

Conservation Tillage Effects on Crop Yield, Carbon Accumulation and Soil Nitrogen Transformation in Rice-Wheat Systems in Northern India

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ABSTRACT

The effect of different tillage practices was determined on crop yield, carbon accumulation, and soil nitrogen availability in a rice-wheat agricultural system (located at Uchana, 29° 51' N, 76° 57' E and 245 m above mean sea level) in northern India. The rice crop was grown under conventional practices and wheat crop under zero-tillage (ZT), conventional tillage (CT) and furrow-irrigated raised bed (FIRB). The zero-tillage in wheat had a favorable effect on soil carbon and nitrogen, crop yield, carbon accumulation and nitrogen uptake. In rice crop, the grain yield varied from 6026 to 6105 kg ha⁻¹, being higher in zero-tillage system. The accumulation of carbon in grain, straw and roots of wheat varied from 4657.99 to 5147.21 kg C ha⁻¹. The carbon accumulation in rice ranged from 5662.47 to 5923.63 kg C ha⁻¹. Total nitrogen uptake in grain, straw and roots of wheat was (kg N ha⁻¹): 154 zero-tillage; 139 furrows irrigated raised bed; 124 conventional tillage. The efficiency of nitrogen uptake in rice crop was 52.30 to 55.69% and that in wheat crop varied from 61.39 to 69.81%. The soil inorganic N in different tillage systems was ($\mu\text{g NO}_3^- \text{ - N} + \text{NH}_4^+ \text{ - N g}^{-1} \text{ soil}$): 9.57 to 16.23 (CT); 4.18 to 15.90 (ZT); 7.54 to 14.52 (FIRB). Due to amendment of straw and roots in the soil, the average soil microbial biomass N was 38.71 to 45.49 $\mu\text{g N g}^{-1} \text{ soil}$. Nitrogen mineralization rates as percent of plant residue nitrogen during 140 days of incubation were: 27.96% (wheat straw), 14.21% (wheat roots), 20.15% (rice straw) and 13.95% (rice roots).

Key Words: Crop Yield, N Uptake, Soil Carbon and Nitrogen, Zero-tillage, Nitrogen Mineralization.

INTRODUCTION

Agriculture is important to human society as it is an essential occupation of people and needed for the food security of the ever-growing population. Today, global agriculture feeds a population of about 6.4 billion besides delivering a wide range of ecosystem services (Pollock et al. 2008). Therefore, it is important to adopt sustainable agriculture through the application of minimal soil disturbance (Baker et al. 2002, Hobbs et al. 2008), maintaining permanent soil cover and adopting crop rotation practices in agriculture (Pollock et al. 2008). No-tillage agriculture is a way of growing crops from year to year without disturbing the soil through tillage so as to make farming profitable as well as improving soil health (Baker et al. 2002). The no-tillage systems have been adopted in different regions of the world and area under no-tillage has shown

worldwide increase since the 1990s. According to the FAO Agriculture 21 / Spotlight 2006, the area under conservation agriculture has been estimated to be 98.8 million hectares, and emphasized the importance of the upper 0 to 20 cm of soil for ensuring soil health and biological productivity.

Rice-wheat systems are among the most widespread cropping systems in India. The conventional systems of growing rice and wheat are not very efficient in terms of water economy and the use of natural resources. Studies have shown that timely sowing, judicious use of irrigation water, appropriate management of small farms, efficient use of fertilizers and weed management are important factors for maintaining the productivity of rice-wheat systems (RWC 2005). In recent years, the zero-tillage with wheat succeeding rice is now the most widely adopted resource conserving technology in the Indo-Gangetic

plains, including regions of Haryana and Punjab (RWC 2005, Hobbs et al. 2008).

Nitrogen is an important nutrient element limiting crop productivity of rice-wheat systems. Some workers have reported that the time of fertilization, tillage systems and environmental conditions affect grain yield, nitrogen accumulation pattern and N-mineralization in wheat (Johnston and Fowler 1991, Wuest and Cassman 1992). The agronomic practices like tillage, the addition of manures and fertilization for crop growth has been found to affect nitrogen mineralization rates in agricultural systems (Franz-luebbers et al. 1994a, 1994b, Power and Peterson 1998, Melaj et al. 2003). Soil nitrogen availability for crop growth is regulated by organic amendment (Boyle and Paul 1989), tillage (Carter and Rennie 1982) and nitrogen fertilization (El-Haris et al. 1983). Mineralization of nitrogen from plant residues in the soil contributes significantly to nitrogen availability to the plants (Jansson and Persson 1982). The continuous turnover of nitrogen through mineralization and immobilization results in the incorporation of N into soil microbial biomass. Thus, soil microbial biomass acts both as a transforming agent and as a source and sink of N in soil (Jenkinson and Ladd 1981, Duxbury et al. 1991, Singh et al. 1989).

