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Tillage and Mulching Effects on Soil Properties, Yield and Water Productivity of Wheat Under Various Irrigation Schedules in Subtropical Climatic Conditions

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Soil microbial biomass (SMB) as a more sensitive indicator of changes in the soil quality. Crop residues are well known to increase the content of soil organic C and that of SMB. Therefore, a 2-year field study was conducted to evaluate the effect of three tillage practices (conventional, zero till and FIRB planting) with four irrigation treatments. The irrigation treatments were (I_1:pre-sowing; I_2: pre-sowing+active tillering or crown root initiation;I_3:pre-sowing+active tillering or crown root initiation+ panicle initiation or flowering; and I_4: pre-sowing+active tillering or crown root initiation+panicle initiation or flowering+ grain filling) applied in primary strips at pre-sowing and critical growth stages and two crop residue management practices (retained and removal) on soil properties, crop productivity and total organic carbon and organic carbon fractions in wheat (*Triticum aestivum* L.) crop. Results indicate that the plots under conservation agriculture practices had nearly 17 and 14% higher of microbial biomass carbon (MBC), total organic carbon (TOC) and organic C fractions (that is, water soluble organic C, easily oxidizable organic C, particulate organic C, humus C and black C) content as compared with conventional tillage after 2 yr of cropping, despite similar mean aboveground biomass yields of wheat crop on both FIRB and ZT plots. The FIRBS planting and irrigation at pre-sowing + active tillering or crown root initiation + panicle initiation or flowering had registered positive impact on MBC and TOC content. Thus, adoption of tillage crop establishment with irrigation scheduling practices was beneficial for the increase of wheat grain yield and the better management option for soil C improvement than CT, and irrigation generally enhances the positive impacts during a short-term period.

Key words: Crop Residue, Irrigation Schedules, Microbial Biomass Carbon (MBC), Planting Methods, Soil Physical Properties, Water Productivity.

In India, RW systems account for >80% of the total cereal production and about 50% of the total calorie intake. More than 90% area of the RW area is irrigated and is facing yield stagnation, soil degradation, declining ground water table [Hira, 2009], and air pollution [Singh *et al*., 2011]. Holistic management of arable soil is the key to dealing with the most complex, dynamic, and interrelated soil properties, thereby maintaining sustainable agricultural production systems, the lone foundation of human civilization. Any management practice imposed on soil for altering the heterogeneous body may result in generous or harmful outcomes [Derpsch *et al*., 2010]. Unsuitable management practices cause degradation in soil health as well as decline in crop productivity [Ramos *et al*., 2011]. Reducing

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disturbance of soil by reduced tillage influences several physically [Lopez-Garrido *et al*., 2012], chemically and biologically [Bronick and Lal, 2005] interconnected properties of the natural body.

Soil tillage is among the important factors affecting soil properties and crop yield. Among the crop production factors, tillage contributes up to 20% [Khurshid *et al*., 2006] and affects the sustainable use of soil resources through its influence on soil properties [Lal and Stewart, 2013].Reducing tillage positively influences several aspects of the soil whereas excessive and unnecessary tillage operations give rise to opposite phenomena that are harmful to soil. Therefore, currently there is a significant interest and emphasis on the shift from extreme tillage to conservation and no-tillage methods for the purpose of controlling erosion process [Iqbal *et al*., 2005]. Conventional tillage practices cause change in soil structure by modifying soil bulk density and soil moisture content. In addition, repeated disturbance by conventional tillage gives birth to a finer and loose-setting soil structure while conservation and no-tillage methods leave the soil intact [Rashidi and Keshavarzpour, 2007]. This difference results in a change of characteristics of the pores network. The number, size, and distribution of pores again control the ability of soil to store and diffuse air, water, and agricultural chemicals and, thus, in turn, regulate erosion, runoff, and crop performance [Kumar *et al*., 2001].With time, conservation tillage, on the other hand, improves soil quality indicators [Plaza *et al*., 2015].

Mulching is an important agronomic practice to check moisture loss from soil surface. Sharma *et al* (2010) in the northwestern Himalayan regions of India observed that mulching is useful for conserving soil moisture resulting in increased productivity and improved soil conditions for the MW cropping system. The retention of rice residue as a surface mulch could be beneficial for enhancing soil water status and moderating soil temperature thereby increasing root growth, plant canopy, wheat yield and water productivity (Singh *et al*., 2011 and Naresh *et al*., 2013). He *et al*., (2010) reported that use of straw mulch reduces water loss and soil temperature of surface soil but increases soil organic content. The quantity of mulching may have differential effects on water use and water use efficiency.

