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Research Article

Effect of Tillage, Residue and Nitrogen Management on Soil Physical Properties, Soil Temperature Dynamics and Yield of Wheat in an Inceptisol

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ABSTRACT

Conventional tillage leads to loss of soil organic carbon, disruption of soil structure, formation of sub-surface hard pan, increased soil erosion leading to deterioration of soil health and low input use efficiency. Thus, adoption of conservation agriculture practices involving no-tillage and crop residue mulch can address this problem. In this backdrop, the present study was carried out in a sandy-loam soil in the research farm of the Indian Agricultural Research Institute, New Delhi during the years 2014-15 and 2015-16 to evaluate the effect of conventional and no tillage (CT and NT, respectively) on soil physical properties and temperature dynamics in a sandy-loam soil under wheat crop both in the absence and presence of maize residue mulch @ 5 t ha^{-1} at three different levels of nitrogen fertilizer application (60, 120 and 180 kg N ha^{-1}) in a split-split plot design. It was found that the bulk density was slightly higher under NT than CT by 3.3 and 1.2% at 0-15 and 15-30 cm soil depth, respectively. Crop residue mulch reduced bulk density by 3.6% at 0-15 cm soil depth than un-mulched condition. The mean weight diameter and water stable aggregates under NT and mulched condition were higher than that of CT and un-mulched condition. The total porosity and air filled porosity under CT and mulched condition was higher than thatof NT and un-mulched condition. Effect of tillage, crop residue mulch and nitrogen management was not significant on SOC at 0-15 and 15-30 cm soil depth. The SOC concentration under crop residue mulch at 0-15 and 15-30 cm soil depths were 3.99 and 3.23 g kg^{-1} whereas under un-mulch treatment, it was 3.91 and 2.71 g kg^{-1}, respectively. The soil temperature at surface, 5 and 10 cm soil depths was higher under NT without mulch than that of CT having crop residue mulch. There was no significant difference between tillage and residue management with respect to grain yield of wheat but with the increase in the nitrogen levels, grain yield of wheat increased significantly. Thus, farmers can successfully adopt NT system in irrigated wheat with maize residue mulch application @ 5 t ha^{-1} and 180 kg N ha^{-1} to attain better soil physical health, soil thermal regime and higher grain yield in the Upper Indo-gangetic plain region.

Key words: Conventional tillage, No tillage, Wheat, Physical properties, Soil temperature

Introduction

Tillage practices involve physical manipulation of soil for improving crop growth. It makes the soil either porous or compact and

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alters the mass and volume relationship of soil, clod-size distribution, increases surface roughness and soil porosity (Allmaras, 1966). It also kills weeds (Swanton, 1999). These changes affect soil-water regime, resistance to erosion, mechanical impedance, aeration status and soil thermal regime. However, excessive and indiscriminate tillage under conventional practices such as deep moldboard plowing, ridging, etc. can cause loss of soil organic carbon, degradation of soil structure, and extensive wind and water erosion leading to deterioration of soil health and low input use efficiency. Most, if not all, of these impeding factors would likely to be mitigated substantially by replacing conventional tillage with conservation tillage, or at least reduced tillage (Abid and Lal, 2008; Bandyopadhyay and Lal, 2015). Conservation agriculture includes practices which minimize the soil disturbance, provide soil cover through crop residues, mulch or cover crops, and crop rotations for attaining higher productivity and minimizing adverse environmental impacts (Holland, 2004). The crop residues placed over the soil surface favors processes that improve soil quality by protecting the soil from raindrops and limiting water evaporation (Klocke *et al.,* 2009). Therefore, conservation agricultural practices lead to sustainable enhancement in the efficient use of water by increasing infiltration and soil water retention and reducing evaporation loss, as well as by improving nutrient balances and their availability (Dahiya *et al.*, 2007; Govaerts *et al.*, 2007; Verhulst *et al.*, 2010). Conservation agriculture (CA) also improves the soil health (mainly by improving soil organic matter) and availability of ground and surface water. Thus, conservation tillage has been found to decrease wind and water erosion and soil water evaporation, increase rainfall infiltration, enhance near-surface soil organic carbon content, increase the size and stability of soil aggregates and decrease fuel and labour input costs relative to most conventional tillage systems (Liu *et al.*, 2013). Application of straw mulch can lower maximum soil temperature due to interception of the incoming solar radiation, high reflectivity and low heat conductivity, the magnitude of which depends upon soil wetness, incidental radiation, rate of mulch application as well as period of the year (Parihar, 1986). The moderation of soil temperature and modification of physical properties of soil under tillage and crop residue mulching may influence the root and shoot growth. With this background, the objective of this study was to evaluate the effect of no-tillage and conventional tillage in the presence and absence of crop residue mulch on physical properties, soil temperature dynamics and wheat crop growth at three different levels of Nitrogen fertilizer application.

Materials and Methods

Soil and climate of the experimental site

The soil of the experimental site was sandy loam (Typic Haplustept) of Gangetic alluvial origin, very deep (>2 m), flat and well drained. Detailed soil physico-chemical characteristics were determined before initiating the experiment and the data are presented in Table 1. It showed that the soil was mildly alkaline, non-saline, low in organic C (Walkley and Black C) and available N, and medium in available P and K content. The surface soil (0–15 cm) has bulk density 1.58 Mg m^{-3}; hydraulic conductivity (saturated) 1.01 cm h^{-1}, saturated water content (0.41 m^3 m^{-3}), EC (1:2.5 soil/water suspension) 0.36 dS m^{-1}; organic C 4.2 g kg^{-1}; total N 0.032%; available (Olsen) P 7.1 kg ha^{-1}; available K 281.0 kg ha^{-1}; sand, silt and clay, 64.0, 16.8 and 19.2%, respectively. The bulk density varied from 1.58 Mg m^{-3} in the 0-15 cm layer to 1.72 Mg m^{-3} in the 90-120 cm layer. Available soil moisture content ranged from 24.6-28.3% (0.033 MPa) to 9.7-12.9% (1.50 MPa) in different layers of 0-120 cm soil depth.

New Delhi has sub-tropical semi-arid climate with dry hot summer and brief severe winter. The average monthly minimum and maximum temperature in January (the coldest month) ranged between 5.9°C and19.9°C, respectively. The corresponding temperature in May (the hottest month) ranged between 24.4 and 38.6°C, respectively. The average annual rainfall is 651 mm, out of which, 75% is received through south-west monsoon during July to September.

