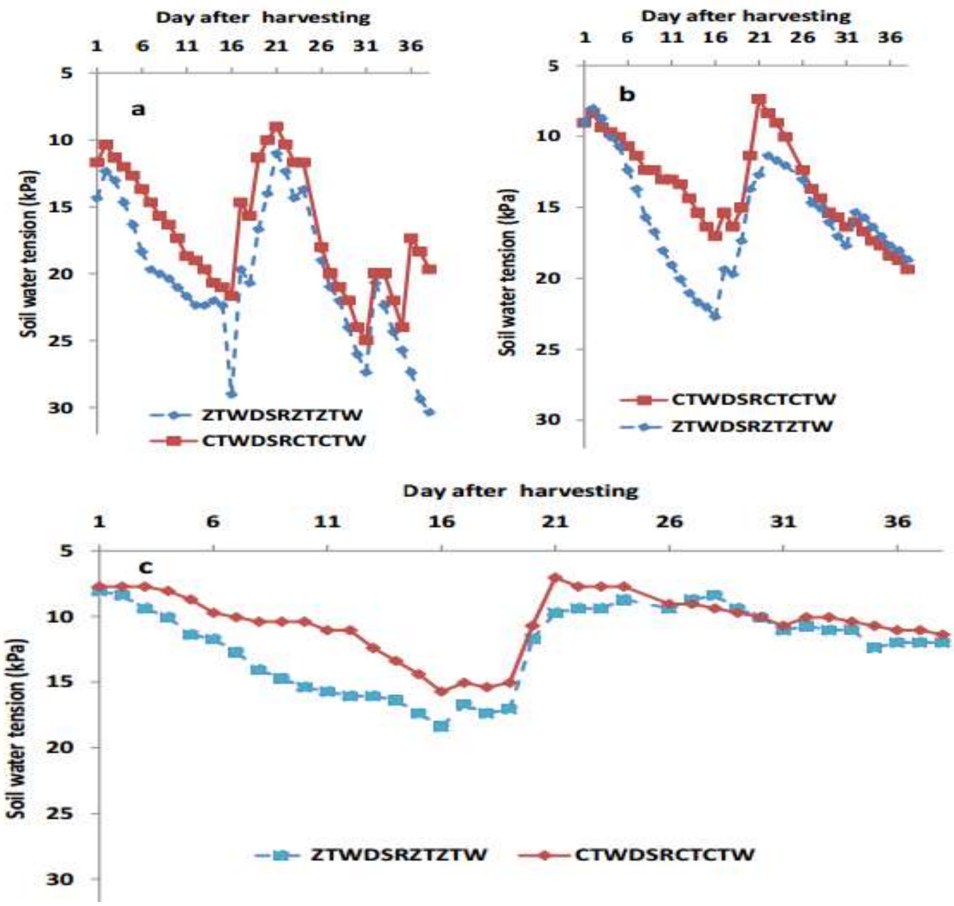

Figure 4: Soil water tension behaviour in relation to different establishment methods at 10 cm (a), 20 cm (b) and 30 cm (c) soil depths. (Arrows depicting rainfall events) (ZTWDSRZTZTW=Zero tilled wheat followed by zero tilled direct seeded rice followed by zero tillage wheat, CTWDSRCTCTW = Conventionally tilled wheat followed by conventionally tilled direct seeded rice followed by conventional tilled wheat)

ment, an end cap fixed on one side and then finally filled and capped mini-lysimeter was placed inside the outer pipe of bigger diameter which was already fixed in the sampled plot (Figure 2). Daily mini-lysimeters were weighted at field using digital balance to have an idea of evaporation. The temporal fluctuations in water contents in plots established under different establishment methods were monitored by using Time Domain Reflectrometer (TDR) (Hallikainen *et al.*, 1985; Wraith and Or, 1999). TDR with 7.5 cm probes was used (Figure 2). Before using, TDR was calibrated by plotting it's different readings with the different readings of product of bulk density and gravimetric water content in different plots using STAR (Statistical Tool for Agricultural Research) package and r^2 comes out to be 0.77 depicting good relationship in between both plotted parameters (Figure 3).

