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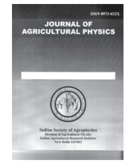

Research Article

Effect of Tillage, Residue and Nitrogen Management on Soil Mineral Nitrogen Dynamics and Nitrogen Use Efficiency of Wheat Crop in an Inceptisol

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ABSTRACT

Indiscriminate tillage practices and unscientific use of nitrogenous fertilizers lead to deterioration of soil and water quality. This could be substantially mitigated by adoption of conservation agricultural practices like no-tillage, application of crop residues and optimum dose of nitrogenous fertilizers. Therefore, the present experiment was conducted to study the effect of tillage, residue and nitrogen management on soil mineral nitrogen dynamics, nitrogen uptake, yield and nitrogen use efficiency of wheat crop in sandy-loam soil of Indo-gangetic plains. 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 factors (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 N ha^{-1}, representing 50% (N_{60}), 100% (N_{120}) and 150% (N_{180}) of the recommended dose of nitrogen (RDN) for wheat, respectively were evaluated in a split-split plot design with three replications. It was found that the effect of tillage on soil mineral nitrogen content was not significant but it was higher under crop residue mulch treatment. Also, with increase in nitrogen dose, soil mineral nitrogen content was increased. The effect of tillage and crop residue mulch on nitrogen uptake, nitrogen use efficiency and yield of wheat was not significant. However, N uptake increased but nitrogen use efficiency decreased with increase in dose of nitrogen upto 150% of RDN. Therefore, the farmers are advised to apply crop residue mulch to decrease nitrogen losses and adopt no-till system to save labour, time and energy. Higher dose of Nitrogen should be applied in No-till plot in order to compensate the losses due to immobilization.

Key words: Soil mineral nitrogen, Conventional tillage, No tillage, Crop residue mulch, Nitrogen uptake, Nitrogen use efficiency

Introduction

The continuously increasing target of food grain production to meet the demands of growing population compel intensive agricultural practices, which ultimately leads to higher production cost, soil health degradation, environmental pollution and vulnerability to climate change. Sustainable agricultural production at extensive level to meet the demand of increasing population with minimum environmental pollution under the scenario of wide gap between demand and supply of key inputs in agriculture *viz.*, water, nutrient and energy can only be achieved by developing technologies for improving the use efficiency of these inputs and efficient management of natural

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resources (Acharya *et al.*, 2005). Wheat (*Triticum aestivum* L.),which is the second most important cereal crop after rice in India, is cultivated in an area of approximately 30-31 million hectares and more than 90% of this area is irrigated. To increase the wheat production, farmers usually apply high rate of nitrogenous fertilizer. This ultimately increases the production cost with simultaneous deterioration of water and soil quality due to increase in N losses by leaching, ammonia volatilization and denitrification. Improved N use efficiency of nitrogenous fertilizers can be achieved by studying the peak requirement period and method of N uptake by the crop so that the nitrogenous fertilizer application can match with this period to facilitate efficient utilization of fertilizer and minimum loss to the ecosystem. So, the crop management practices should be such that maximum amount of available soil N is supplied to crop during that period (Ebrayi *et al.*, 2007).

Tillage and mulching alters the soil microenvironment and has significant effects on many hydrothermal and biochemical processes in the soil, leading to changes in N-availability, N use efficiency and accumulation of residual N in soil. Application of plant residues can contribute to nutrient cycling and greater crop yields (Kamkar *et al.*, 2014). Mineralization intensity and, hence, available nitrogen is found less in no-tillage system than in plowed tillage system leading to higher nitrogen fertilization requirement in no-till system (Alvarez and Steinbach, 2009). Conventional tillage system raises the temperature of uncovered soil along with disruption of aggregates, which exposes organic matter to rapid decomposition and, thus, increases mineralization (Alvarez and Steinbach, 2009). Lopez-Bellido *et al*. (1998) reported that nitrate nitrogen content was higher for the top 60 cm of soil for CT as compared to NT. Doran (1980) reported increase in total organic carbon and total N pool in 0-30 cm soil depth under 3-10 years of conservation tillage. This was attributed to higher immobilization of Nitrogen and lower mineralization of residues under conservation tillage (Rice and Smith, 1984). Mostafa *et al*. (1997) showed that with increase in nitrogen levels, tillers proportion, spike length and its number per unit area, plant height, number of grains per spike, grain and straw yields of wheat increased. Sieling *et al*. (1998) also showed that mineral fertilizer NUE for winter wheat decreased with increasing N levels. Westermann and Crothers (1993) reported that wheat crop planted in no-till system with stubbles of alfalfa showed 76% apparent nitrogen fertilizer recovery and 78% average plant recovery of mineralized nitrogen. Mahala and Shaktawat (2004) reported that with increase in fertilizer application, the nitrogen uptake throughout the growth season significantly increased. As the mulch treatment enhanced the nitrogen availability, the nitrogen uptake increased more in mulched treatment than that of without mulch treatment. In this backdrop, the present study was conducted to study the effect of tillage, residue and nitrogen management on soil mineral nitrogen dynamics, nitrogen uptake and nitrogen use efficiency of wheat crop.

Materials and Methods

The experimental site

Field experiments were conducted in the MB-4C farm of ICAR-Indian Agricultural Research Institute, New Delhi (28°35′N latitude, 77°12′E longitude and at an altitude of 228.16 m above mean sea level) with wheat as a test crop during the year 2015-16.

Climate

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 and 19.9°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.

Soil

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 given in Table 1. It showed that the soil was mildly alkaline, non-saline, low in soil organic C (Walkley and Black C) and available N and medium in available P and K content. The 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 kg ha^{-1}; sand, silt and clay, 64.0, 6.8 and 19.2%, respectively. The bulk density varied from 1.58 Mg m^{-3} in the 0-15cm 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.

Experimental details

The field experiments were conducted during *rabi* season of 2015-16 at ICAR-IARI Research Farm (MB 4C) to study the effects of tillage, residue and nitrogen management on soil mineral nitrogen dynamics, nitrogen uptake and nitrogen use efficiency of 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 factors (Maize residue @ 5t/ha (R_+) and without residue (R_0)), and three levels of Nitrogen as sub-sub plot factors (60, 120 and 180 kg/ha, 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.

Wheat (cv. HD 2967) was sown by a tractor drawn no-till seed drill (at a depth of 4-5 cm) in No tillage treatment. 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. Maize residue was applied manually at the rate of 5 t ha^{-1} under R_+ treatment at CRI stage. Nitrogen was supplied as urea in three splits *i.e.*, 50% at sowing, 25% at CRI stage and remaining 25% at flowering stage. All the plots received a uniform dose of 60 kg P_2O_5 ha^{-1} as single super phosphate and 60 kg K_2O ha^{-1} as muriate of potash applied as basal dose at sowing. All the plots received five irrigations at critical growth stages *viz*., CRI, tillering, jointing, flowering and milk stage. Field was kept weed free by employing manual weeding 3-4 times during crop growth stages.

Mineral nitrogen content in soil

Soil samples were collected at 15 days interval from 0-15, 15-30, 30-45 and 45-60 cm soil depth for analysis of mineral-N (NH_4^+-N and NO_3^--N) following standard procedure (Bremner *et al.,* 1965 and Keeney *et al*., 1982) to study the nitrogen dynamics in the profile. In this method, 10 g moist soil sample was extracted with 100 mL of 2M KCl solution by continuous shaking for one hour. The contents were filtered through Whatman No. 42 filter paper and collected in plastic bottles. The NH_4^+-N and NO_3^--N content in these soil extracts were determined using N

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

Autoanalyzer (M/S Medizin- und Labortechnik Engineering GmbH Desden, Germany). The basic principle of the detection of NH_4^+-N and NO_3^--N concentration is colorimetric, according to which, the intensity of colour produced with reagents is directly proportional to its concentration. A subsample of soil was used to determine the moisture content and the result was expressed on dry weight basis.