Table 1. Physico-chemical properties of the soil at the experimental site

Depth (cm)	Bulk density ($Mg\ m^{-3}$)	pH	EC ($dS\ m^{-1}$)	Saturated hydraulic conductivity ($cm\ h^{-1}$)	SOC ($g\ kg^{-1}$)	Particle size distribution			Soil texture	Soil moisture constants (cm^3/cm^3)	
						Sand (%)	Silt (%)	Clay (%)		0.033 MPa	1.5 MPa
0-15	1.58	7.1	0.46	1.01	4.2	64.00	16.80	19.20	SL	0.254	0.101
15-30	1.61	7.2	0.24	0.82	2.2	64.40	10.72	24.88	SCL	0.269	0.112
30-60	1.64	7.5	0.25	0.71	1.6	63.84	10.00	26.16	SCL	0.283	0.129
60-90	1.71	7.5	0.25	0.49	1.2	59.84	10.00	30.16	SCL	0.277	0.110
90-120	1.72	7.7	0.30	0.39	1.1	53.68	13.44	32.88	SCL	0.247	0.097

Experiment details

The field experiments were conducted during *rabi* season of 2014-15 and 2015-16 at ICAR-IARI Research Farm (MB 4C) to study the effects of tillage, residue and nitrogen management on soil water and nitrogen dynamics, evapo-transpiration and nitrogen uptake in wheat (*Triticum aestivum* L). The treatments comprising of two levels of tillage as main plot factor [Conventional tillage (CT) and No Tillage (NT)), two levels of residue as subplot factor (maize residue @ 5 t ha^{-1} (R_+) and without residue (R_0)], and three levels of Nitrogen as sub-sub plot factors (60, 120 and 180 kg ha^{-1}, representing 50% (N_{60}), 100% (N_{120}) and 150% (N_{180}) of the recommended dose of nitrogen for wheat, respectively) were evaluated in a split-split plot design with three replications.

The sub subplot-size was 4.5 m × 5 m. Wheat crop (cv. HD 2967) was sown on 16th and 28th November in 2014 and 2015 respectively, by a tractor drawn no-till seed drill (at a depth of 4-5 cm) with a row spacing of 22.5 cm at a seed rate of 100 kg/ha and harvested on 17thApril 2015 and 5th April 2016, respectively. In Conventional tillage treatment, the plot was ploughed once with disc plough and once with duck-foot tine cultivator followed by leveling and sowing by seed drill. In No tillage treatments, the seed was directly sown using an inverted T type no-till seed drill. Weedicide glyphosate @ 10 ml L^{-1} was used for control of weeds before sowing of wheat. Maize residue was applied manually at the rate of 5 t/ha under R_+ treatment after CRI stage. Nitrogen was supplied as urea in three splits *i.e.*, 50% at sowing, 25% at CRI stage and rest 25% at flowering stage. All the plots received a uniform dose of 60 kg P_2O_5/ha as single super phosphate and 60 kg K_2O/ha as muriate of potash applied as basal dose at sowing. All the plots received five irrigations at critical growth stages i.e., CRI, Tillering, Jointing, Flowering and Milk stage. Field was kept weed free by employing manual weeding 3-4 times during crop growth stages.

Measurements

Bulk density and porosity

The bulk density was determined by undisturbed core method. The core sampler was pushed into the soil to the desired depth in such a way that soil core (5 cm internal diameter and 5 cm length) is collected from the centre of the given depth. Soil core samples were dried in oven at 105 °C for 48 hrs. Bulk density (Mg m^{-3}) was calculated by dividing weight of dried soil by the volume of core used (Veihmeyer and Hendrickson, 1948).

Total porosity was determined as Pt= (1-BD/PD) × 100

where, BD = Bulk density: PD = Particle density of soil (normally taken as 2.65 Mg m^{-3} for mineral soils)

Air filled porosity, Pe = Pt – θ

where θ = volumetric moisture content = water filled porosity

Mechanical composition of soil

The percentages of sand, silt and clay contents were determined by hydrometer method (Bouyoucos, 1962).

Soil aggregate analysis

The aggregate size distribution of the surface (0-15 cm) soil was determined by wet sieving method using Yodder's apparatus (Yodder, 1936). For this purpose, after capillary rewetting for 10 minutes, 100 g of soil aggregates (4-8 mm size) were kept on the top of 4 mm size sieve and shaken through a series of six sieves *i.e.* 4 mm, 2 mm, 1 mm, 0.5 mm, 0.25 mm and 0.125 mm, in a water drum for a period of 10 min approximately 3 cm up and down with the frequency of 50 times during 2 min. Soil samples from each sieve was collected. This resulted in distributing the aggregates into the following size classes *viz.*, (i) >4000 µm, (ii) 2000-4000 µm (iii) 1000-2000 µm (iv) 500 to 1000µm, (v) 250-500 µm (vi) 125-250 µm and (vii) <125 µm. Then these samples were dried in an oven and the dry weight was recorded. To determine the percentage of sand free mass in the size classes, soil from each of the size classes were shaken overnight with 1% (w/w) sodium hexametaphosphate solution and sieved through the corresponding sieve (Elliott, 1986). After rinsing several times with deionized water, the sand fraction retained in the sieve was oven dried at 100˚C and the dry weight was recorded. Water stable aggregation was expressed as the percentage of aggregates greater than 250 µm diameter. Mean weight diameter was calculated following Van Bavel (1949) from the weighted mean of the aggregate retained in each sieve using the following formula

$$MWD = \sum_{i}^{n} x_i \times w_i$$

where, x_i is mean diameter of the sieve and w_i is the proportion of the weight of soil retained in each sieve.

Soil temperature

Soil temperature was measured at weekly interval at soil surface, 5 cm and 10 cm soil depth at 2 pm. It was measured using digital soil thermometer (Thermotech TH-044 by M/S Loctron Instruments Private Ltd.). This thermometer was based on the principle of thermocouple. The output was provided in °C on display unit.