Soil temperature was measured by using digital soil thermometer (Figure 2). Daily fluctuating readings of soil matric tension, soil temperature, soil evaporation helps us to identify an integrated package of tillage treatment (Figure 3) which could conserve higher soil moisture by maintaining evaporation losses during intervening period and this conserved moisture helps to cultivate intervening crops.

Results and Discussion

Soil matric suction trends

At 10 cm soil depth under ZT dried out much more quickly than the plots under CT which was because continuity of soil pores and recorded higher soil temperature and retained higher moisture during wheat season (Figure 4) while in CT plots, the continuity of soil pores was broken by tillage operations. At 20 cm soil depth, ZT plots dried out quickly while at 30 cm soil depth, both the plots receiving differential tillage treatments dried out at almost same rate though ZT plots dried out quickly. On an average, during the intervening period after wheat, SMT was 21, 16 and 17% more in ZT plots than CT plots at 10, 20 and 30 cm, respectively. In general, at all the soil depths moisture as compared to the plots under ZT during the intervening periods after wheat as air temperature started increasing (with an exception to the rainfall day) after wheat harvesting (Figure 5).

Volumetric water content

Conventionally tilled wheat (CTW) plots had higher

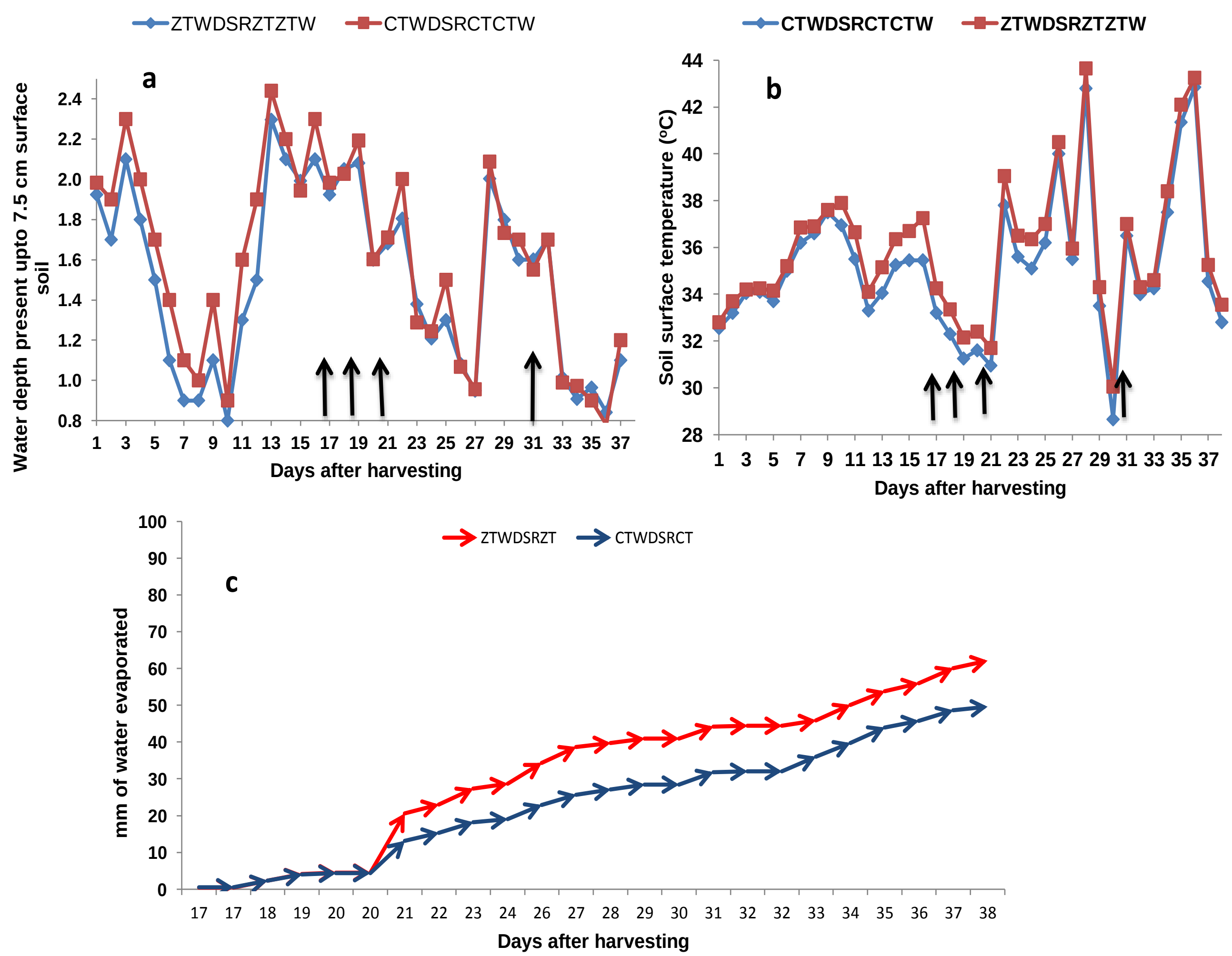

Figure 5: Variation in volumetric water content (a), surface soil temperature at 2.00 pm (b) and cumulative water evaporated, mm (c) as affected by residual effect of different tillage treatments (Arrows depicting rainfall events) (ZTWDSRZTZTW=Zero tilled wheat followed by zero tilled direct seeded rice followed by zero tillage wheat, CTWDSRCTCTW=Conventionally tilled wheat followed by conventionally tilled direct seeded rice followed by conventional tilled wheat)

SMT values go on increasing at 16 days after harvesting (DAH) while on 17 DAH, the SMT values decreased due to rainfall. Generally SMT in ZT plots increased at much more faster rates than the plots under CT plots at all the soil depths indicating greater and prolonged retention of soil moisture content than the ZTW plots. Recorded water depths at 7.5 cm of soil surface was 9.5% higher in CT plots which may be because of recorded lower soil temperature in CT plots while plots under zero tillage experienced higher soil temperatures (Figure 5b), leading to faster drying of soil throughout the intervening period (Figure 4).