The aim of this study was to (i) analyze the effect of conservation tillage on crop yield, carbon accumulation and nitrogen uptake in rice-wheat system, (ii) soil nitrogen availability in relation to crop growth and tillage systems, (iii) soil nitrogen transformation in residue amended soils.

MATERIAL AND METHODS

The study was carried out in a rice-wheat agricultural system on the farmer's field located at Uchana (29° 51' N, 76° 57' E and 245 m above mean sea level) in Karnal (northern India). The agricultural field selected for the study has been under zero-tillage and furrow irrigated raised bed systems since November 1997. The rice-wheat crop rotation was followed for the conventional, zero-tillage and furrow irrigated raised bed systems on the farmer's field.

Climate and Soil

Climate of the study area is semiarid and monsoonic, characterized by hot summer and cold winter. The mean annual rainfall of the area is 750 mm, nearly

70% of which is received during the rainy season from June to September. The rainfall during the study period varied from 619 to 717 mm per year. The mean maximum temperature varied from 17.30 to 38.90 °C and mean minimum temperature ranged from 6.1 to 26.70 °C during April 2003 to December 2005. Soil of the study area is sandy-loam in texture and moderately alkaline in soil reaction. The bulk density of soil ranged from 1.20 to 1.41 g cm⁻³ in different tillage systems at 0 to 30 cm soil depth. Soil pH varied from 7.52 to 7.71 (0 to 7.5 cm soil depth) and 8.13 to 8.23 (7.5 to 15 cm soil depth). The organic carbon content of the soil varied from 0.35 to 0.61% (0 to 7.5 cm soil depth), from 0.25 to 0.33% (7.5 to 15 cm soil depth) and from 0.18 to 0.25% (15 to 30 cm soil depth) in different tillage systems (Table 1).

Analysis of Crop Yield, Carbon Accumulation and Nitrogen Uptake

Crop biomass and grain yield were recorded from agricultural field under rice-wheat crop rotation during October 2003 to April 2005 by harvesting 1m x 1m harvest plots (five plots) from each systems (conventional tillage, zero-tillage and furrow irrigated raised bed) at crop maturity during October for rice and during April for wheat. The roots were dug up to 20 cm soil depth from the subplots from within the harvested plots using a soil corer of 12 cm in diameter. The soil cores were transported to laboratory in polythene bags. For determination of root biomass, the soil cores were soaked in water for a few hours, and the roots were washed under a fine jet of water. The roots were collected by flotation and oven-dried at 65 °C. The crop residues from aboveground parts were sampled from within 1m x 1m quadrats for estimating organic matter input to the soil after crop harvest.

Plant samples of rice and wheat were oven-dried and powdered in a Wiley mill equipped with 2 mm sieve. Organic carbon in plant samples was analyzed using the dichromate oxidation method (Kalembasa and Jenkinson 1973). Carbon content and carbon accumulation by rice and wheat crop was calculated on the basis of dry matter production and average nitrogen concentration in respective plant components.

Total nitrogen concentration in roots, straw and grain were estimated by the semi-micro Kjeldahl method (Bremner 1965a). Nitrogen content and uptake by rice and wheat crop were calculated on the basis of dry matter production and average nitrogen concentration in respective plant components.

Table 1. Some soil characteristics under conventional tillage (CT), zero-tillage (ZT) and furrow irrigated raised bed (FIRB) rice-wheat systems.