Root studies

Root samples were collected at flowering stage using core sampler of 15 cm height and 7 cm diameter at 15 cm depth increments up to the depth of 30 cm. The shoot of the plant was cut close to the soil and the soil surface was cleaned by removing unwanted materials if any. The core of the auger was inserted into the soil in such a manner that shoot was at the centre of the inserted core. The collected soil cores were sealed in polythene bags, brought to the laboratory, washed and processed for scanning. The lengths were recorded through the scanning and image analysis of the root skeleton (WINRHIZO system, Regent Instruments Inc., Canada). The root length was divided by the core volume to estimate root length density (RLD). Then these root samples were dried at 60°C using a hot air oven till constant weight was achieved. The root weight was divided by the volume of the soil core to get the root mass density.

Biomass partitioning

Representative plant samples were collected at grain filling stage and partitioned manually to root, stem, leaf and spike. Then these plant parts were dried in oven at 65p C using a hot air oven till constant weight is achieved.

Crop yield

For the measurement of grain yield, wheat crop was harvested from net plot after leaving the border area and the yield was expressed in kg ha^{-1}.

Results and Discussion

Weather

The monthly average maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity, bright sunshine hours, rainfall and pan evaporation

Table 2. Monthly weather condition during wheat growth during the year 2014-15 and 2015-16

Parameter→	Max. temp. (°C)		Min. temp. (°C)		Max. R.H. (%)		Min. R.H. (%)		Sunshine hours		Rainfall (mm)		Pan evaporation (mm)	
Month↓	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
November	28.3	28.1	10.6	11.9	84.3	90.3	37.6	47.4	5.7	2.4	0	2.2	3.1	3.4
December	20.6	22.6	6.7	6.1	93.8	93.9	59.0	49.7	4.4	3.5	26.4	0.0	2.1	2.8
January	16.9	20.7	6.8	6.5	96.0	95.9	68.8	59	2.3	2.4	35.8	0.0	1.9	2.5
February	24.6	24.6	10.6	8.1	91.9	88.7	48.0	53	5.1	5.7	0	0.0	2.6	3.0
March	27.2	30.8	13.1	13.7	90.8	88.2	51.0	54	6.9	6.8	201.8	0.6	3.7	5.1
April	33.9	38.7	19.2	19.1	76.6	67.7	43.4	45	7.2	7.8	51.8	0.0	6.8	8.2

during the growth period of wheat for the year 2014-15 and 2015-16 are presented in the Table 2. It was observed that during the year 2015-16, the crop experienced higher maximum temperature during the month of December, January, March and April by 9.7, 22.4, 13.2 and 14.2%, respectively than that of the year 2014-15. During the year 2014-15, the crop received total rainfall of 315.8 mm whereas during the year 2015-16, the crop received only 2.8 mm of rainfall. The month of March was the wettest month for the year 2014-15 with the rainfall of 201.8 mm. The average bright sunshine hours during the month of November and December in 2015-16 were less than that of 2014-15.

Bulk density

Bulk density at 0-15 and 15-30 cm soil depth after harvest of wheat 2015-16 as influenced by tillage, crop residue mulch and nitrogen management is depicted in Fig. 1. The average bulk density of soil at 0-15 and 15-30 cm soil depth were 1.52 and 1.69 Mg m^{-3}, respectively. It was observed that bulk density of soil under NT were marginally higher by 3.3 and 1.2%, respectively as compared to CT at 0-15 and 15-30 cm soil depth. This may be due to more close packing of soil solids under NT as compared to CT because tillage reduces the size of aggregates and thus, decreases soil solid's mass per unit volume (Hill, 1985). Further, since the experiment

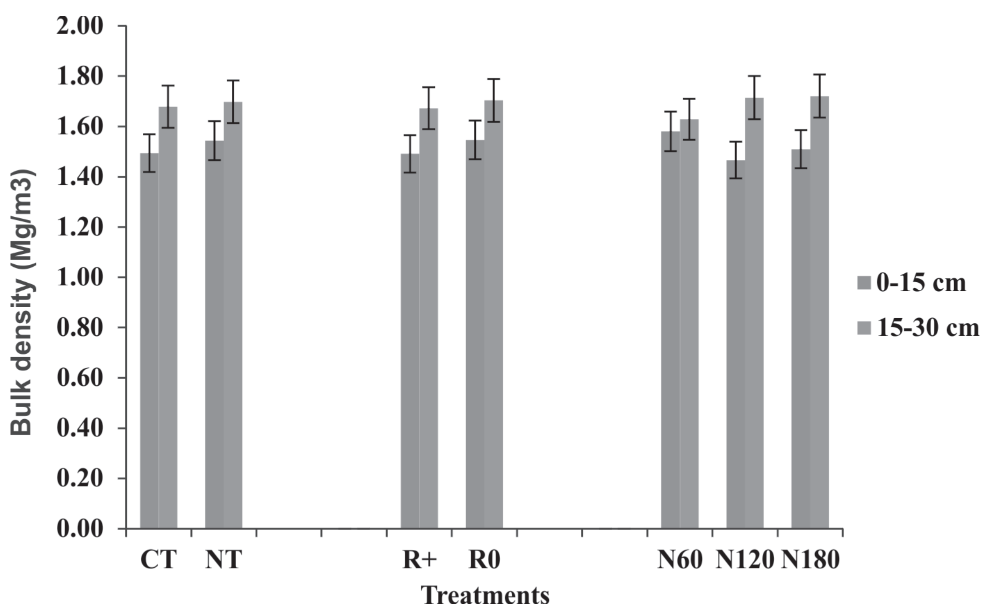

Fig. 1. Bulk density at 0-15 and 15-30 cm soil depth as influenced by tillage, residue mulch and nitrogen levels after wheat harvest during the year 2015-16

is only three years old, development of biopores in NT is yet to be experienced, which in the long run is expected to reduce the BD under NT. There was decrease in bulk density of soil by 3.6 and 1.8% at 0-15 and 15-30 cm, respectively under mulched as compared to un-mulched treatment. This may be due to addition of organic matter under mulched condition having lower mass and increased the soil porosity (Adams, 1973). The effect of nitrogen levels on bulk density of soil was not consistent.