Average mineral N content during the crop growth period was computed based on weighted mean approach as follows:

Weighted average NH_4^+-N and NO_3^--N = Σ_0^n $(Ni \times di)/\Sigma_1^n\ di$

Where Ni = Mean NH_4^+-N and NO_3^-N for the period di

Nitrogen uptake, nitrogen use efficiency and grain protein content

Nitrogen uptake in grain and straw was determined by multiplying the N concentration with the corresponding grain and straw biomass, respectively. Nitrogen content in the grain and straw samples was determined by Micro-Kjeldhal method (AOAC, 1970). The total N uptake in the plant was determined by summation of N uptake in grains and straw.

Nitrogen use efficiency parameters were determined as follows:

Partial factor productivity of N (PFPN) = [Grain yield (kg ha^{-1})] / [N applied (kgha^{-1})]

N utilization efficiency (NUtE) = [Grain yield (kg ha^{-1}] / [Total N uptake (kg ha^{-1})]

The protein content in grain was measured by grain analyzer from Foss Tecator AB (Infratec™ model 1241) through the spectroscopic investigations of the grain samples.

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.

Results and Discussion

Soil temperature dynamics

During the year 2015-16 soil temperature at surface ranged from 17.1 to 30.5 with a mean value of 24.9°C, at 5 cm ranged from 15.1 to 35.2 with a mean value of 27.1°C, at 10 cm ranged from 14.3 to 34.0 with a mean value of 25.8°C whereas air temperature ranged from 19.3 to 35.1 with a mean value of 28.7°C. No tillage without residue treatment registered the maximum soil temperature at surface, 5 cm and 10 cm soil depth. Application of maize residue mulch registered lower soil temperature than the un-mulch treatment in the surface soil (Fig. 1).

Distribution of mineral nitrogen in the soil profile

Temporal variation in the NH_4^+-N and NO_3^--N at 0-15, 15-30, 30-45 and 45-60 cm soil depth due to different tillage, crop residue mulch and nitrogen levels are depicted in the Fig. 2 to 5. Both the NH_4^+-N and NO_3^--N content showed peak at 31 DAS and 97 DAS, which coincided with the split application of urea at CRI and flowering stage, respectively. It was observed that in 0-15 cm soil depth, NH_4^+-N content ranged from 11.8 kg ha^{-1} (NT R_0 N_{60} at sowing) to 38.7 kg ha^{-1} (CT R_+ N_{180} at 31 DAS) with a mean value of 19.5 kg ha^{-1} (Fig. 2). Averaged over residue and nitrogen levels, NH_4^+-N under CT ranged from 12.2 (at sowing) to 28.3 kg ha^{-1} (31 DAS) with a mean value of 20.2 kg ha^{-1} whereas NH_4^+-N under NT ranged from 11.8 (at sowing) to 26.2 kg ha^{-1}(31 DAS) with a mean value of 20.6 kg ha^{-1}.

Averaged over tillage and nitrogen levels, NH_4^+-N under no-mulch treatment ranged from 12.0 (at sowing) to 24.1 kg ha^{-1}(97 DAS) with a mean value of 19.4 kg ha^{-1} whereas under mulched condition, NH_4^+-N ranged from 12.0 (at sowing) to 31.9 kg ha^{-1} (31 DAS) with a mean value of 19.5 kg ha^{-1}. Averaged over tillage and

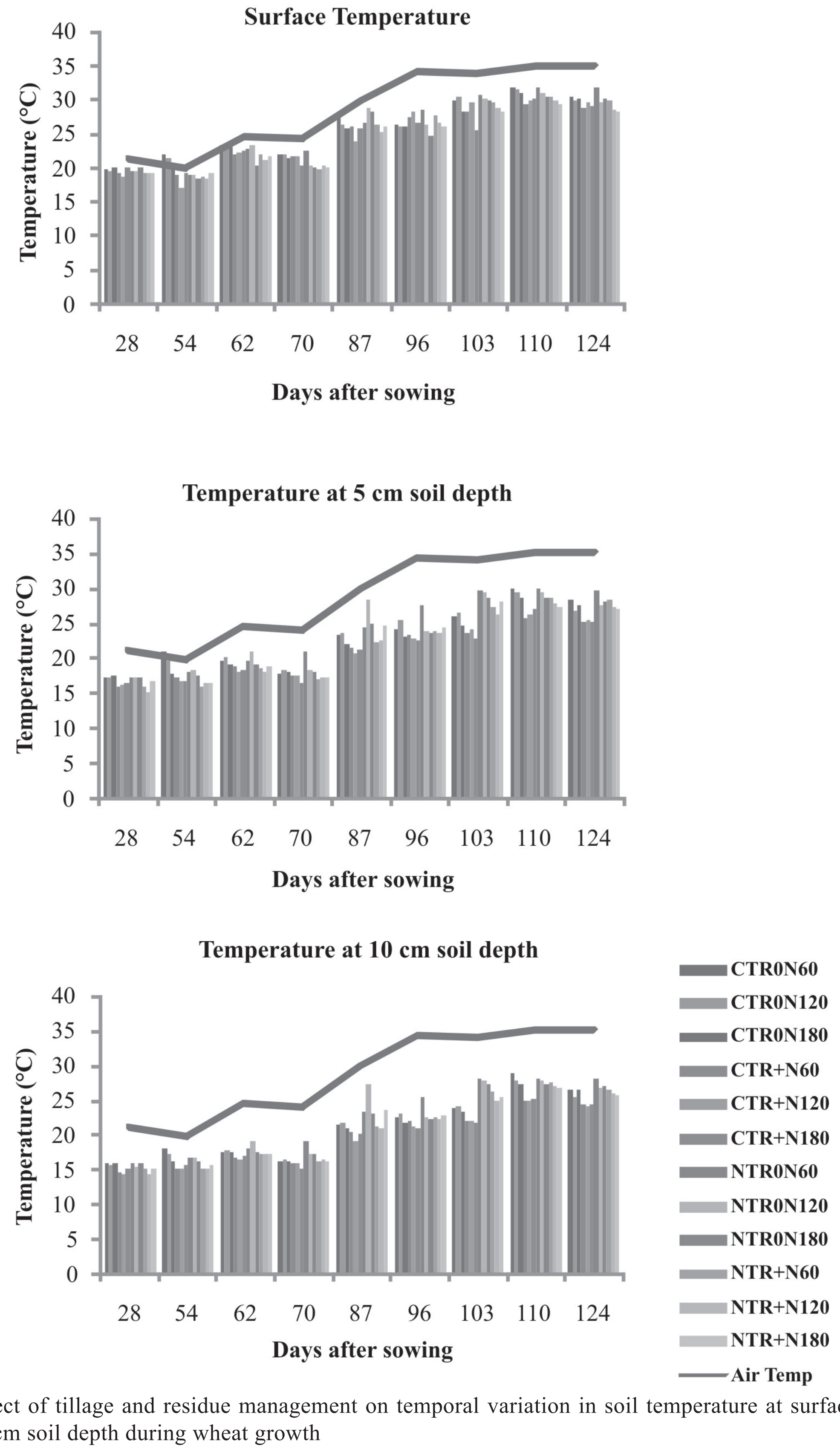

Fig. 1. Effect of tillage and residue management on temporal variation in soil temperature at surface, 5 cm and 10 cm soil depth during wheat growth