Soil depth/ Tillage Systems	pH (1:2)	Bulk density (g cm ⁻³)	Carbon (%)	Nitrogen (%)
0-7.5cm				
CT	7.71±0.21	1.26±0.030	0.44±0.04	0.051±0.0054
ZT	7.52±0.15	1.20±0.017	0.61±0.03	0.070±0.0041
FIRB	7.63±0.32	1.28±0.023	0.35±0.047	0.041±0.0068
7.5-15cm				
CT	8.23±0.18	1.33±0.024	0.25±0.023	0.031±0.002
ZT	8.16±0.34	1.39±0.032	0.33±0.21	0.040±0.0029
FIRB	8.13±0.14	1.37±0.043	0.30±0.026	0.037±0.0026
15-30cm				
CT	8.42±0.14	1.36±0.023	0.18±0.01	0.024±0.001
ZT	8.35±0.10	1.41±0.015	0.25±0.02	0.032±0.002
FIRB	8.20±0.10	1.39±0.016	0.20±0.01	0.026±0.002

Soil organic carbon and nitrogen stocks (kg ha⁻¹) were estimated from bulk density, concentrations of carbon and nitrogen in soil for a given soil depth. Soil bulk density was determined using soil core method.

Soil Nitrogen Availability

The changes in soil inorganic nitrogen were studied in all the three tillage systems during the wheat growing period. During the rice growing season, the soil samples were collected from the zero-tillage and conventional wheat plots. The total soil inorganic N (NH₄⁺ and NO₃⁻) was analyzed using Devardas alloy and Magnesium Oxide (MgO) following Bremner (1965b).

Nitrogen Transformation in Residue Amended Soil

A laboratory experiment was carried out to see the effect of crop residue amendment on nitrogen mineralization and immobilization in the soil microbial biomass. The straw and root samples of rice and wheat were collected from the experimental fields. The root samples were collected from plants at the time of crop harvest. The air-dried plant material was cut into small pieces and finely ground using a Wiley mill to pass through 2 mm sieve.

The soil was collected from 0 to 15 cm soil depth from the conventional field. The soil was sieved through 2 mm sieve and soil moisture was adjusted to

40% of water holding capacity (WHC) and pre-incubated for 10 days. Plant material equivalent to one-gram dry weight was mixed with 50 g soil contained in 100 mL plastic vials. The changes in N mineralization rates were studied under laboratory condition. Nitrogen mineralization rates were determined at 7, 14, 28, 56, 84, 112 and 140 days after incorporation of roots and straw material in the soil and incubating the samples at 27 °C in the incubator. On each sampling date, the amended and unamended soils equivalent to 50 g were extracted with 200 mL 0.5N K₂SO₄.

Using the four materials, amended soil samples were prepared and incubated at 27 °C in the incubator. For different treatments of straw and root amended soils, soil microbial biomass N were measured at 7, 14, 28, 56, 84, 112 and 140 days using the fumigation extraction method (Brookes et al. 1985). The unamended soil was kept as control

RESULTS

Plant Biomass and Crop Yield

Grain yield is an important component of crop performance under a set of agricultural practices. The grain yield of rice ranged from 6026 to 6105 kg ha⁻¹. There was no significant effect of tillage on grain yield,

straw production and root biomass. The grain yield of rice crop was found to increase by 5 to 10% in zero-tillage system during the two years of cropping season (Table 2). There was no significant effect of tillage practices on biomass production of grain and straw in rice system across the year ($P>0.05$). The interactive effect of tillage and the year was also not significant ($P>0.05$).

Table 2. Grain yield, and straw and root biomass (kg ha^{-1}) in conventional tillage (CT), zero-tillage (ZT) and furrow irrigated raised bed system (FIRB) in rice and wheat during October 2003 to April 2005. (The values in parenthesis are for second year of cropping from October 2004 to April 2005).

Tillage System	Grain	Straw	Roots
Rice			
CT	6080±113 (6026±96)	5844±102 (5629±157)	1402±36 (1270±85)
ZT	6105±181 (6040±151)	5821±217 (5881±137)	1491±63 (1509±131)
Wheat			
CT	4832±96.74 (4593±71.04)	4953±138.04 (5124±104.6)	789±48.80 (861±54.01)
ZT	5155±126.84 (4960±44.35)	5358±143.9 (5406±199.6)	646±37.70 (771±63.63)
FIRB	5075±51.93 (5020±85.0)	5509±147.4 (5744±164.0)	906±42.55 (947±61.25)

Crop yield in wheat system was found to be influenced by tillage practices (Table 2). The grain yield of wheat was 6.8 to 11.7% higher in zero-tillage (ZT) and furrow irrigated raised bed system (FIRB) compared to the conventional tillage (CT). There was appreciable increase in the amount of root biomass of wheat crop in the zero-tillage and furrow irrigated raised bed tillage systems as compared to that of the conventional tillage (Table 2). At the time of crop harvest, the root biomass (kg ha^{-1}) of wheat crop in the three tillage systems was: 789 to 861 (CT), 646 to 771 (ZT) and 906 to 947 (FIRB). It was of interest to note that under zero-tillage wheat, the roots were concentrated in the surface layer of soil (0 to 7.5 cm)

due to greater horizontal spread of roots. In the case of conventional tillage, the growth of wheat roots was more in vertical plane resulting in accumulation of more root biomass at 15 to 20 cm soil depth.