Total Porosity and Air-filled porosity

The total porosity and air-filled porosity as influenced by tillage, residue and nitrogen management are depicted in Fig. 2. The average total porosity of soil at 0-15 and 15-30 cm soil depth was 0.43 and 0.36 $cm^3\ cm^{-3}$, respectively. Average air-filled porosity of soil under CT was higher than that of NT by 4.47 and 2.06% at 0-15 and 15-30 cm, respectively. Similarly, air-filled porosity under CT was higher than NT by 12.9 and 10.8% at 0-15 and 15-30 cm soil depth, respectively. This may be because of better pulverization of soil through tillage under CT than that of NT. The total porosity under crop residue mulch was higher than un-mulch treatment by 5.05 and 3.26% at 0-15 and 15-30 cm soil depth, respectively whereas the air filled porosity under crop residue mulch at 0-15 cm soil depth was 10.4% higher than that of un-mulch treatment, but at 15-30 cm soil depth, it was lower by 15.1% than that of crop residue mulch treatment. The total porosity increased under mulched condition due to addition of organic matter, which formed stable soil structure, but the air-filled porosity under sub-surface condition was reduced due to more storage of water as compared to un-mulched condition. The effect of nitrogen management on total porosity and air-filled porosity of soil was not consistent at 0-15 and 15-30 cm soil depths.

Mean Weight Diameter

The mean weight diameter at 0-15 and 15-30 cm soil depth as influenced by tillage, residue and nitrogen management is depicted in Fig. 3. The mean weight diameter at 0-15 cm soil depth ranged from 0.68 to 1.26 mm with a mean value of 0.90 mm and at 15-30 cm soil depth, it ranged from 0.41 to 0.91 mm with a mean value of 0.64

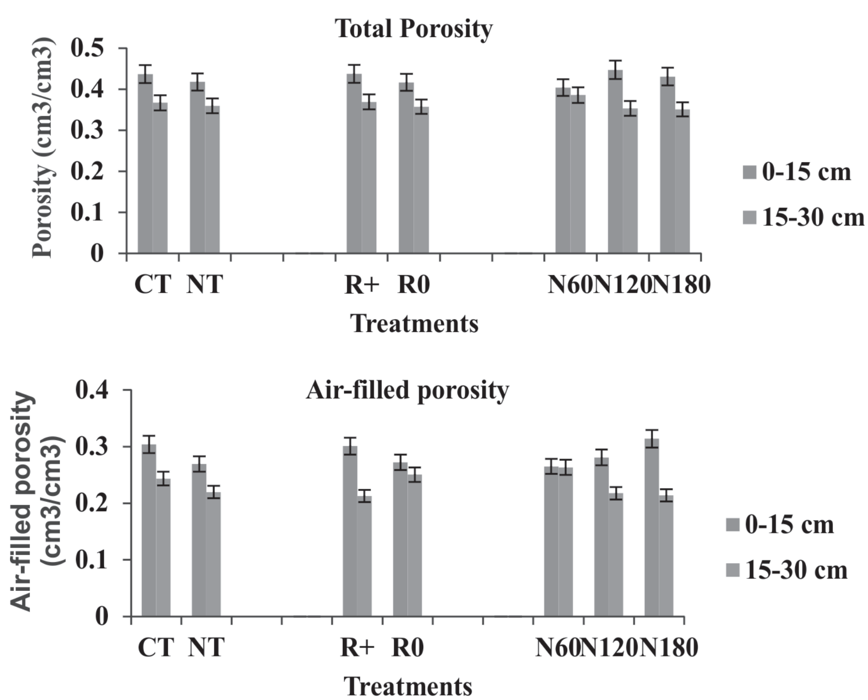

Fig. 2. Total porosity and air-filled porosity of soil at 0-15 and 15-30 cm soil depth as influenced by tillage, residue and nitrogen management after wheat harvest during the year 2015-16

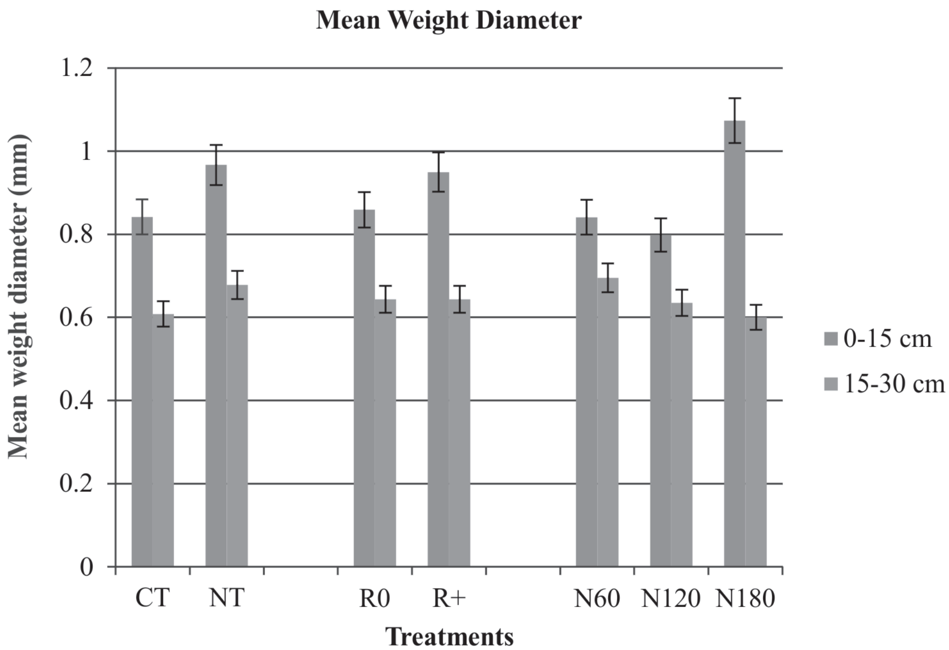

Fig. 3. Mean weight diameter as influenced by tillage, residue and nitrogen levels during the year 2015-16

mm. Averaged over crop residue mulch and N levels, the mean weight diameter under NT at 0-15 and 15-30 cm soil depths were higher than that under CT by 14.9 and 11.5%, respectively. This may be due to non disturbance of soil under NT. Averaged over tillage and N levels, the mean weight diameter under crop residue mulch at 0-15 cm soil depth was higher than that under un-mulch treatment by 10.5% but there was no significant difference in the mean weight diameter due to mulching at 15-30 cm soil depth. This was because the effect of organic matter addition and protection of soil aggregates from raindrop impact by crop residue mulch was mainly confined upto surface layer. Effect of N levels on mean weight diameter was not consistent.