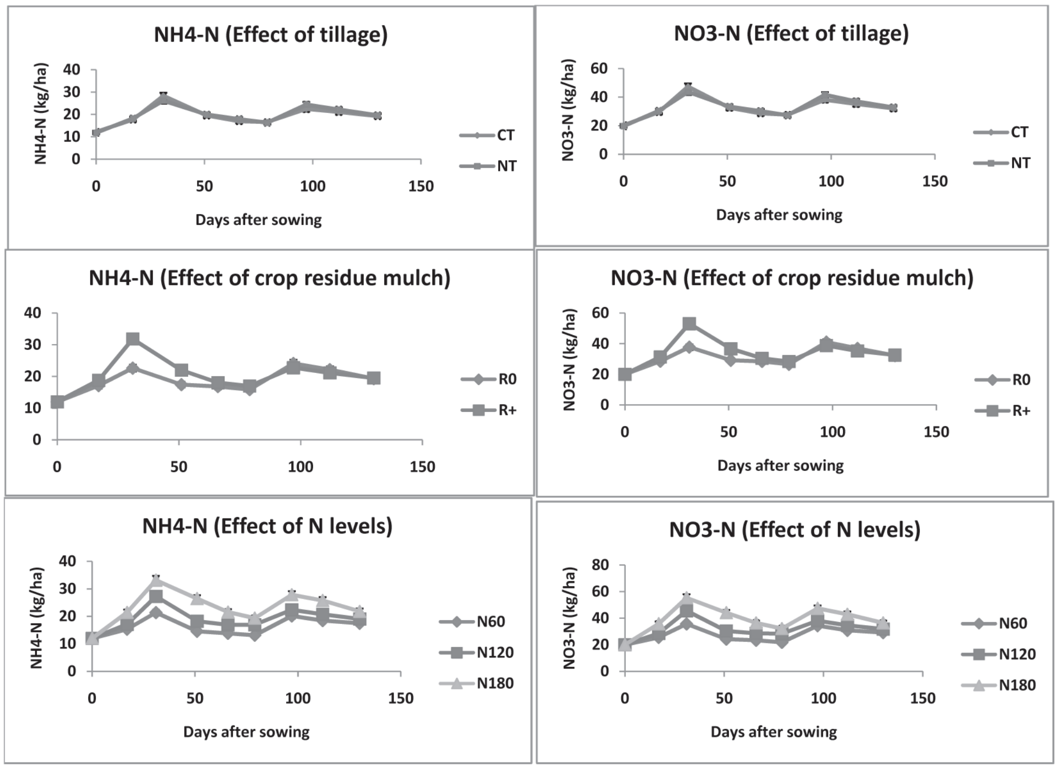

Fig. 2. Temporal variation in NH^+_4-N and NO_3^--N at 0-15 cm soil depth during wheat growth as influenced by tillage, crop residue mulch and nitrogen levels

residue management, NH_4^+-N due to application of 60 kg N ha^{-1} ranged from 12.0 (at sowing) to 21.4 kg ha^{-1} (31 DAS) with a mean value of 16.8 kg ha^{-1} whereas NH_4^+-N content due to 120 kg N ha^{-1}ranged from 12.0 (at sowing) to 27.3 kg ha^{-1} (31 DAS) with a mean value of 19.8 kg $ha^{-1}$and with the application of 180 kg N ha^{-1}, it ranged from 12.0 (at sowing) to 33.1 kg ha^{-1} (31 DAS) with a mean value of 24.6 kg ha^{-1}.

NO_3^- -N content at 0-15 cm soil depth ranged from 19.68 kg ha^{-1} (NT R_0 N_{60} at sowing) to 64.6 kg ha^{-1} (CT R_+ N_{180} at 31 DAS) with a mean value of 32.6 kg ha^{-1}. Averaged over residue and nitrogen levels, NO_3^- -N content at 0-15 cm soil depth under CT ranged from 20.3 (at sowing) to 47.3 kg ha^{-1} (31 DAS) with a mean value of 32.4 kg ha^{-1} whereas under NT it ranged from 19.7 (at sowing) to 43.6 kg ha^{-1} (31 DAS) with a mean value of 32.9 kg ha^{-1} (Fig. 2). Averaged over tillage and nitrogen levels, NO_3^- -N under no-mulch treatment ranged from 20.0 (at sowing) to 41.0 kg ha^{-1} (97 DAS) with a mean value of 31.2 kg ha^{-1} whereas under mulched condition, NO_3^--N ranged from 20.0 (at sowing) to 53.1 kg ha^{-1} (31 DAS) with a mean value of 34.1 kg ha^{-1}. Averaged over tillage and residue management, NO_3^--N due to application of 60 kg N ha^{-1} ranged from 20 (at sowing) to 35.6 kg ha^{-1} (31 DAS) with a mean value of 27.2 kg ha^{-1} whereas NO_3^- -N content due to 120 kg N ha^{-1}ranged from 20.0 (at sowing) to 45.5 kg ha^{-1} (31 DAS) with a mean value of 31.7 kg ha^{-1} and NO_3^- -N content due to 180 kg N ha^{-1} ranged from 20.0 (at sowing) to 55.2 kg ha^{-1} (31 DAS) with a mean value of 38.9 kg ha^{-1}.

In 15-30 cm soil depth, NH_4^+-N content ranged from 9.1 kg ha^{-1} (CT R_0 N_{60} at sowing) to 33.8 kg ha^{-1} (NT R_+ N_{180} at 31 DAS) with a mean value of 17.3 kg ha^{-1}. Averaged over residue and nitrogen levels, NH_4^+-N under CT ranged from 9.1 (at sowing) to 25.5 kg ha^{-1} (31 DAS) with a mean value of 17.1 kg ha^{-1} (Fig. 3) whereas NH_4^+-N under NT ranged from 11.1 (at sowing) to 26.2 kg ha^{-1} (31 DAS) with a mean value of 19.3 kg ha^{-1}. Averaged over tillage and nitrogen levels, NH_4^+-N under no-mulch treatment ranged from 10.1 to 23.4 kg ha^{-1}with a mean value of 17.4 kg ha^{-1} whereas under mulched condition, NH_4^+-N ranged from 10.1 (at sowing) to 28.3 kg ha^{-1} (31 DAS) with a mean value of 19.0 kg ha^{-1}. Averaged over tillage and residue management, NH_4^+-N due to application of 60 kg N ha^{-1} ranged from 10.1 (at sowing) to 20.4 kg ha^{-1}(31 DAS) with an average of 14.9 kg ha^{-1} whereas NH_4^+-N content due to 120 kg N ha^{-1}ranged from 10.1 (at sowing) to 27.1 kg ha^{-1}(31 DAS) with a mean value of 18.1 kg ha^{-1}and with the application of 180 kg N ha^{-1}, NH_4^+-N content ranged from 10.1 (at sowing) to 30.1 kg ha^{-1}(31 DAS) with a mean value of 21.6 kg ha^{-1}.