Proper scheduling of irrigation (amount and timing) to crops is an important component of water saving technologies. There are numerous ways to schedule irrigations and estimate the required depth of water application [Prihar *et al*.1997].All irrigation scheduling methods consist of monitoring indicators that determine the need for irrigation. Therefore, it is essential to improve irrigation water productivity and decrease irrigation demand while maintaining the crop productivity. [Li *et al*., 2010] reported that wheat receiving four irrigations at CRI, maximum tillering, boot stage and milk stage resulted in 13.7and 29.0% higher grain yield over two (at CRI and boot stages) and three irrigations (at CRI, boot and milk stages), respectively. Irrigations are recommended at times corresponding to the specific growth stages (crown root initiation, early tillering, late jointing/ boot, and heading/flowering) of the wheat [Maurya *et al*., 2008, Naresh *et al*. 2015]. Depending upon the soil type, four to five irrigations are generally required to get optimum grain yield of wheat under normal climatic conditions of North West India. [Naresh *et al*., 2015] reported that wheat grain yield increased in a step-wise manner as additional irrigation was applied but the highest protein content was achieved only with the fewest number of irrigations. Being the prime natural resource for assured crop production, water has to be used judiciously and in scientific manner. To increase availability of irrigation water there is need to quantify the irrigation water by using improved irrigation method and proper scheduling of irrigation to obtain more yield and economic returns. The objective of this research was to evaluate the effects of mulching and irrigation schedules on wheat yield, water use, economics, physical properties of soil and nutrient uptake under tillage alternatives.

MATERIALS AND METHODS

Experimental site

The experiment was conducted at the crop research centre (29°4’N, 77°46’E, and 237-m above mean sea level) of the Sardar Vallabhbhai Patel University of Agriculture & Technology Meerut, Uttar Pradesh, India, during 2010-11 and 2011-12. Before start of the experiment, the field was under continuous conventional tillage and puddle transplanted rice conventional till wheat system since past over 6 years. The soil (0–30-cm) of the experimental field was a typic Ustochrept alluvial sandy loam as analyzed in 2010 and soil property data at initialization is provided in Table 1.The climate of the area is semi-arid subtropical, characterized by very hot summers and cool winters. The hottest months are May and June, when the maximum temperature reaches 45–46æ%C, whereas, during December and January, the coldest months of the year, the temperature often drops below 5æ%C.The average annual rainfall of 800 mm (75–80% of which is received during July to September) and relative humidity of 67–83% throughout the year.

Experimental details

Treatments

The experiment was laid out in a split plot design keeping seven tillage crop establishment methods **T_1**- Zero Tillage with residue,(ZTR) **T_2**- Zero Tillage without residue,(ZTWR) **T_3**- Narrow raised beds with residue,(NBR) **T_4**- Narrow raised beds without residue,(NBWR) **T_5**- Wide raised beds with residue,(WBR) **T_6**- Wide raised beds without residue,(WBWR) **T_7**- Conventional tillage (CT) in main plots and four irrigations levels in sub-plots, and replicated three times. The experiment was conducted in main plot of 8.0 m×9.6 m having subplot of 8.0 m×2.0 m size with buffers all around the main plots. The experiment was established on same location and treatments were imposed on same plots in both the years of study. Chopped rice straw of size 15–20 cm was applied as mulch manually on the same day after sowing of wheat in each year.

Irrigation

The irrigation levels included: **I_1:**pre-sowing; **I_2:** pre-sowing + active tillering or crown root initiation**; I_3:** pre-sowing+active tillering or crown root initiation+ panicle initiation or flowering; and **I_4**: pre-sowing +active tillering or crown root initiation +panicle initiation or flowering+ grain filling. The critical growth stages of wheat were selected based on the information available from the previous studies (Huang *et al*., 2012).

Cultural practices

Fertilizers application

In experiment, all plots received N: P: K 120:60:40 kg ha^{-1}.Half dose of N and full dose of P and K were applied as basal at the time of seeding through multi crop zero till cum raised bed planter with inclined plate seed metering device. Remaining half N was top dressed in two equal split doses; first split before 1st post-sowing irrigation at CRI stage and the second split before 3rd irrigation at pre-flowering stage.