There was significant effect of tillage practices in grain production ($P<0.05$) and root production ($P<0.01$). The interactive effect of tillage practices and the year of study were significant for only roots ($P<0.05$).

Carbon and Nitrogen Concentration

The concentration of carbon in wheat straw and roots varied from 37.86 to 41.85% and in straw and roots of rice, the carbon concentration varied from 36.70 to 39.58%. Under conventional tillage, zero-tillage and furrow irrigated raised bed tillage systems; the concentration of carbon in wheat straw was: 39.42% (CT), 41.85% (ZT) and 39.42% (FIRB) and in wheat root, the values were: 37.86% (CT), 38.73% (ZT) and 39.38% (FIRB). In conventional system of rice crop, the values were 38.77% in straw and 36.70% in roots. Under zero-tillage, the carbon concentration was 36.70% in rice straw and 38.04% in rice roots. In the rice systems, roots accounted for return of carbon ranging from 467 to 574 kg ha^{-1} at the time of crop maturity.

The concentration of nitrogen in straw, grain and roots was higher under zero-tillage (0.85 to 2.02%) as compared to that of the conventional tillage (0.65 to 1.80%) and furrow irrigated raised bed (0.65 to 1.89%) wheat system. The concentration of nitrogen in straw and roots of wheat were found to be higher by 11 to 31% in zero-tillage as compared to that of furrow irrigated raised bed wheat system.

At the time of crop maturity, nitrogen concentration was more in grains (1.80 to 2.02%) than in straw (0.65 to 0.85%) in all the three tillage systems. In wheat crop, nitrogen concentration under different tillage systems was: 1.80% (CT), 20.2% (ZT) and 1.89% (FIRB) in grain. Nitrogen concentration in wheat straw varied from 0.65 to 0.85% and the values was: 65% (CT), 0.85% (ZT) and 0.65% (FIRB). In wheat roots, nitrogen concentration was 0.78 to 0.87%. Under conventional and zero-tillage, nitrogen concentration in different plant components of rice was: 1.12 to 27% in grains; 0.58 to 0.61% in straw; 0.65 to 0.67% in roots. Under zero-tillage, there was increase in carbon and nitrogen concentration in straw, grain and roots of wheat crop.

Carbon Accumulation and Nitrogen Uptake in Plant Biomass

The accumulation of carbon in grain, straw and roots of wheat was found to be greater under zero-tillage system (5041.02 to 5070.01 kg C ha⁻¹) as compared to the conventional tillage (4657.99 to 4682.14 kg C ha⁻¹) and furrow irrigated raised bed system (5065.93 to 5147.21 kg C ha⁻¹) (Table 3). This increase in C accumulation by wheat crop could be attributed to increase in total plant biomass by 5 to 10% under zero-tillage wheat and furrow irrigated raised bed. The values of carbon accumulation ranged from 5662.47 to 5923.63 kg C ha⁻¹ in rice (Table 3). In wheat crop, the average nitrogen uptake by the plants varied from 124 to 154 kg N ha⁻¹ under conventional tillage, zero-tillage and furrow irrigated raised bed systems, being higher in zero-tillage. This increased supply of nitrogen in zero-tillage wheat might come from rice residues retained in the system as well as from increased nitrogen mineralization of soil organic matter. The straw and stubbles of rice contributed an input of about 33 kg N ha⁻¹ in the zero-tillage wheat.

Table 3. Carbon accumulation (kg C ha⁻¹) and nitrogen uptake (kg N ha⁻¹) in rice and wheat in grain and total plant biomass under conventional tillage (CT), zero-tillage (ZT) and furrow irrigated raised bed (FIRB) systems during October 2003 to April 2005. (The values in parentheses are for second year of cropping from October 2004 to April 2005).