NO_3^- -N content at 15-30 cm soil depth ranged from 17.7 kg ha^{-1} (CT R_0 N_{60} at sowing) to 65.7 kg ha^{-1} (NT R_+ N_{180} at 31 DAS) with a mean value of 33.7 kg ha^{-1}. Averaged over residue and nitrogen levels, NO_3^- -N content under CT ranged from 17.7 (at sowing) to 49.5 kg ha^{-1} (31 DAS) with a mean value of 33.4 kg ha^{-1} whereas NO_3^- -N under NT ranged from 21.6 (at sowing) to 51 kg ha^{-1} (31 DAS) with a mean value of 37.5 kg ha^{-1} (Fig. 3). Averaged over tillage and nitrogen levels, NO_3^- -N under no-mulch treatment ranged from 19.7 (at sowing) to 45.5 kg ha^{-1}(31 DAS) with a mean value of 33.8 kg ha^{-1} whereas under mulched condition, NO_3^- -N ranged from 19.7 (at sowing) to 55.1 kg ha^{-1} (31 DAS) with a mean value of 37.1 kg ha^{-1}. Averaged over tillage and residue management, NO_3^- -N due to application of 60 kg N ha^{-1}ranged from 19.7 (at sowing) to 39.6 kg ha^{-1} (31 DAS) with a mean value of 29.0 kg ha^{-1}whereas NO_3^- -N content due to 120 kg N ha^{-1}ranged from 19.7 (at sowing) to 52.7 kg ha^{-1} (31 DAS) with a mean value of 35.2 kg ha^{-1} and NO_3^--N content due to 180 kg N ha^{-1} ranged from 19.7 (at sowing) to 58.6 kg ha^{-1} (31 DAS) with a mean value of 42.0 kg ha^{-1}.

In 30-45 cm soil depth, NH_4^+-N content ranged from 7.8 kg ha^{-1} (CT R_0 N_{60} at 79 DAS) to 28.8 kg ha^{-1} (NT R_+ N_{180} at 31 DAS) with a mean value of 15.2 kg ha^{-1}. Averaged over residue and nitrogen levels, NH_4^+-N under CT ranged from 8.3 (at sowing) to 21.5 kg ha^{-1}(31 DAS) with a mean value of 14.9 kg ha^{-1} (Fig. 4) whereas NH_4^+-N under NT ranged from 10.6 (at sowing) to 24.4

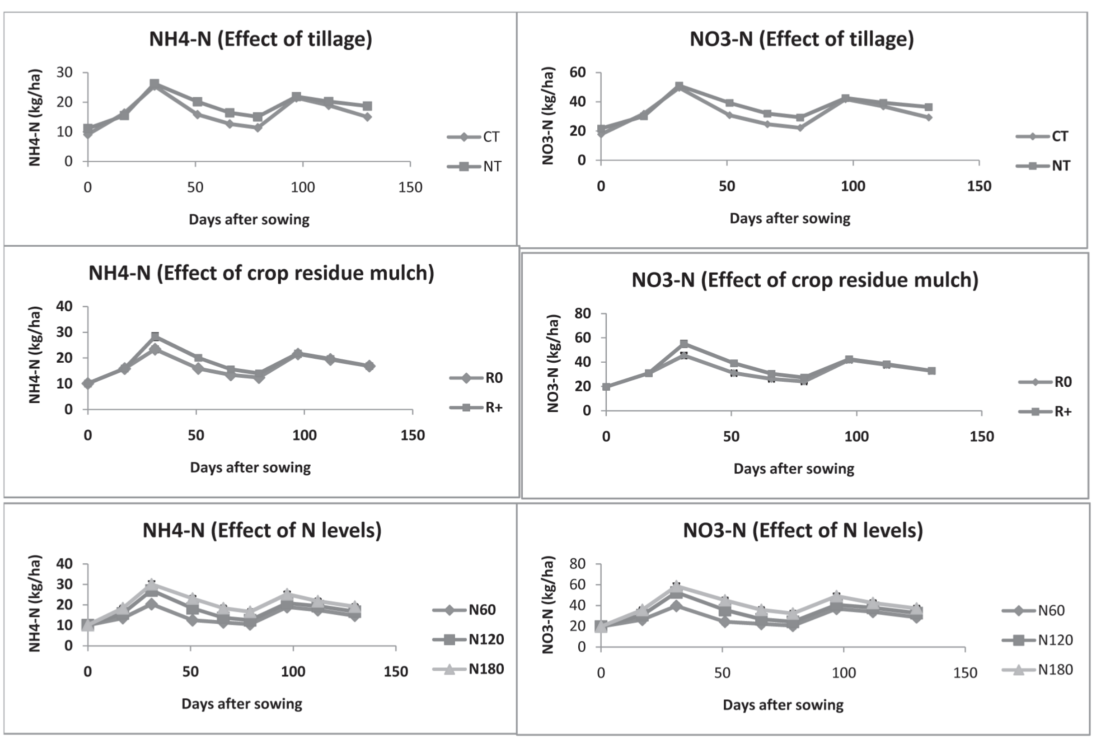

Fig. 3. Temporal variation in NH^+_4-N and NO_3^--N at 15-30 cm soil depth during wheat growth as influenced by tillage, crop residue mulch and nitrogen levels

kg ha^{-1} (31 DAS) with an average of 17.0 kg ha^{-1}. Averaged over tillage and nitrogen levels, NH_4^+-N under no-mulch treatment ranged from 9.4 (at sowing) to 21.1 kg ha^{-1} (31 DAS) with a mean value of 15.1 kg ha^{-1}whereas under mulched condition, NH_4^+-N ranged from 9.4 (at sowing) to 24.8 kg ha^{-1} (31 DAS) with a mean value of 16.9 kg ha^{-1}. Averaged over tillage and residue management, NH_4^+-N due to application of 60 kg N ha^{-1} ranged from 9.4 (at sowing) to 19.3 kg ha^{-1} (31 DAS) with a mean value of 13.0 kg ha^{-1} whereas NH_4^+-N content due to 120 kg N ha^{-1} ranged from 9.4 (at sowing) to 23.4 kg ha^{-1} (31 DAS) with a mean value of 16.1 kg $ha^{-1}$and with the application of 180 kg N $ha^{-1}$$NH_4^+$-N content ranged from 9.4 (at sowing) to 26.1 kg ha^{-1} (31 DAS) with a mean value of 18.9 kg ha^{-1}.

NO_3^--N content at 30-45 cm soil depth ranged from 12.3 kg ha^{-1} (CT R_0 N_{60} at 79 DAS) to 45.3 kg ha^{-1} (NT R_+ N_{180} at 31 DAS) with a mean value of 24.0 kg ha^{-1}. Averaged over residue and nitrogen levels, NO_3^--N content under CT ranged from 13.0 (at sowing) to 33.8 kg ha^{-1} (at 31 DAS) with a mean value of 23.4 kg ha^{-1} whereas NO_3^--N under NT ranged from 16.4 (at sowing) to 38.4 kg ha^{-1} (31 DAS) with a mean value of 26.8 kg ha^{-1} (Fig. 4). Averaged over tillage and nitrogen levels, NO_3^--N under no-mulch treatment ranged from 14.8 (at sowing) to 33.2 kg ha^{-1} (31 DAS) with a mean value of 23.7 kg ha^{-1} whereas under mulched condition, NO_3^--N ranged from 14.8 (at sowing) to 39.0 kg ha^{-1} (31 DAS) with a mean value of 26.5 kg ha^{-1}. Averaged over tillage and residue management, NO_3^--N due to application of 60 kg N ha^{-1} ranged from 14.8 (at sowing) to 30.3 kg ha^{-1} (31 DAS) with an average of 20.4 kg ha^{-1} whereas NO_3^- -N content due to 120 kg N ha^{-1} ranged from 14.8 (at sowing) to 36.9 kg ha^{-1} (31 DAS) with a mean value of 25.3 kg $ha^{-1}$and NO_3^- -N content due to 180 kg N ha^{-1}ranged from 14.8 (at sowing) to 41.1 kg ha^{-1} (31 DAS) with a mean value of 29.7 kg ha^{-1}.