Preparation of field for conventional tillage

After the rice harvest, following the conventional practice of two harrowing, three ploughing (using a cultivator) and one planking (using a wooden plank) that followed pre-sowing irrigation and wheat was seeded in rows 20 cm apart using a seed drill with a dry-fertilizer attachment.

Preparation of raised beds

At the beginning of the experiment soil was tilled by harrowing and plowings followed by one field leveling with a wooden plank, and raised beds were made using a tractor-drawn multi crop zero till cum raised bed planter with inclined plate seed metering devices. The dimension of the wide beds were 107 cm wide (top of the bed) x 12 cm height x 30 cm furrow width (at top) and the spacing from centre of the furrow to another centre of the furrow was kept at 137 cm. Six rows of wheat were sowing on each raised bed. The dimension of the narrow beds were 37 cm wide (top of the bed) x 15 cm height x 30 cm furrow width (at top) and the spacing from centre of the furrow to another centre of the furrow was kept at 67 cm. Two rows of wheat were sowing on each raised bed.

Crop management

Wheat variety DBW-17 was seeded at 100 kg seed ha^{-1} at 20-cm row spacing in conventional tillage and zero tillage, and a seed rate of 80 kg ha^{-1} was used in bed planting. Two to six rows of wheat were planted on bed. To control weeds in the experimental field Clodinafop 15 % WP @ 400 g ha^{-1} 30 DAS was used and one hand weeding at 45-50 DAS.

Measurement of soil properties

Soil Sampling and analyses

Bulk density and particle density of the soil samples were determined by core sampler method and pycnometer method [Karim *et al.*, 1988]. The soil porosity was computed from the relationship between bulk density and particle density using (1). Soil field capacity and permanent wilting point were measured using pressure plate apparatus, while available water content was calculated using (2) [Black, 1965]. Consider

$$\text{Porosity}(\%) = 1 - \frac{BD}{PD} x100 \qquad ...(1)$$

Where BD is bulk density (g cm^{-3}), PD is particle density (g cm^{-3}), and

$$d = \frac{FC - PWP}{100}\ x\ BD\ x\ soil\ depth \qquad ...(2)$$

Where d is available water content (cm) at 60 cm depth, FC is field capacity (%), and

PWP is permanent wilting point (%)

The double ring infiltrometer method was used to determine the water infiltration and was computed as cumulative infiltration and rate of infiltration in mm h^{-1}.

Soil samples were taken at the end of each season in 2011 and 2012 following harvest. Soil samples were collected at 0–10 cm depth in furrows and 0–20 cm in beds. The soil was sieved (2mm) and stored at 4°C for a few days to prevent moisture loss before assaying for soil analysis. Soil total organic carbon (TOC) was determined by $K_2Cr_2O_7$ oxidation and total N by semi-micro Kjeldahl method (Lao, 1988).The water soluble organic carbon (WSOC) and humus carbon (HC) in each sample were successively analyzed according to the method described by Zhang *et al*. (2010). Briefly, the soil samples were first suspended in distilled water at 70±1°C for 60 min. The supernatant was referred to as the water soluble fraction (WSF).After centrifugation; the remaining soil was further extracted using a solution of 0.1mol l^{-1} NaOH and 0.1mol $l^{-1}Na_4P_2O_7$ at 70±1°C for 60 min. The dark brown alkaline supernatant solution, corresponding to the total alkali-soluble humic extract (HE),was separated into the acid-insoluble humic acid (HA) and the acid soluble fulvic acid (FA) fractions by acidifying the alkaline supernatant to pH 1.0.The residue remaining after extraction was referred to as the humin (HM) fraction. The carbon contents of WSF (WSOC), HE (HEC) and HA (HAC) were directly determined, while that of HM (HMC) was calculated b y subtraction. Easily oxidizable organic carbon (EOC) was determined as described by Blair *et al.*, (1995).Soil samples containing 15 mg of organic carbon were reacted with 333m mol l^{-1} $KMnO_4$ solution for 60 min, and the amount of EOC was spectrophotometrically determined from the amount of $KMnO_4$ reduced.