Tillage system	Carbon accumulation		Nitrogen uptake	
	Grain	Total	Grain	Total
Rice				
CT	3040.0 (3013.0)	5821.4 (5662.5)	68.10 (67.49)	111.39 (108.65)
ZT	3052.5 (3020.0)	5923.6 (5921.3)	77.53 (76.71)	122.73 (122.39)
Wheat				
CT	2416.0 (2296.5)	4682.1 (4658.0)	86.98 (82.67)	125.46 (122.78)
ZT	2577.5 (2480.0)	5070.0 (5041.0)	104.13 (100.19)	155.29 (152.85)
FIRB	2537.5 (2510.0)	5065.9 (5147.2)	95.92 (94.88)	138.8 (139.61)

In the case of rice crop, the average nitrogen uptake varied from 110.02 to 122.56 (Table 3). Thus, nitrogen uptake was enhanced in the case of zero-tillage as compared to that of the conventional tillage. N uptake was higher in grain as compared to straw and roots in case of all the systems. Uptake of nitrogen in wheat was increased by about 24% in zero-tillage systems as compared to the conventional tillage. In zero-tillage rice crop, the increase in nitrogen uptake was 10 to 12% due to residual effect.

The efficiency of nitrogen uptake in wheat crop varied from 61.39 to 69.81%, being greatest in the case of furrow irrigated raised bed systems. The average nitrogen use efficiency in wheat crop under different tillage systems was: 62.06% (CT), 65.84% (ZT) and 69.60% (FIRB). In the case of rice crop, the efficiency of N uptake varied from 52.30 to 55.69% and the average value of nitrogen use efficiency was: 55% (CT) and 52.37% (ZT). Thus, enhanced crop production could be associated with increased N uptake from the soil due to higher plant nutrient availability from both organic and inorganic sources in zero-tillage and furrow irrigated raised bed systems.

Seasonal Variations in Available Soil Inorganic Nitrogen

Soil inorganic nitrogen (NH₄-N and NO₃-N) levels at two soil depths during rice growing season in 2003 and 2004 are shown in Table 4. There were significant differences in soil inorganic nitrogen at the time sowing and harvest of the rice crop across the soil depth. The soil inorganic nitrogen just before the transplantation of rice crop varied from 8.37 to 10.13 µg N g⁻¹ soil during June 2003 and June 2004 (Table 4). At the time of crop harvest in October, there was marked decrease in available soil inorganic N, the values varied from 4.94 to 6.83 µg N g⁻¹ soil. Soil inorganic nitrogen levels were higher in the surface layer of soil at the time of sowing and harvesting of rice crop during the two years of study. At 7.5 to 15 cm soil depth, the soil inorganic N was markedly low (3.06 to 6.87 µg N g⁻¹ soil) across the sampling dates and tillage systems (Table 4).

The soil inorganic nitrogen levels varied with crop growth during the wheat growing season. During the study period, the soil inorganic N at 7.5 cm soil depth (µg N g⁻¹ soil) were: 9.57 to 16.23 (CT), 4.18 to 15.90 (ZT), 7.54 to 14.52 (FIRB). The soil inorganic N levels at 7.5 to 15 cm depth (µg N g⁻¹ soil) during the same period were: 4.66 to 5.33 (CT), 2.64 to 6.23 (ZT), 3.68 to 6.12 (FIRB).

Table 4. Soil inorganic N in rice crop at the time of sowing and crop harvest at two different soil depth in conventional tillage (CT) and zero-tillage (ZT) systems.

Soil depth/ Sampling dates	Inorganic N ($\mu\text{g N g}^{-1}$ soil)	
	CT	ZT
0-7.5 cm		
June 2003	8.37 \pm 0.29	8.37 \pm 0.29
June 2004	8.72 \pm 0.55	10.13 \pm 0.55
October 2003	6.56 \pm 1.12	4.94 \pm 0.31
October 2004	6.83 \pm 1.08	6.53 \pm 1.07
7.5-15 cm		
June 2003	4.94 \pm 0.31	6.87 \pm 1.25
June 2004	(4.32 \pm 0.23)	3.19 \pm 0.38
October 2003	3.16 \pm 0.41	6.87 \pm 1.25
October 2004	(3.06 \pm 0.45)	3.19 \pm 0.38

The soil inorganic N varied significantly across the sampling dates and the tillage systems during the wheat crop from November 2004 to April 2005 (Table 6). In different tillage systems, soil inorganic N varied from 6.43 to 16.53 $\mu\text{g N g}^{-1}$ soil at 0 to 7.5cm soil depth and from 3.49 to 7.75 $\mu\text{g N g}^{-1}$ soil at 7.5 to 15 cm soil depth during November 2004 to April 2005 (Table 5).