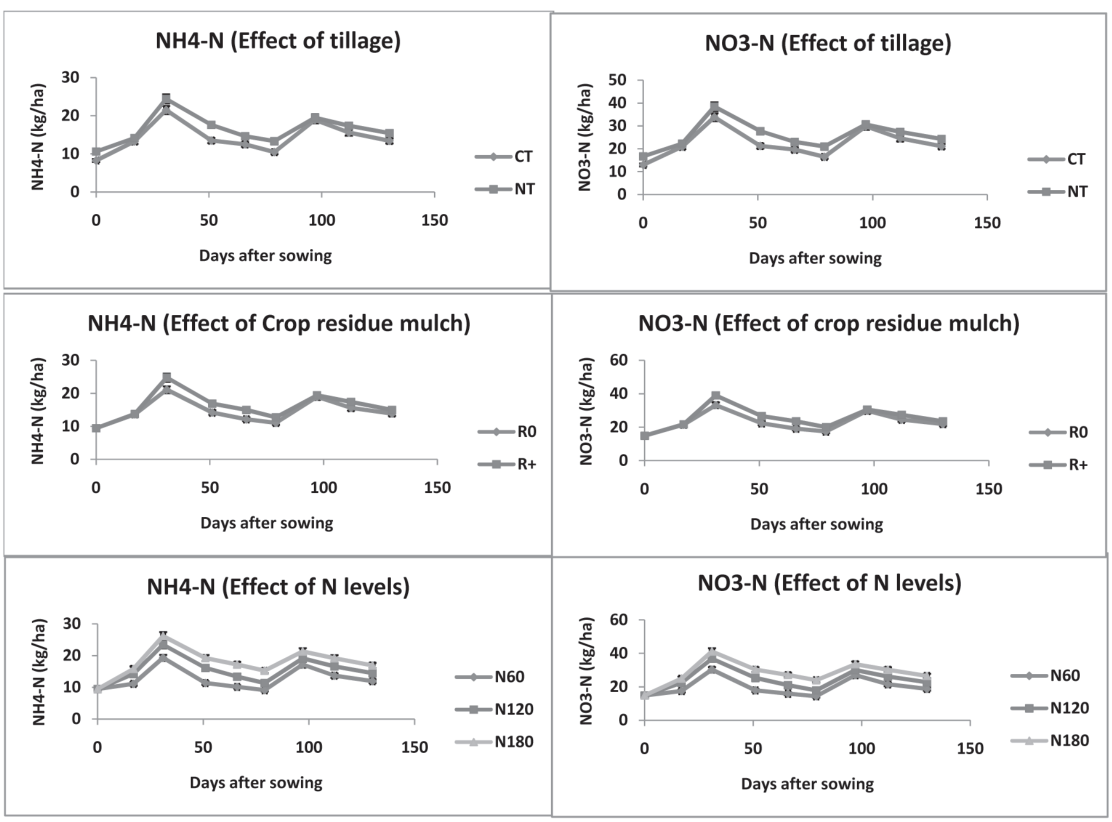

Fig. 4. Temporal variation in NH^+_4-N and NO_3^--N at 30-45 cm soil depth during wheat growth as influenced by tillage,crop residue mulch and nitrogen levels

In 45-60 cm soil depth, NH_4^+-N content ranged from 7.0 kg ha^{-1} (CT R_0 N_{60} at 79 DAS) to 25.2 kg ha^{-1} (NT R_+ N_{180} at 31 DAS) with a mean value of 13.8 kg ha^{-1} (Fig. 5). Averaged over residue and nitrogen levels, NH_4^+-N under CT ranged from 8.2 (at sowing) to 19.4 kg ha^{-1} (31 DAS) with a mean value of 13.2 kg ha^{-1} whereas NH_4^+-N under NT ranged from 10 (at sowing) to 21.7 kg ha^{-1}(31 DAS) with an average of 15.5 kg ha^{-1} (Fig. 4). Averaged over tillage and nitrogen levels, NH_4^+-N under no-mulch treatment ranged from 9.1 (at sowing) to 19.4 kg ha^{-1} (31 DAS) with an average of 13.7 kg ha^{-1} whereas under mulched condition, NH_4^+-N ranged from 9.1 (at sowing) to 21.6 kg ha^{-1}(31 DAS) with a mean value of 15.0 kg ha^{-1}. Averaged over tillage and residue management, NH_4^+-N due to application of 60 kg N ha^{-1} ranged from 8.2 (79 DAS) to 17.6 kg ha^{-1}(31 DAS) with an average of 11.7 kg ha^{-1} whereas NH_4^+-N content due to 120 kg N ha^{-1} ranged from 9.1 (at sowing) to 21.0 kg ha^{-1} (31 DAS) with a mean value of 14.6 kg ha^{-1}and with the application of 180 kg N ha^{-1}, NH_4^+-N content ranged from 9.1 (at sowing) to 23.1 kg ha^{-1} (31 DAS) with a mean value of 16.8 kg ha^{-1}.

NO_3^--N content at 45-60 cm soil depth ranged from 9.7 kg ha^{-1} (CT R_0 N_{60} at 79 DAS) to 35 kg ha^{-1} (NT R_+ N_{180} at 31 DAS) with a mean value of 19.1 kg ha^{-1} (Fig. 5). Averaged over residue and nitrogen levels, NO_3^--N content under CT ranged from 11.4 (at sowing) to 26.9 kg ha^{-1} (at 31 DAS) with a mean value of 18.3 kg ha^{-1}whereas NO_3^--N under NT ranged from 13.9 (at sowing) to 30.1 kg ha^{-1} (31 DAS) with a mean value of 21.5 kg ha^{-1} (Fig. 4). Averaged over tillage and nitrogen levels, NO_3^--N under no-mulch treatment ranged from 12.6 (at sowing) to 27.0 kg ha^{-1} (31 DAS) with a mean value of 19.0 kg ha^{-1} whereas under mulched condition, NO_3^--N ranged from 12.6 (at sowing) to 30.0 kg ha^{-1}(31 DAS) with a mean value of 20.8 kg ha^{-1}. Averaged over tillage and residue management, NO_3^--N due to application of 60 kg N ha^{-1} ranged from 11.3 (79 DAS) to 24.4 kg ha^{-1} (31 DAS) with a mean value of 16.2