Soil samples were dispersed in 100ml of 5 g L^{-1} $(NaPO_3)_6$ solution and shaken at 90rmin^{-1} for18 h. The suspension was passed through a 53 ìm screen and the retained coarse fraction was rinsed with distilled water, dried at 65°C, weighed and ground for determination of organic C. Black carbon (BC) was analyzed by the method given by Aiken *et al*. (1985). Soil samples were reacted with 25 ml of 0.1 mol L^{-1} $K_2Cr_2O_7$+2mol L^{-1} H_2SO_4 solution at 55±1°C for 60 h, and the oxidized organic C was determined by titration using 0.2mol $L^{-1}FeSO_4$ solution. The content of BC was calculated by subtracting the oxidized organic carbon from the TOC. The microbial biomass carbon content (MBC) was determined by the chloroform fumigation–extraction method modified by Gregorich *et al*. (1990).

Roots analyses

The root mass density was measured at maximum vegetative stage in three different soil depths (0–15, 15–30, and 30–45 cm) with auger-like root sampler 15 cm (6 inch) in diameter and 22.5 cm (9 inch) in length using (3) [Schuurman and Goodewaagen, 1971].

$$\text{Root mass density} = \frac{Mass\ of\ root}{Total\ volume\ of\ soil}\ mg\ cm^{-3} \qquad ...(3)$$

Crop harvest and yield determination

At maturity, wheat was harvested manually at 10 cm above ground level. Grain and straw yields were determined from an area of 70.2 m^2 in flat beds and 69.7 m^2 in raised beds located in the center of each plot. The grains were threshed using a plot thresher, dried in a batch grain dryer and weighed. Grain moisture was determined immediately after weighing. Grain yield was reported at 12% moisture content.

Statistical analysis

Data were pooled and all parameters were analyzed as Split-plot model (Tillage crop residue practices as main effect, irrigation levels as sub-plot effect) by SAS software. All the treatments were compared by F-test at 5% level of probability.

RESULTS AND DISCUSSION

Changes of Soil Physical Properties

Bulk Density and Porosity

Among tillage and crop establishment methods, plots under zero till without residue T_2 had about 5% higher soil bulk density (1.62gm^{-3})

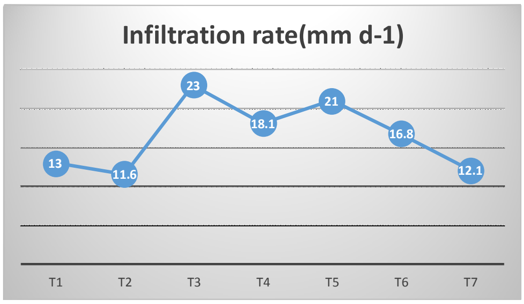
Table 1. Initial soil properties

Depthof soil(cm)	Total organiccarbon (g kg^{-1})	Total N(g kg^{-1})	Bulk density (g cm^{-3})	Field waterholding capacity (mm cm^{-1})	Saturationmoisture capacity(mm cm^{-1})	Soil particle fraction (mm) <0.002 (%)	0.002- 0.02	>0.02
0	18.2	1.8	1.51	2.3	4.3	35.0	30.9	34.1
5	17.7	1.8	1.55	2.5	5.1	35.6	28.3	36.1
10	16.8	1.7	1.58	2.3	4.5	37.2	26.4	36.4
20	14.0	1.4	1.61	2.3	4.9	38.1	27.2	34.7
30	13.0	1.3	1.69	2.5	5.6	38.8	27.5	33.7

Table 2. Effect of tillage crop establishment on Bulk density, Cation exchange capacity, Aeration porosity, Capillary porosity, Total porosity, Hydraulic conductivity, Field capacity, Permanent wilting point and infiltration rate in wheat crop.

Treatments	Bulk density (gcm^{-3})	Cation exchange capacity (cmol kg^{-1})	Aeration porosity (>60[micro]m)	Capillary porosity (> 60[micro]m)	Total porosity (%)	Hydraulic conductivity (mm h^{-1})	Field capacity (%) 0-5	5-20	Permanent wilting point (%) 0-5	5-20 cm
Tillage crop establishment										
T_1	1.52	24.40	37.24	10.67	51.86	53.5	31	32	11	10
T_2	1.62	22.33	34.33	10.02	37.98	45.6	29	30	9	10
T_3	1.44	22.43	42.99	8.03	54.25	46.3	29	30	12	11
T_4	1.46	20.87	41.19	7.93	52.36	36.6	29	29	11	10
T_5	1.45	23.04	46.32	9.72	53.01	48.5	30	31	13	11
T_6	149	21.89	42.64	8.34	49.74	43.8	28	30	12	10
T_7	1.54	19.86	39.59	6.15	41.58	35.3	27	29	11	09
LSD < 0.05	0.09	1.05	2.38	1.88	8.83	9.38	-	-	-	-