Water stable aggregates

The water stable aggregate percentage at 0-15 and 15-30 cm soil depth as influenced by tillage, residue and nitrogen management has been depicted in Fig. 4. The water stable aggregate percentage at 0-15 cm soil depth ranged from 41.7 to 60.1% with a mean value of 49.9% and at 15-30 cm soil depth it ranged from 38.6 to 55.1% with a mean value of 47.1%. Averaged over crop residue mulch and N levels, the water stable aggregate percentage under NT at 0-15 and 15-30

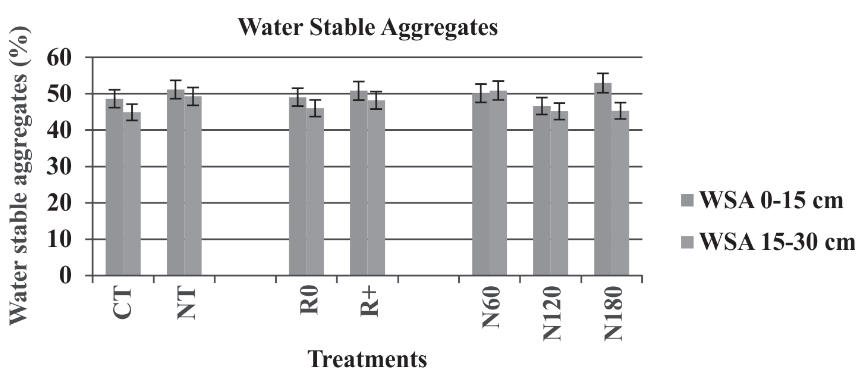

Fig. 4. Water stable aggregates percentage as influenced by tillage, residue and nitrogen levels during the year 2015-16

cm soil depths were higher than that under CT by 2.5 and 4.3%, respectively due to non-disturbance of soil under NT whereas disruption of aggregation due to tillage under CT. Averaged over tillage and N levels, the water stable aggregate percentage under crop residue mulch at 0-15 and 15-30 cm soil depth was higher than that under un-mulch treatment by 1.8 and 2.1%, respectively and higher organic matter and protection of aggregates from raindrop impact by mulch are responsible for the same. Effect of N levels on water stable aggregate percentage was not consistent.

Soil temperature dynamics

Temporal variation in soil temperature at surface, 5 and 10 cm soil depth as influenced by tillage and residue management for the year 2014-15 and 2015-16 is depicted in Fig. 5 and 6, respectively. During the year 2014-15 soil temperature at surface ranged from 13.4 to 31.9° C with a mean value of 23.4° C, at 5 cm soil depth it ranged from 12.6 to 27.6° C with a mean value of 20.8° C and at 10 cm soil depth it ranged from 12.3 to 26.9° C with a mean value of 19.6° C whereas air temperature ranged from 12.6 to 33.9°C with a mean value of 24.6°C. During the

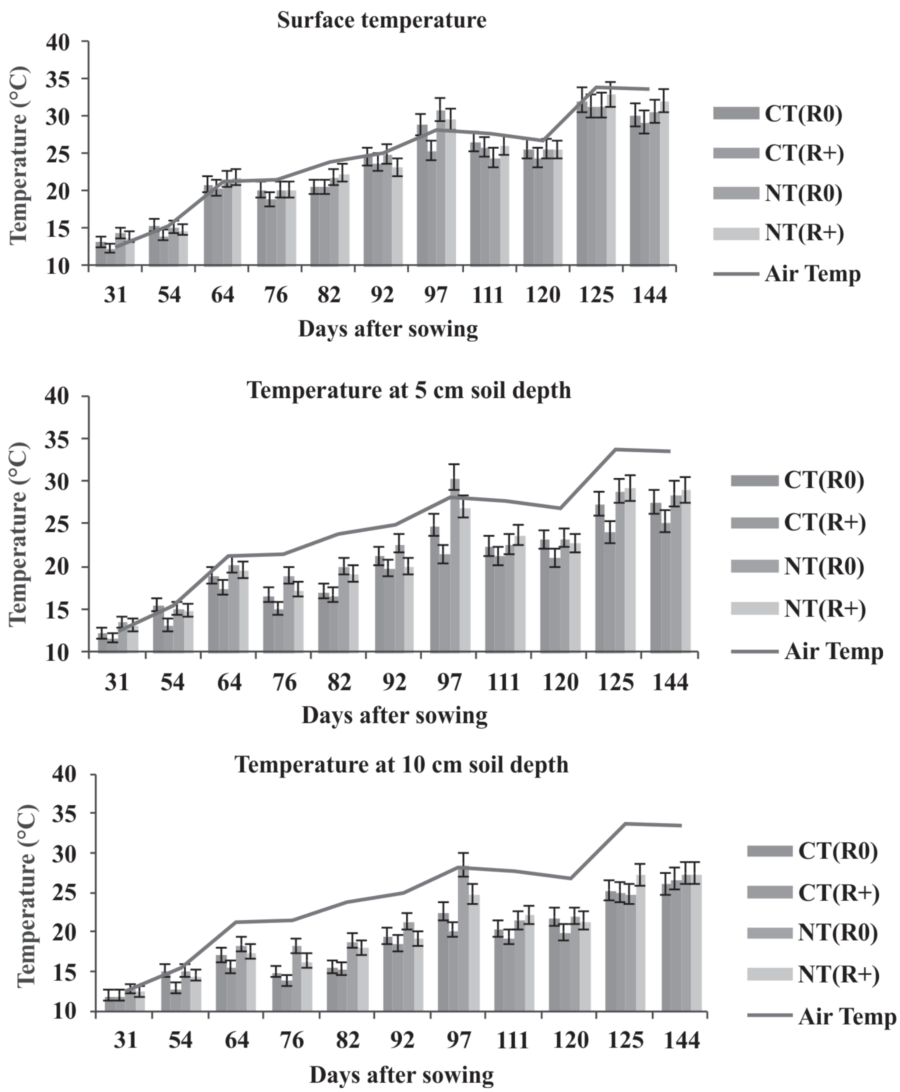

Fig. 5. Effect of tillage and residue management on temporal variation in soil temperature at surface, 5 cm and 10 cm soil depth during wheat, 2014-15