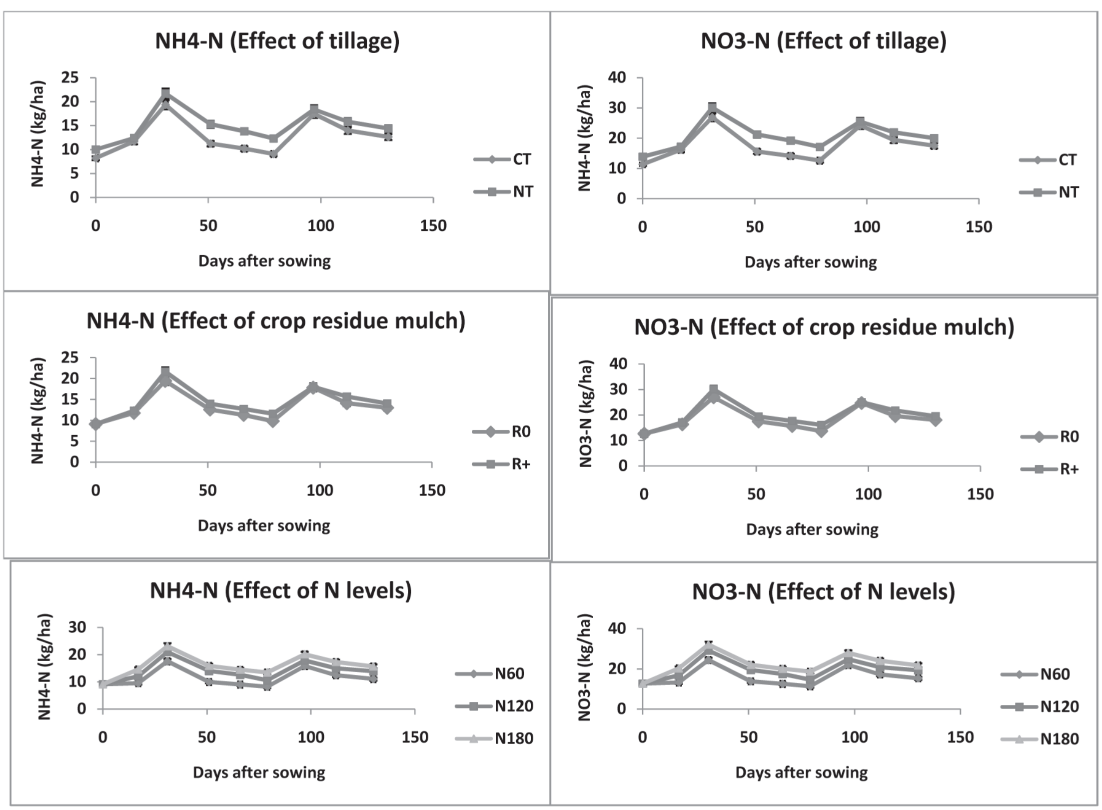

Fig. 5. Temporal variation in NH^+_4-N and NO_3^--N at 45-60 cm soil depth during wheat growth as influenced by tillage, crop residue mulch and nitrogen levels

kg ha^{-1} whereas NO_3^--N content due to 120 kg N ha^{-1} ranged from 12.6 (at sowing) to 29.1 kg ha^{-1} (31 DAS) with a mean value of 20.2 kg ha^{-1} and NO_3^--N content due to 180 kg N ha^{-1} ranged from 12.6 (at sowing) to 32 kg ha^{-1} (31 DAS) with a mean value of 23.3 kg ha^{-1}.

Both NH_4^+-N and NO_3^--N contents under crop residue mulch was higher than that of un-mulched treatment in all the soil depths. This may be attributed to the fact that volatilization and leaching loss was reduced under mulched condition (Fuentes *et al.*, 2003). Low soil temperature recorded under mulched condition may be responsible for this phenomenon. There was no significant difference between CT and NT with respect to NH_4^+-N and NO_3^--N content at all depths. This finding is in agreement with Fuentes *et al.* (2003) who reported that the dynamics of nitrate nitrogen in soil were similar under no-tillage and conventional tillage condition in which nitrogen level were higher in starting of season and lower at the maturity of wheat crop. However, Lopez-Bellido *et al.* (1998) reported that nitrate nitrogen content was higher for upper 60 cm of soil for CT as compared to NT. In general, NO_3^--N content was higher than NH_4^+-N content. This may be attributed to higher nitrification under aerobic environment and the pH of soil was 7.64 which is optimum for nitrification. With the increase in nitrogen fertilizer dose, the NH_4^+-N and NO_3^--N content increases at all soil depths. However, presence of higher NO_3^--N content in the sub surface (>30 cm) at higher nitrogen levels may lead to its loss through leaching as it may not be utilized by the crop (Wang *et al.*, 2010).

Nitrogen concentration in grain and straw, and grain protein content of wheat

Nitrogen concentration in grain and straw, and grain protein content of wheat for the year 2015-16 is presented in Table 2. Nitrogen concentration in grain ranged from 1.49% (CT R_0 N_{60}) to 2.38% (NT R_+ N_{180}) with a mean value of 2.01%. Effect of tillage, residue and nitrogen management interaction was not significant on Nitrogen concentration of wheat grain. Nitrogen concentration in grain increased significantly with the increase in nitrogen levels. Application of 180 kg N ha^{-1} significantly increased the nitrogen concentration in grain by 15.7 and 37.2% than that of 120 kg N ha^{-1}and 60 kg N ha^{-1}, respectively.

Nitrogen concentration in wheat straw ranged from 0.35% (CT R_0 N_{60}) to 0.61% (CT R_+ N_{180}) with a mean value of 0.46%. Effect of tillage, residue and nitrogen management interaction was not significant on Nitrogen concentration of wheat straw. Similarly, nitrogen concentration in wheat straw increased significantly with the increase in nitrogen levels. Application of 180 kg N ha^{-1} significantly increased the nitrogen concentration in wheat straw by 22.8 and 59.0% than that of 120 kg N ha^{-1}and 60 kg N ha^{-1}, respectively.

Protein concentration in wheat grain ranged from 10.93% (NT R_+ N_{60}) to 14.1% (NT R_0 N_{180}) with a mean value of 12.4%. Effect of tillage, residue and nitrogen management interaction was not significant on grain protein content. However, grain protein concentration increased significantly with increase in the nitrogen levels. The grain protein concentration due to 60, 120 and 180 kg N ha^{-1} were 11.16, 12.39 and 13.87%, respectively. Application of 180 kg N ha^{-1} significantly increased the grain protein concentration than that of 120 and 60 kg N ha^{-1} by 11.9 and 24.3%, respectively. Application of 120 kg N ha^{-1} significantly increased the grain protein concentration by 11.1% than that of 60 kg N ha^{-1}.Several workers also reported increased levels of wheat grain protein at higher levels of Nitrogen application (Fowler *et al.,* 1990; Abderrazak *et al*., 1995; Li-Hong *et al*., 2007).

Total nitrogen uptake and nitrogen use efficiency by wheat

Total nitrogen uptake, nitrogen utilization efficiency (NUtE) and partial factor productivity of Nitrogen (PFPN) by wheat is presented in Table 3. The nitrogen uptake by wheat grain and straw ranged from 57.09 (CT R_+ N_{60}) to 124.10 kg ha^{-1} (NT R_+ N_{180}) with a mean value of 90.49 kg ha^{-1}. Neither tillage nor crop residue mulch significantly influenced the nitrogen uptake by wheat straw during both the years of study.