than T_7 plots (Table 2).Unlike residue management, tillage had greater impacts on soil bulk density. Plots under T_3 and T_5 had ~7% less soil bulk density as compared with T_7 treated plots (Table 2).The bulk density did varied significantly due to planting techniques and it was significantly reduced under raised bed planting compared to flat sowing. This was attributed mainly due to more pore spaces created in the beds through modified land configuration by accumulations the topsoil. Bed planting provides natural opportunity to reduce compaction by confining traffic to the furrow bottoms [Govaerts *et al*., 2006].The field capacity (FC) was also increased due to different tillage practices. The highest FC increase (12.5%) was found in T_1 followed by T_5.After two years treatment T_7 showed the lowest increase of field capacity value (Table 2). Permanent wilting point



(PWP) was also influenced by the different tillage practices. After two years, the permanent wilting point was decreased due to tillage practices (Table 2). The highest reduction (8.3%) was found in raised beds configuration followed by CT (7.8%) and the lowest reduction (7.5%) in ZT.

Aeration porosity, Capillary porosity, Total porosity

Soil porosity results showed that the residue retention treatments (T_2, T_3 and T_5) could increase the total porosity of soil, while zero tillage without residue (T_2) would decrease the soil porosity for aeration, but increase the capillary porosity; as a result, it enhances the water holding capacity of soil along with bad aeration of soil. However, the effects of tillage and residue retention treatments (T_3 and T_5) on the total porosity and porosity size distribution were not significant and zero tillage without residue (T_2) could increase the quantity of big porosity. Residue retention treatments shown an improvement in the soil porosity and was most probably related to the beneficial effects of soil organic matter caused by zero tillage and residue cover (Table 2). Oliveira and Merwin, 2001 found that the increased porosity is especially important for the crop development since it may have a direct effect on the soil aeration and enhances the root growth.

Table 3. Effects of tillage crop establishment on the contents of total organic carbon (TOC), water soluble organic carbon (WSOC),easily oxidizable organic carbon (EOC),total alkali-soluble humic extract carbon (HEC),humic acid carbon (HAC),humin carbon (HMC), black carbon (BC) and microbial biomass carbon (MBC) in soils

Treatments	TOC (g kg^{-1})	WSOC (g kg^{-1})	EOC (g kg^{-1})	HEC (g kg^{-1})	HAC (g kg^{-1})	HMC (g kg^{-1})	BC (g kg^{-1})	MBC (mg kg^{-1})
Tillage crop establishment								
T_1	8.95	0.34	6.17	5.16	3.07	4.13	4.08	461.22
T_2	8.13	0.30	5.16	4.13	2.16	3.03	2.84	381.82
T_3	8.79	0.33	5.98	4.87	2.98	3.92	3.72	436.26
T_4	8.07	0.27	4.67	3.66	2.63	2.68	2.49	331.64
T_5	9.36	0.36	6.89	5.66	3.45	4.78	4.49	484.16
T_6	8.25	0.31	5.78	4.93	2.78	3.38	3.36	451.64
T_7	7.30	0.23	3.91	2.91	2.05	2.30	2.29	283.67
LSD < 0.05	0.87	0.06	1.43	1.31	0.96	1.51	1.33	108.78
Irrigation levels								
I_1	6.05	0.21	3.66	3.36	2.56	4.35	3.14	293.25
I_2	6.87	0.23	3.82	4.68	3.02	4.68	3.76	309.47
I_3	7.13	0.27	4.83	5.36	3.26	5.14	4.12	311.53
I_4	7.95	0.32	5.09	5.87	3.92	5.82	4.83	328.15
LSD < 0.05	0.86	0.07	0.31	0.67	0.78	0.69	0.81	36.13

Table 4. Effect of tillage crop establishment and irrigation levels on root volume (cm^3 $plant^{-1}$), root length (cm $plant^{-1}$) and average root dry weight (g $plant^{-1}$)