Soil temperature

Soil temperature affects the absorption, translocation of water and nutrients in soil and plants (Moraru and Rusu, 2012). Higher the soil temperature faster the evaporation and lesser the soil moisture retention. On an average, soil temperature was 2.1% higher in the ZT plots during the study period (Figure 5b) while in CT plots lower soil temperature was recorded in the surface soil responsible for lower evaporation rates which further conserved the moisture for longer periods of time.

Evaporation

It was revealed that evaporation trend observed to follow ZTW-ZTDSR-ZTW> CTW-CTDSR-CTW > ZTW-CTDSR-ZTW (Figure 5c). The triple ZT plots were reported to have higher evaporation losses (12.8%) as compared to the triple CT plots during intervening periods. The zero tilled plots (without straw load) having higher soil temperature, soil matric tension values resulted in higher evaporation losses during intervening periods after wheat. It was mainly because of the continuity of the soil pores and recorded higher soil temperature however in the CT plots, continued supply of moisture from the deeper layers to the surface soil prohibited as regularity of the soil pores was disturbed by tillage operations during field preparations. Moreover, the soil temperature was also recorded to be on the lower side in the CT plots as compared to the ZT plots which further promoted higher evaporation losses in the ZT plots

Conclusion

The study leads us to conclude that CTW plots retain higher soil moisture content than ZT plots during the intervening period after wheat harvesting till rice sowing in sandy loam soils. However, there is a need to carry out such studies in texturally divergent soils under different agro-climatic regions to understand the intervening soil moisture dynamics as affected by residual effects of different resource conservation techniques in the region.

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