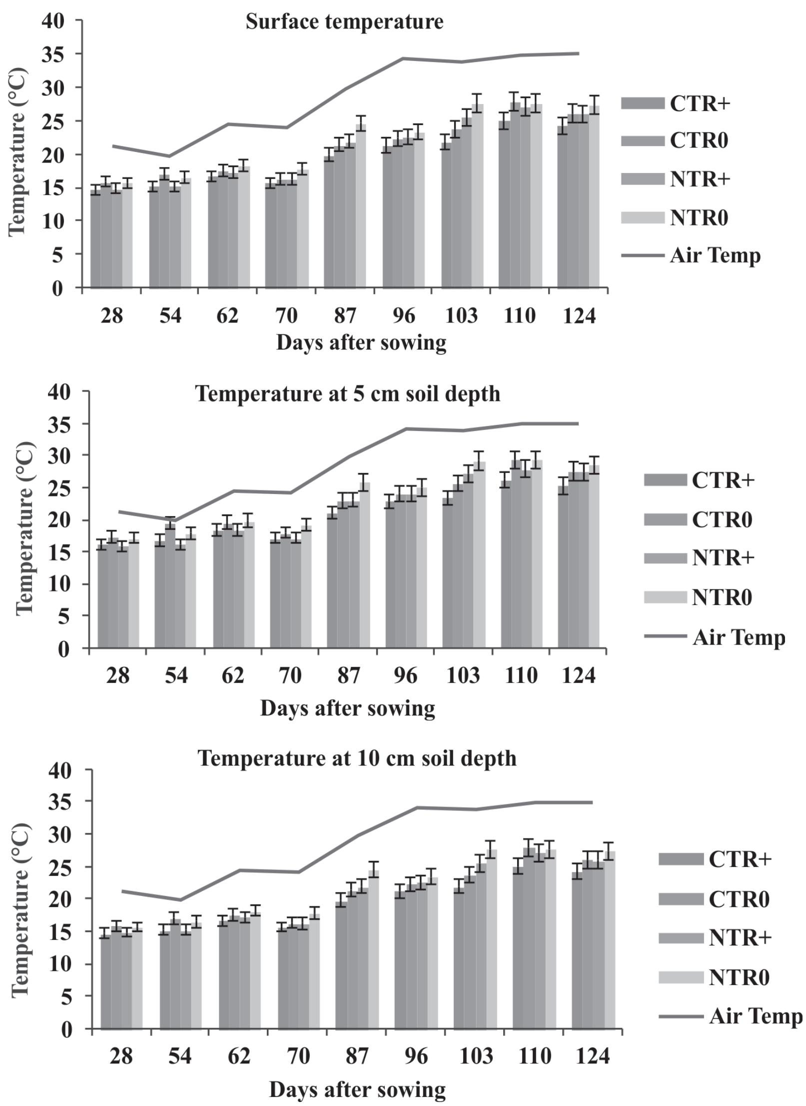

Fig. 6. Effect of tillage and residue management on temporal variation in soil temperature at surface, 5 cm and 10 cm soil depth during wheat, 2015-16

year 2015-16, soil temperature at surface ranged from 17.1 to 30.5°C with a mean value of 24.9°C, at 5 cm soil depth it ranged from 15.1 to 35.2°C with a mean value of 27.1°C and at 10 cm soil depth it ranged from 14.3 to 34.0°C with a mean value of 25.8°C whereas air temperature ranged from 19.3 to 35.1°C with a mean value of 28.7°C. Soil temperature at surface was higher than that of 5 and 10 cm soil depth in both the years of the study. Soil temperature followed the trend similar to that of air temperature. Soil temperature at surface, 5 cm and 10 cm soil depth was lower than that of air temperature except at 97 DAS during the year 2014-15. No tillage without residue treatment registered the maximum soil temperature at surface, 5 cm and 10 cm soil depth during the entire crop growth period during the year 2014-15 and 2015-16.This finding is in agreement with Gauer *et al.* (1981) who reported that No-tillage with straw removed had more soil temperature than tilled soil due to more bulk density which facilitated better heat flow. Application of maize residue mulch registered lower soil temperature than the un-mulch treatment in the surface soil. This may be attributed to the fact that application of straw mulch decreases maximum soil temperature by intercepting incoming solar radiation, increasing reflectivity and decreasing heat conductivity, the quantity of which is affected by soil wetness, rate of mulch application, incidental radiation, as well as, time of the year (Acharya *et al.,* 2005). However, difference in soil temperature at 5 and 10 cm depth due to mulching was less than that of surface soil. The soil temperature under CT was lower than that of NT. Soil temperature under higher nitrogen level (180 kg ha^{-1}) was less than that of lower nitrogen level (60 kg ha^{-1}) at the surface, 5 cm and 10 cm soil depth (data not given) because of better shading effect of canopy at higher N levels than at lower N levels.

Root growth

Root Length Density (RLD) and Root Mass Density (RMD) of wheat at 0-15 cm soil depth at flowering stage for the year 2015-16 has been depicted in Fig. 7. Averaged over residue and nitrogen levels, RLD of wheat at flowering stage was 0.513 and 0.336 cm cm^{-3} for CT and NT, respectively whereas RMD was 4.386 and 3.469 mg cm^{-3}, respectively. RLD under NT were significantly lower than under CT by 52.9% whereas RMD under NT was 24.7% lower than that of CT. Higher BD in the surface soil under NT than CT might have retarded the root growth in the former treatment. Further, higher biomass partitioning towards stem and leaves, and lower biomass partitioning towards roots and spikes in NT as compared to CT might have led to lower root mass density under NT. CT combined with application of mulch has large and deep root system and, hence, more nitrogen uptake as compared to zero-tilled system (Acharya and Sharma, 1994). However, Wilhelm (1998) found that the no-till treatment had highest root weight than plowed and sub-tilled treatment. There was no significant difference between RLD and RMD