Treatments	Root volume (cm^3 $plant^{-1}$)				Root length (cm $plant^{-1}$)				Root dry weight (g $plant^{-1}$)			
	45 DAS		90 DAS		45 DAS		90 DAS		45 DAS		90 DAS	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Tillage crop residue practices												
T_1	8.20	8.05	15.30	15.40	21.90	21.30	43.60	44.70	0.88	0.92	2.53	2.53
T_2	6.75	6.95	12.35	13.00	15.80	17.20	36.30	36.90	0.81	0.87	2.49	2.36
T_3	8.30	8.40	15.50	15.70	22.50	21.20	44.70	45.90	0.93	0.99	2.59	2.59
T_4	7.30	7.05	13.50	13.10	18.50	18.60	38.90	39.90	0.82	0.87	2.35	2.45
T_5	8.40	8.70	16.40	16.60	22.60	24.50	45.10	46.90	0.99	1.03	2.73	2.74
T_6	8.10	7.90	14.80	14.90	18.80	19.40	39.70	40.20	0.84	0.90	2.51	2.49
T_7	6.40	6.55	11.90	12.30	16.60	17.40	37.50	37.20	0.79	0.82	2.31	2.34
LSD < 0.05	1.01	1.16	1.74	1.63	2.21	2.36	4.36	4.52	0.059	0.057	0.125	0.135
Irrigation levels												
I_1	8.10	7.60	15.20	15.00	21.90	21.50	44.90	44.20	0.69	0.76	2.27	2.25
I_2	8.30	8.10	15.50	15.15	22.80	21.90	45.60	46.90	0.81	0.82	2.35	2.36
I_3	8.40	8.30	16.30	15.30	21.70	21.30	44.60	45.70	0.93	0.92	2.59	2.59
I_4	7.20	8.10	14.80	15.10	21.50	21.20	44.30	45.40	0.97	0.96	2.69	2.68
LSD < 0.05	0.70	1.01	1.69	1.74	2.01	2.21	4.42	4.52	0.135	0.125	0.295	0.291

The improved root growth would hence increase plant water as well as nutrient uptake. Within the conservation tillage treatments, T_3 and T_5 produced more aeration porosity than T_1, but the effect on capillary porosity appeared to be reversed. Husnjak and Kosutic (2002) reported that higher BD reduced the total porosity and changed the ratio of water holding capacity to air capacity in favour of water holding capacity.

Cation Exchange Capacity

Cation exchange capacity (CEC) was also increased due to tillage crop establishment. The highest CEC increase (10.3%) was found in T_1 followed by T_5 (4.2%) and T_3 (1.4%). Treatment T_7 showed the lowest increase of CEC from the experimentation (Table 2).The large loss of aggregate stability for the zero-till system is of particular concern, as it suggests that the increased aggregate stability of surface soil under no-till is due to surface residue rather than an intrinsic property of zero-tillage. This observation is consistent with that of Hammer beck *et al*., (2012).

Infiltration

Infiltration of water into soil was influenced by tillage crop establishment. After two years, the highest increase (28.2%) was found in T_3 followed by T_5 (21.4%) and T_1 (7.4%), whereas T_2 and T_7 showed decreasing trend after two years (Table 2). Tillage plays a vital role in improve the soil condition by altering the mechanical impedance to root penetration, hydraulic conductivity and water holding capacity. Increases in the bulk density usually result in large decreases in water flow through the soil. Naresh *et al*., (2015) reported that retaining crop residues on the soil surface with conservation tillage would reduce evapo-transpiration and increase infiltration rate. Bhattacharyya *et al*., (2008) observed that the retaining crop residues on the soil surface with conservation tillage plots showed enhanced infiltration characteristics (infiltration rate, cumulative infiltration and sorptivity) and saturated hydraulic

Soil Chemical Properties

Soil total organic carbon and organic carbon fractions

The contents of soil total organic C and organic C fractions are shown in Table 3. The contents of TOC, WSOC, EOC, HEC, HAC, HMC and BC, MBC were all higher in the residue retained tillage crop establishment than in the without residue and conventional tillage treatments, respectively. Although the differences between the two treatments were non-significant. The increase amplitudes were larger for the EOC and HEC (65.5 and 53.2%, respectively) than for the HAC, HMC and BC (14.0, 17.7 and 16.1%, respectively). In previous studies, higher soil organic C contents under zero till with residue return than under conventional tillage (Razafimbelo *et al*.,2008),

Table 5. Yield, water application and water productivity under various crop establishment techniques