Table 2. Nitrogen concentration in grain and straw of wheat and grain protein concentration as influenced by tillage, residue and nitrogen management

Treatment	Grain N concentration (%)	Straw N concentration (%)	Grain Protein concentration (%)
Effect of tillage			
CT	1.93 ^{A}	0.49^{A}	12.38 ^{A}
NT	2.08 ^{A}	0.44^{B}	12.57 ^{A}
Effect of residues			
R_0	1.97 ^{A}	0.47 ^{A}	12.52 ^{A}
R_+	2.05 ^{A}	0.46 ^{A}	12.42 ^{A}
Effect of Nitrogen			
N_{60}	1.69^{C}	0.36^{C}	11.16^{C}
N_{120}	2.01^{B}	0.46^{B}	12.39^{B}
N_{180}	2.32^{A}	0.57^{A}	13.87^{A}
Effect of Tillage × Residue × Nitrogen			
CTR_0N_{60}	1.49 ^{a}	0.35 ^{a}	10.97 ^{a}
CTR_0N_{120}	1.96 ^{a}	0.51 ^{a}	12.37 ^{a}
CTR_0N_{180}	2.24 ^{a}	0.58 ^{a}	13.87 ^{a}
CTR_+N_{60}	1.68 ^{a}	0.37 ^{a}	11.60 ^{a}
CTR_+N_{120}	1.87 ^{a}	0.49 ^{a}	11.80 ^{a}
CTR_+N_{180}	2.33 ^{a}	0.61 ^{a}	13.67 ^{a}
NTR_0N_{60}	1.77 ^{a}	0.35 ^{a}	11.13 ^{a}
NTR_0N_{120}	2.01 ^{a}	0.44 ^{a}	12.70 ^{a}
NTR_0N_{180}	2.33 ^{a}	0.56 ^{a}	14.10 ^{a}
NTR_+N_{60}	1.82 ^{a}	0.35 ^{a}	10.93 ^{a}
NTR_+N_{120}	2.19 ^{a}	0.40 ^{a}	12.70 ^{a}
NTR_+N_{180}	2.38 ^{a}	0.51 ^{a}	13.83 ^{a}
LSD (T)	NS	0.04*	NS
LSD(R)	NS	NS	NS
LSD(N)	0.10*	0.05*	0.46*
LSD(T×R×N)	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

Table 3. Nitrogen uptake, partial factor productivity of nitrogen and nitrogen utilization efficiency of wheat as influenced by tillage, residue and nitrogen management

Treatment	Total N uptake (kg/ha)	Partial factor productivity of N (kg grain/kg N applied)	N utilization efficiency (kg grain/kg N uptake)
Effect of tillage			
CT	87.45 ^{A}	29.9^{A}	37.2^{A}
NT	93.53 ^{A}	30.7^{A}	35.5^{A}
Effect of residues			
R_0	89.14 ^{A}	30.4^{A}	37.0^{A}
R_+	91.83 ^{A}	30.2^{A}	35.7^{A}
Effect of Nitrogen			
N_{60}	61.39^{C}	43.9^{A}	42.9^{A}
N_{120}	90.48^{B}	27.0^{B}	36.0^{B}
N_{180}	119.59^{A}	20.0^{C}	30.2^{C}
Effect of Tillage ×Residue × Nitrogen			
CTR_0N_{60}	60.33 ^{a}	47.3 ^{a}	47.3^{a}
CTR_0N_{120}	90.30 ^{a}	26.6 ^{a}	35.7^{a}
CTR_0N_{180}	115.20 ^{a}	20.0 ^{a}	31.5^{a}
CTR_+N_{60}	57.10 ^{a}	40.2 ^{a}	42.1 ^{a}
CTR_+N_{120}	85.20 ^{a}	26.7 ^{a}	38.0 ^{a}
CTR_+N_{180}	116.57 ^{a}	18.6 ^{a}	28.7 ^{a}
NTR_0N_{60}	62.47 ^{a}	43.2 ^{a}	41.7 ^{a}
NTR_0N_{120}	84.07 ^{a}	25.2 ^{a}	36.0 ^{a}
NTR_0N_{180}	122.50 ^{a}	20.1 ^{a}	29.7 ^{a}
NTR_+N_{60}	65.67 ^{a}	45.1 ^{a}	40.3 ^{a}
NTR_+N_{120}	102.37 ^{a}	29.5 ^{a}	34.4 ^{a}
NTR_+N_{180}	124.10 ^{a}	21.3 ^{a}	30.9 ^{a}
LSD (T)	NS	NS	NS
LSD(R)	NS	NS	NS
LSD(N)	6.68*	5.30*	2.7*
LSD(T×R×N)	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

However, nitrogen uptake by wheat grain and straw increased significantly with increase in the nitrogen levels. Application of 180 kg N ha^{-1} significantly increased the nitrogen uptake by wheat grain and straw by 94.8% than that of 60 kg N ha^{-1}. Application of 180 kg N ha^{-1} significantly increased the nitrogen uptake by wheat grain and straw by 32.2% than that of 120 kg N ha^{-1}. Application of 120 kg N ha^{-1} significantly increased the total nitrogen uptake by wheat grain and straw by 47.4% than that of

60 kg N ha^{-1}. The increase in N uptake with increase in the Nitrogen levels was due to higher biomass production and higher nitrogen concentration in grain and straw at higher nitrogen levels. Mineralization intensity and, hence, available nitrogen was less in no-tillage system than in plowed tillage system. This led to higher nitrogen fertilization requirement in no-till system (Alvarez and Steinbach, 2009). Effect of tillage, residue and nitrogen management interaction was not significant on nitrogen uptake by wheat grain and straw.

Neither tillage nor crop residue mulch significantly influenced PFPN and NUtE by wheat. However, both PFPN and NUtE by wheat decreased with increase in nitrogen levels. PPFN ranged from 18.6 (CT R_+ N_{180}) to 47.3 kg grain/ kg N applied (CT R_0 N_{60}) with a mean value of 30.3 kg grain/kg N applied. The PFPN of wheat due to 60 kg N ha^{-1} were significantly higher than that of 120 kg N ha^{-1}and 180 kg N ha^{-1}by 62.6 and 119.8%. Application of 120 kg N ha^{-1} registered significantly higher PFPN by 35.1% than that of 180 kg N ha^{-1}.This is mainly attributed to the losses of Nitrogen at higher level of N application and also due to the fact that yield of wheat didn't increase in the same proportion as that of Nitrogen application. Similar results have been reported by many workers (Gajri *et al.*, 1993; Bandyopadhyay *et al.*, 2009; Chakrabarty *et al.*, 2010; Pradhan *et al.,* 2013 and Pradhan *et al.,* 2014). During both the years, effect of tillage, residue and nitrogen management interaction was not significant on PFPN.

NUtE by wheat ranged from 28.7 (CT R_+ N_{180}) to 47.3 kg grain/kg N uptake (CT R_0 N_{60}) with a mean value of 36.4 kg grain/ kg N uptake. Similar to PFPN, the NUtE decreased significantly with the increase in the N levels. Application of 60 kg N ha^{-1} significantly increased NUtE of wheat by 18.9 and 41.9% than that of 120 kg N ha^{-1}and 180 kg N ha^{-1}, respectively. Application of 120 kg N ha^{-1} significantly increased NUtE by 19.3% than that of 180 kg N ha^{-1}. Effect of tillage, residue and nitrogen management interaction was not significant on NUtE by wheat.