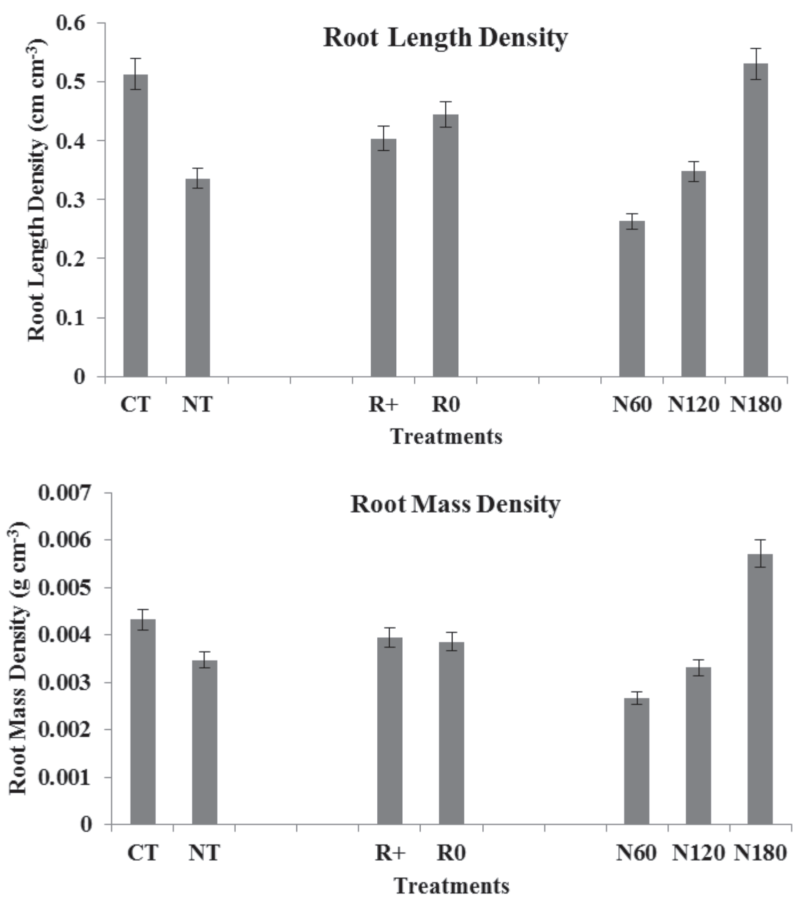

Fig. 7. Root length density (a) and Root mass density (b) of wheat at 0-15 cm soil depth as influenced by tillage, crop residue mulch and nitrogen levels for the year 2015-16

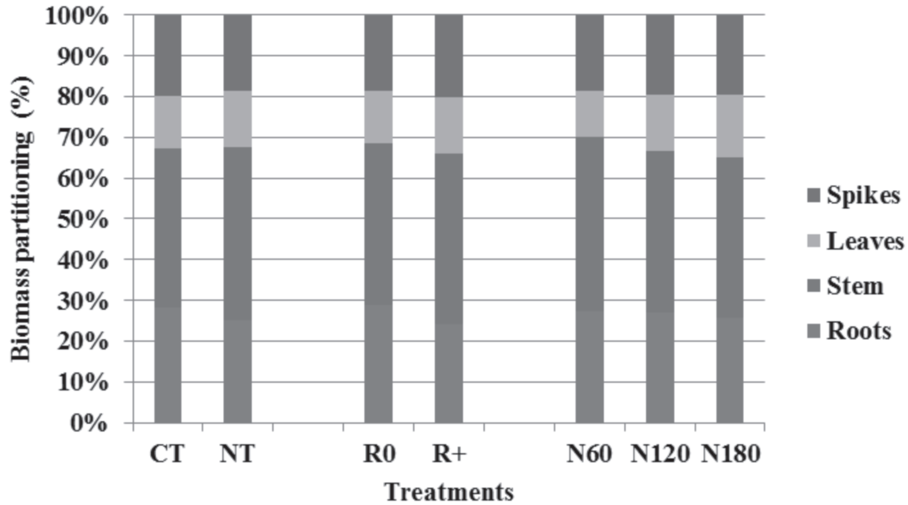

Fig. 8. Biomass partitioning of wheat at grain filling stage (120 days after sowing) as influenced by tillage, irrigation and nitrogen management

due to crop residue mulch. Averaged over tillage and nitrogen management, RLD at 0-15 cm soil depth was 0.40 and 0.44 cm cm^{-3} for mulched and un-mulch treatment, respectively. Similarly, the RMD was 3.94 and 3.85 mg cm^{-3} for mulched and un-mulch treatment, respectively. The RLD and RMD of wheat at 0-15 cm soil depth increased significantly with increase in the Nitrogen levels. Averaged over tillage and residue management, RLD at 0-15 cm soil depth was 0.26, 0.35 and 0.53 cm cm^{-3} for 60, 120 and 180 kg N ha^{-1}, respectively. Similarly, the RMD was 2.67, 3.31 and 5.71 mg cm^{-3} for 60, 120 and 180 kg N ha^{-1}, respectively. Application of 180 kg N ha^{-1} increased the RLD by 52.5 and 101.7% compared to 120 kg N $ha^{-1}$and 60 kg N ha^{-1}, respectively. Similarly, application of 180 kg N ha^{-1} increased the RMD by 72.3 and 113.5% compared to 120 kg N $ha^{-1}$and 60 kg N ha^{-1}, respectively. Application of 120 kg N ha^{-1} increased RLD and RMD by 32.3 and 23.9% as compared to 60 kg N ha^{-1}, respectively.

Biomass partitioning

Biomass partitioning of wheat plant at grain filling stage as influenced by tillage, residue and nitrogen management has been depicted in Fig. 8. It was observed that stem biomass (40.8%) was major contributor to the total biomass of the wheat followed by roots (26.6%), spike (19.2%) and leaves (13.4%). Averaged over nitrogen and residue management, NT resulted in higher biomass partitioning towards stem and leaves but lower biomass partitioning towards roots and spikes compared to CT. Averaged over nitrogen levels and tillage, crop residue mulch resulted in higher biomass partitioning towards stem, leaves and spikes but lower towards roots as compared to un-mulch treatment. With increase in nitrogen levels, biomass partitioning towards spike and leaves increased but biomass partitioning towards stem and roots decreased.