Table 5. Soil inorganic N in the conventional tillage (CT), zero-tillage (ZT) and furrow irrigated raised bed (FIRB) systems during wheat growing season from 4 November 2004 to 6 April 2005.

Soil depth/ Sampling date	CT	ZT	FIRB	LSD (P<0.05)
0 - 7.5 cm				
4 Nov. 2004	11.14 \pm 1.00	13.81 \pm 1.06	9.91 \pm 1.73	4.10
19Dec. 2004	16.53 \pm 1.00	7.29 \pm 0.72	10.66 \pm 1.20	3.44
20 Jan. 2005	14.29 \pm 2.53	7.63 \pm 0.79	9.09 \pm 0.56	5.42
3 Mar. 2005	12.96 \pm 2.04	9.40 \pm 1.03	7.17 \pm 0.72	4.80
6 Apr. 2005	10.18 \pm 2.21	6.43 \pm 1.15	6.85 \pm 1.16	5.50
LSD (P<0.05)	5.84	3.53	3.05	
7.5 - 15 cm				
4 Nov. 2004	5.77 \pm 0.33	5.10 \pm 0.81	7.75 \pm 0.60	2.14
19Dec. 2004	5.50 \pm 0.76	3.49 \pm 0.40	6.19 \pm 1.12	2.84
20 Jan. 2005	7.73 \pm 0.59	4.35 \pm 0.74	5.65 \pm 0.52	2.17
3 Mar. 2005	6.31 \pm 0.85	4.44 \pm 0.61	4.52 \pm 0.46	2.31
6 Apr. 2005	4.84 \pm 0.55	5.72 \pm 0.92	4.98 \pm 0.80	2.99
LSD (P<0.05)	1.98	2.29	2.34	

Nitrogen Transformation in Straw Amended Soil

In the unamended soil, the soil microbial nitrogen concentration varied from 14.35 to 11.54 $\mu\text{g N g}^{-1}$ soil (Figure 1). Amendment with straw and roots in the soil, the soil microbial biomass nitrogen increased markedly during the initial phase of residue decomposition. At 28 days, the soil microbial biomass N ($\mu\text{g N g}^{-1}$ soil) in different treatments were: 48.87 (wheat roots), 44.34 (rice roots), 52.39 (rice straw), 45.13 (wheat straw). The soil microbial N consistently decreased in the soil amended with straw and roots of wheat and rice from 56 to 140 days. After 140 days of incubation, soil microbial biomass N was 35.02 to 46.64 $\mu\text{g N g}^{-1}$ soil of the four treatments (Figure 1). The changes in soil inorganic nitrogen in unamended and residue-amended soil are given in Figures 2 and 3. Net nitrogen mineralization was positive on all the sampling dates during 140 days of incubation in the unamended soil. In unamended soil, the nitrogen mineralization rate was 15.23 $\mu\text{g N g}^{-1}$ soil at 14 days of incubation. The net nitrogen mineralization accounted to 27.72 $\mu\text{g N g}^{-1}$ soil after 112 days.

In root- and straw-amended soil, there was immobilization of nitrogen (negative net N mineralization) during the initial phase of plant residue decomposition upto 28 days of soil incubation (Figures 2 and 3). The values of net immobilization of nitrogen ranged from 3.28 to 15.79 $\mu\text{g N g}^{-1}$ soil at 28 days' incubation of



Figure 1. Soil microbial biomass N in unamended soil and amended soil (a) rice roots and rice straw, (b) wheat roots and wheat straw.

Table 6. Total nitrogen mineralization, soil microbial biomass (averaged across sampling dates) and percent nitrogen mineralization (all values $\mu\text{g N g}^{-1}$ soil) in decomposing wheat straw, wheat roots, rice straw and rice roots during 140 days of incubation.