Treatments	Crop yield ($t\ ha^{-1}$)		Water application ($mmhm^{-2}$)		Water productivity (kgm^{-3})		Net return ($Rs.ha^{-1}$)	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Tillage crop residue practices								
T_1	5.30	5.10	330	318	1.55	1.67	37189	37495
T_2	4.95	4.87	348	359	1.40	1.38	34995	33057
T_3	5.25	4.98	278	252	1.79	2.08	35028	33925
T_4	4.80	4.79	305	296	1.57	1.62	29783	28090
T_5	5.45	5.40	250	246	2.16	2.21	36288	35230
T_6	5.10	4.91	275	268	1.79	1.90	33642	31059
T_7	4.64	4.59	380	391	1.21	1.19	27972	26775
LSD < 0.05	0.51	0.59	-	-	-	-	178.35	173.38
Irrigation levels								
I_1	4.59	4.30	384	349	1.12	1.32	35784	31248
I_2	4.63	4.45	450	417	0.99	1.11	38367	31815
I_3	4.78	4.65	527	533	0.88	0.90	38690	31o59
I_4	4.80	4.98	535	582	0.90	0..86	32685	36031
LSD < 0.05	0.45	0.43	-	-	-	-	297.6	283.17

under reduced tillage than under conventional tillage (Šimanský *et al*.,2008),have been reported. These could explain our present result that the content of TOC was higher in the conservation agricultural practices than in the conventional agricultural (Table 3). In accordance with our results the larger increase in the active organic carbon fractions EOC than in the resistant organic carbon fractions (HEC,HAC,HMC and BC) (Table 3) implied that the two active organic carbon fractions could be a more sensitive index for the effects of agricultural practices.

The contents of soil total organic C and organic C fractions of the bulk soil were significantly affected by irrigation levels. Plots under I_4 and I_3 had about 29 and 24% higher EOC contents, respectively, in the bulk soil than I_1 plots (3.66 g kg^{-1} bulk soil). Both I_1 and I_2 plots had similar EOC contents in that soil. Furthermore, the plots under I_4 had significantly higher EOC content than both I_2 and I_1 plots.

Rooting characteristics

Planting system and irrigation management on root volume ($cm^3 plant^{-1}$)

Among planting systems, at 45 DAS significantly higher root volume (8.3 and 8.4 $cm^3 plant^{-1}$) was registered under raised beds planting with retention as compared to conventional planting system during the years of experimentation (Table 4).Similar trend was observed at 90 DAS. The water application at CRI and active tillering stages showed a significantly higher root volume at 45 and 90 DAS over pre sowing (I_1).

Planting system and irrigation management on root length (cm plant-^{1})

A perusal of data clearly indicates that root length cm $plant^{-1}$ was significantly increased under raised beds configuration.The maximum root length cm $plant^{-1}$ at 45 DAS was recorded in T_5 (22.60 & 24.50 cm) which were significantly higher as compared to all other treatments except T_3 which recorded significantly more root length over T_1 treatment. However, the differences over the treatments T_2 and T_7 were no significant during 2010-11 and 2011-12, respectively (Table 4). At 90 DAS, treatment T_5 (45.60 & 46.90 cm) produced significantly taller root length than rest of the treatments. Treatments T_1 and T_3 were significantly superior over T_7 but the difference of T_1 and T_3 were non-significant. Treatments T_2 and T_7 were at par with each other but T_2 statistically superior over least (37.50 & 37.20 cm) treatment T_7 during experimentation. Higher root length in raised beds treatments due to lower bulk density, more porosity, better infiltration and penetration resistance in soil layers and sufficient amount of moisture. Aggarwal *et al*., 2006 and Naresh *et al*., 2015 also reported higher root length under bed planting than that of zero and conventional tillage.

Planting system and irrigation management on root dry weight (g plant-^{1})

Table 4, shows the effect of different treatments on root dry weight of wheat during 2010-11 and 2011-12 years of study. At 45 DAS, treatment T_5 recorded numerically higher root dry weight (0.99 & 1.03 g $plant^{-1}$) over all the treatments during the years of study. T_7 produce lowest (0.79 & 0.82 g $plant^{-1}$) root dry weight. The higher root dry weight from 45 to 90 days stage was found maximum under raised beds planting with residue retention treatments. At 90 days stage, maximum root dry weight (2.73 & 2.74 g $plant^{-1}$) was obtained under T_5 treatment being significantly higher than those for the rest of the tillage crop establishment system, except T_3 and least (2.31 & 2.34 g $plant^{-1}$) under T_7 "conventional tillage". The difference in root dry weight between T_1 and T_5 treatment was statistically at par with each other during 2010-11 and 2011-12, respectively. Amongst irrigation levels/schedule, at 45 and 90 days stage the significant higher root dry weight was obtained in I_4 treatment as compared to other irrigation levels during experimentation but was statistically at par with I_3 irrigation level, respectively.