Grain and biomass yield of wheat

The grain yield of wheat as influenced by tillage, residue and nitrogen management for the year 2014-15 and 2015-16 are presented in the Table 3. During the year 2014-15, grain yield of wheat ranged from 3291 kg ha^{-1} (NT R_0 N_{60}) to 4884 kg ha^{-1} (NT R_0N_{180}) with an average value of 4282 kg ha^{-1}. Neither the tillage treatment nor the crop residue mulch significantly influenced grain yield of wheat in both the years of study. However, nitrogen levels significantly influenced the grain yield of wheat in both the years of study. Application of 180 kg N ha^{-1} significantly increased the grain yield of wheat by 26 and 36% than that of 60 kg N ha^{-1}during the year 2014-15

Table 3. Grain and biomass yield of wheat as influenced by tillage, residue and nitrogen management

Treatment	Grain yield (kg ha^{-1})		Biomass yield (kg ha^{-1})	
	2014-15	2015-16	2014-15	2015-16
Effect of tillage				
CT	4439$^{A\#}$	3096^{A}	11106^{A}	8467^{A}
NT	4125^{A}	3220^{A}	10633^{A}	8992^{A}
Effect of residues				
R_0	4319^{A}	3143^{A}	10649^{A}	8687^{A}
R_+	4245^{A}	3173^{A}	11090^{A}	8772^{A}
Effect of nitrogen				
N_{60}	3727^{B}	2636^{C}	8800^{B}	7388^{C}
N_{120}	4429^{A}	3241^{B}	11672^{A}	8837^{B}
N_{180}	4691^{A}	3598^{A}	12137^{A}	9963^{A}
Effect of tillage × residue × nitrogen				
CTR_0N_{60}	4016^{a}	2836^{a}	9765^{a}	7905^{a}
CTR_0N_{120}	4406^{a}	3187^{a}	11532^{a}	8556^{a}
CTR_0N_{180}	4680^{a}	3592^{a}	11160^{a}	9479^{a}
CTR_+N_{60}	4034^{a}	2412^{a}	9347^{a}	6801^{a}
CTR_+N_{120}	4659^{a}	3203^{a}	12137^{a}	8370^{a}
CTR_+N_{180}	4841^{a}	3343^{a}	12695^{a}	9693^{a}
NTR_0N_{60}	3291^{a}	2592^{a}	6603^{a}	7324^{a}
NTR_0N_{120}	4639^{a}	3028^{a}	12137^{a}	8434^{a}
NTR_0N_{180}	4884^{a}	3622^{a}	12695^{a}	10422^{a}
NTR_+N_{60}	3568^{a}	2702^{a}	9486^{a}	7522^{a}
NTR_+N_{120}	4011^{a}	3544^{a}	10881^{a}	9989^{a}
NTR_+N_{180}	4359^{a}	3833^{a}	11997^{a}	10259^{a}
LSD (T)	NS	NS	NS	NS
LSD(R)	NS	NS	NS	NS
LSD(N)	445.8*	322.6*	517.3*	579.7*
LSD(T×R×N)	NS	NS	NS	NS

#Values in a column followed by same letters are not significantly different at $p<0.05$ as per DMRT ;The uppercase letters and the lower case letters are used for comparing main plot and subplot effects, respectively; *Significant at $p<0.05$

and 2015-16, respectively. Although application of 180 kg N ha^{-1}significantly increased the grain yield of wheat by 11% than that of 120 kg N ha^{-1} during the year 2015-16, but these treatments were statistically at par during the year 2014-15. Effect of tillage, residue and nitrogen interaction was not significant in grain yield of wheat during both the years of study. There was reduction in the grain yield and biomass yield of wheat by 35.6 and 24.5%, respectively during the year 2015-16 than that of the year 2014-15. This may be attributed to the lower rainfall and higher maximum temperature experienced by the crop during 2015-16 than that of 2014-15. There was no significant difference between CT and NT with respect to grain yield of wheat during both the years of study. This may be attributed to the fact that the experiment was only two years old and hence favourable changes in soil physical environment due to no tillage is yet to be achieved.

The above ground biomass yield of wheat as influenced by tillage, residue and nitrogen management for the year 2014-15 and 2015-16 are presented in the Table 3. During the year 2014-15, the above ground biomass yield of wheat ranged from 6603kg ha^{-1} (NT R_0N_{60}) to 12695kg ha^{-1}(NT R_0 N_{180} and CT R_+ N_{180}) with an average value of 10870kg ha^{-1}whereas during the year 2015-16, the biomass yield of wheat ranged from 6801 kg ha^{-1} (CT R_+ N_{60}) to 10422 kg ha^{-1} (NT R_0N_{180}) with an average value of 8730 kg ha^{-1}. The effect of tillage and crop residue mulch was not significant on biomass yield of wheat during both the years of study. Application of 180 kg N ha^{-1} significantly increased the biomass yield of wheat by 38 and 35% than that of 60 kg N ha^{-1}during the year 2014-15 and 2015-16, respectively. Application of 180 kg N ha^{-1}significantly increased the biomass yield by 13% than that of 120 kg N ha^{-1} during the year 2015-16, but these two treatments were statistically at par during the year 2014-15 with respect to biomass yield of wheat. During both the years of study, effect of tillage, residue and nitrogen interaction was not significant for the biomass yield of wheat. The mean harvest index of wheat during the year 2014-15 was 0.40 whereas during the year 2015-16 it was 0.36. Tillage, crop residue mulch, nitrogen levels and their interaction did not influence the harvest index of wheat significantly in both the years of study (data not presented).

Conclusions

Thus from this study it may be concluded that soil bulk density was slightly higher under NT than CT. The mean weight diameter and water stable aggregates were higher under NT than that of CT which indicates the beneficial impact of NT over soil structure and thus, lower disruption of soil aggregates. The total porosity and air-filled porosity under CT was more than that of NT, but its impact on crop growth was negligible as this was short term NT experiment. The soil temperature under mulched condition was lower than under un-mulched condition which is favorable for soil flora and fauna. The contrasting weather conditions of the two years have major impact on the wheat yield but the effect of tillage and residue management was not significant on wheat grain yield. However the grain yield of wheat increased significantly with the increase in N levels. This shows that the farmer can successfully adopt the NT system with crop residue mulch and 180 kg N/ha in wheat under maize-wheat cropping system for improving soil physical and hydrothermal environment without any significant reduction in crop yield and saving time, energy, money and resources.

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