Correlation between mineral-N content and N uptake by wheat

The data of weighted average of NH_4^+-N + NO_3^--N content for 0-15, 15-30, 30-45 and 45-60 cm soil depth for the entire crop growth period is presented in Table 4. The data shows that the mineral N content was higher under NT and R_+ treatment which resulted in higher nitrogen uptake by wheat crop under these treatments. Also, with increase in Nitrogen levels, the mineral nitrogen content in soil increased which resulted in increasing Nitrogen uptake. Weighted average NH_4^+-N , NO_3^--N and NH_4^+-N + NO_3^--N content

Table 4. Weighted average mineral N content for different soil depths for the entire growth period as influenced by tillage, residue and Nitrogen management

Treatment	Mineral N content (kg ha^{-1})			
	0-15 cm	15-30 cm	30-45 cm	45-60 cm
Effect of tillage				
CT	53.22	49.78	37.69	31.07
NT	54.03	55.70	43.36	36.57
Effect of residues				
R_0	50.96	50.23	38.29	32.38
R_+	56.29	55.25	42.75	35.25
Effect of Nitrogen				
N_{60}	44.20	43.41	33.21	27.80
N_{120}	52.07	52.47	40.81	34.34
N_{180}	64.60	62.34	47.55	39.32
Effect of Tillage ×Residue × Nitrogen				
CTR_0N_{60}	43.05	39.66	28.56	24.07
CTR_0N_{120}	52.26	47.67	35.70	29.68
CTR_0N_{180}	59.12	54.98	40.36	34.23
CTR_+N_{60}	43.56	41.59	31.77	26.53
CTR_+N_{120}	53.77	51.20	40.71	33.33
CTR_+N_{180}	67.56	63.60	49.03	38.57
NTR_0N_{60}	42.97	44.04	34.70	29.02
NTR_0N_{120}	49.38	54.20	41.59	36.23
NTR_0N_{180}	58.99	60.83	48.84	41.07
NTR_+N_{60}	47.24	48.36	37.79	31.58
NTR_+N_{120}	52.88	56.83	45.22	38.13
NTR_+N_{180}	72.75	69.93	51.99	43.40

for 0-15, 15-30, 30-45 and 45-60 cm soil depth for the entire crop growth period was correlated with the total N uptake by the wheat crop (Table 5). The NH_4^+-N and NO_3^-–N content and NH_4^+-N + NO_3^-–N content for 0-15, 15-30, 30-45 and 45-60 cm soil depth were significantly correlated among themselves. However, the correlation coefficient between NH_4^+-N and NO_3^-–N content and NH_4^+-N + NO_3^-–N content for 0-15 and other layers decreased beyond 30 cm soil depth. It was observed that all the soil depths the NH_4^+-N , NO_3^--N and NH_4^+-N + NO_3^-–N content were significantly ($p<0.01$) correlated with the final N uptake. However the correlation coefficient decreases beyond 30 cm soil depth.

Grain and biomass yield of wheat

The grain and biomass yield of wheat as influenced by tillage, residue and nitrogen management is presented in the Table 6. The grain yield of wheat ranged from 2412 kg ha^{-1} (CT R_+ N_{60}) to 3833 kg ha^{-1}(NT R_+ N_{180}) with an average value of 3158 kg ha^{-1}. Neither the tillage treatment nor the crop residue mulch significantly influenced grain yield of wheat. This may be attributed to the fact that the experiment was only two years old. However, Ghosh *et al.* (2015) reported that under conservation agriculture in a sandy-loam soil having maize–wheat rotation, the equivalent yield of wheat was 47% higher than conventional agriculture. 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 36.5% and 11% than that of 60 120 kg N ha^{-1}, respectively. The biomass yield of wheat ranged from 6801 kg ha^{-1} (CT R_+ N_{60}) to 10422 kg ha^{-1} (NT R_0 N_{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. Application of 180 kg N ha^{-1} significantly increased the biomass yield of wheat by 34.9% and 12.7% than that of 60 and 120 kg N ha^{-1}, respectively. The effect of tillage, residue and nitrogen interaction was not significant for the both grain and biomass yield of wheat.

Table 5. Correlation matrix between mineral N content at different soil depths and N uptake by wheat

	0-15 cm			15-30 cm			30-45 cm			45-60 cm			Total N uptake
	NH_4^+-N	NO_3^--N	Mineral N	NH_4^+-N	NO_3^--N	Mineral N	NH_4^+-N	NO_3^--N	Mineral N	NH_4^+-N	NO_3^--N	Mineral N	
0-15 cm													
NH_4^+-N	1.00												
NO_3^--N	1.00	1.00											
Mineral N	1.00	1.00	1.00										
15-30 cm													
NH_4^+-N	0.94	0.94	0.94	1.00									
NO_3^--N	0.94	0.94	0.94	1.00	1.00								
Mineral N	0.94	0.94	0.94	1.00	1.00	1.00							
30-45 cm													
NH_4^+-N	0.88	0.88	0.88	0.98	0.98	0.98	1.00						
NO_3^--N	0.88	0.88	0.88	0.98	0.98	0.98	1.00	1.00					
Mineral N	0.88	0.88	0.88	0.98	0.98	0.98	1.00	1.00	1.00				
45-60 cm													
NH_4^+-N	0.84	0.84	0.84	0.97	0.97	0.97	0.99	0.99	0.99	1.00			
NO_3^--N	0.84	0.84	0.84	0.97	0.97	0.97	0.99	0.99	0.99	1.00	1.00		
Mineral N	0.84	0.84	0.84	0.97	0.97	0.97	0.99	0.99	0.99	1.00	1.00	1.00	
Total N uptake	0.91	0.92	0.92	0.92	0.92	0.92	0.89	0.89	0.89	0.88	0.88	0.88	1.00

Table 6. 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})
Effect of tillage		
CT	3096^{A}	8467^{A}
NT	3220^{A}	8992^{A}
Effect of residues		
R_0	3143^{A}	8687^{A}
R_+	3173^{A}	8772^{A}
Effect of Nitrogen		
N_{60}	2636^{C}	7388^{C}
N_{120}	3241^{B}	8837^{B}
N_{180}	3598^{A}	9963^{A}
Effect of Tillage ×Residue × Nitrogen		
CTR_0N_{60}	2836^{a}	7905^{a}
CTR_0N_{120}	3187^{a}	8556^{a}
CTR_0N_{180}	3592^{a}	9479^{a}
CTR_+N_{60}	2412^{a}	6801^{a}
CTR_+N_{120}	3203^{a}	8370^{a}
CTR_+N_{180}	3343^{a}	9693^{a}
NTR_0N_{60}	2592^{a}	7324^{a}
NTR_0N_{120}	3028^{a}	8434^{a}
NTR_0N_{180}	3622^{a}	10422^{a}
NTR_+N_{60}	2702^{a}	7522^{a}
NTR_+N_{120}	3544^{a}	9989^{a}
NTR_+N_{180}	3833^{a}	10259^{a}
LSD (T)	NS	NS
LSD(R)	NS	NS
LSD(N)	322.6*	579.7*
LSD(T×R×N)	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 $p<0.05$

Conclusions

It may be concluded that NH_4^+-N and NO_3^--N content under crop residue mulch was higher than that of un-mulched treatment in all the soil depths. There was no significant difference between CT and NT with respect to NH_4^+-N and NO_3^--N content at all depths. With the increase in nitrogen fertilizer dose, the NH_4^+-N and NO_3^--N content increases at all soil depths. Therefore, the farmers are advised to apply crop residue mulch to avoid nitrogen losses. It was observed that all the soil depths the NH_4^+-N , NO_3^--N and NH_4^+-N + NO_3^--N content were significantly ($p<0.01$) correlated with the final N uptake. However the correlation coefficient decreases beyond 30 cm soil depth. Also, the effect of tillage and crop residue mulch was not significant on grain and biomass yield of wheat, nitrogen uptake, Partial Factor Productivity of Nitrogen and Nitrogen Utilization Efficiency of wheat. So, the farmers can successfully adopt No-tillage with crop residue mulch and can save time, labour and energy. Nitrogen uptake, grain protein content and nitrogen concentration in plant increased with increase in Nitrogen levels but nitrogen utilization efficiency and partial factor productivity of N decreased with the increase in N levels. So, there is a tradeoff between yield and nitrogen use efficiency with respect to nitrogen dose which needs to be optimized.

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