Yield parameters

Crop productivity

Irrigation and tillage have a strong effect on production of wheat. However, the residue rates did not have significant effect on grain yield in the second year. Grain yield was higher in T_5 treatments in both years. However, there was no significant difference in grain yield in the second year, which is in agreement with the reduced and no-tillage experiment of Naresh *et al*., (2015) for continuous irrigated wheat. Grain yield was significantly lower in the second compared to the first year due to rice residues accumulation. As rice residues have a slow decomposition rate (Singh *et al*., 2011), un-decomposed residues remained in the field in the second year. Irrigation water which is unsuitable for decomposition. This can immobilize a relevant amount of soil mineral N reducing its availability to wheat crops sown following rice. As a consequence, grain yield significantly decreased in the second year mainly due to immobilization of N as residues with high C:N ratio are incorporated into the soil (Singh *et al*., 2011).Table 5 shown that maximum yield between irrigation and tillage treatment was found as 5.16 tha^{-1} when T_5 I_4 treatment was applied and minimum yield between irrigation and tillage treatment was obtained as 4.53 tha^{-1} for treatment $T_7 I_1$.Although the overall yield performance was a little worse than the other treatments, but the irrigation water was used most effectively resulting comparatively higher water productivities. From Table 5 it can be seen that the maximum yield for irrigation treatment I_4 was obtained as 4.89 tha^{-1} in tillage treatment T_5 and the minimum yield was obtained as 4.45tha^{-1} in tillage treatment T_7.In Table 5 from the above discussion it can be decided that for the Irrigation treatment I_3 and I_4 better yield was obtained in tillage treatment T_1, T_3 and T_5, respectively.

Water application use and water productivity

The irrigation water application depends on the total rainfall and its pattern of distribution. On average, the highest water application (388.5&558.5 mm) was in T_7 with I_4 followed by T_2 with I_3 (353.5&530 mm), and T_4 with I_2(300.5&433.5mm).Treatments T_5,T_3 and T_1 (raised beds with residue retention and zero till with residue retention) applied 137.5,120.5 and 61.5mm/hm^2 less irrigation water than T_7 (conventional tillage) Table 5. Averaged over two years WP_I wheat was 36.5% higher in raised beds than conventional tillage, respectively. The increase in WP_I is the resultant of increase the saving in irrigation water.

Profitability

The cost of cultivation in wheat was significantly affected by tillage systems in all the years (Table 5). The cost of cultivation was significantly higher under conventional tillage and raised beds than under zero tillage. The higher cost of production under raised beds and conventional tillage systems compared to zero tillage was mainly due to cost of tillage and irrigation water. Gross and net returns were significantly higher in zero tillage and raised beds systems compared to conventional tillage .The increase in net income in zero tillage treatments compared with conventional tillage was 8310 Rs/hm^2, respectively. The saving was mainly through reduced cost in land preparation and planting method (53%), irrigation water (11%), and labor. These findings are in agreement with reference Naresh *et al*., (2015) and Saharawat *et al*., (2010).

CONCLUSIONS

Soil conservation management improved the quality of the soil by enhancing the total organic carbon fractions and biological status of soil. Results of this 2-year field study on wheat crop indicate that the content of TOC, WSOC, EOC, HEC, HAC, HMC, BC and MBC increased with residue retention in soil. The enhanced proportions of EOC, HEC, HAC, HMC, BC and MBC in conservation tillage with the supply of optimum moisture and retention of crop residues indicate that the improvement in forms of both total organic C and organic C fractions.

In the subtropical climatic conditions, a reduction in tillage intensity led to a significantly greater SOC concentration in the soil. Conservation-tillage plots, however, had significantly more SOC on an equivalent depth basis. Frequent irrigations at the critical growth stages of wheat improved the SOC status in the soil. There was a significant increase in wheat yields in the plots where three irrigations were applied compared with only one or two irrigation. Wheat yield also increased significantly in plots with four irrigations compared with two irrigations. These findings indicate that conservation tillage with residue retention may be more desirable than conventional tillage in terms of crop productivity and SOC retention under an irrigated wheat system. A minimum of three irrigations in wheat crops is necessary for maintaining crop productivity and contents of soil total organic C and organic C fractions in the soil. Frequently irrigated plots had better total organic C and organic C fractions.

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