Treatments	N mineralization	Microbial biomass nitrogen	% mineralization of substrate nitrogen
Unamended soil	27.92 ± 2.12	11.54 ± 0.76	-
Soil +wheat straw	53.42 ± 4.70	38.71 ± 1.55	27.96 ± 2.46
Soil +wheat roots	29.72 ± 3.99	44.89 ± 1.96	14.21 ± 1.91
Soil + rice straw	23.38 ± 1.05	45.49 ± 2.68	20.15 ± 0.91
Soil + rice roots	18.70 ± 1.60	39.48 ± 1.39	13.95 ± 1.19

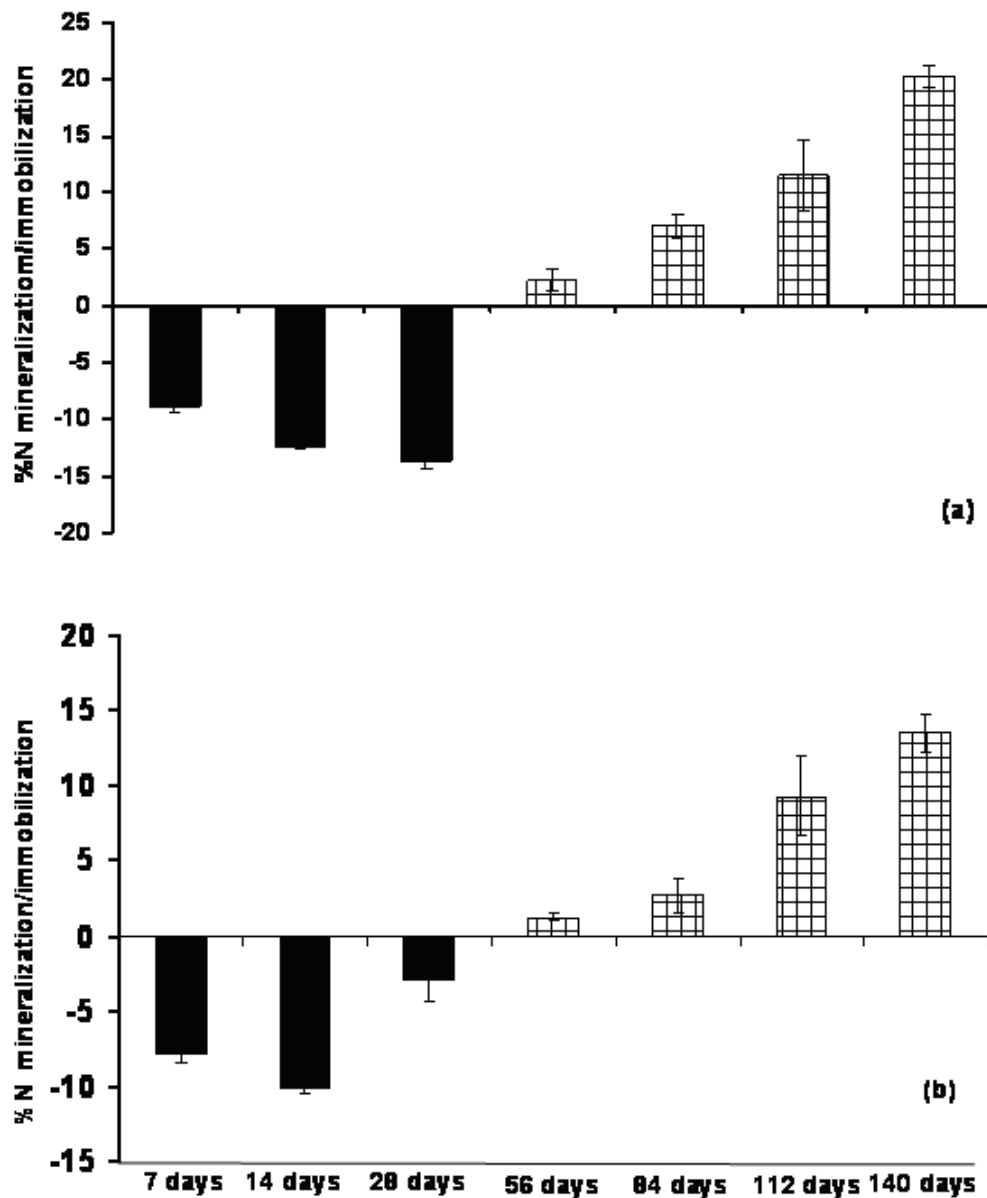


Figure 2. Percent nitrogen mineralization and immobilization in amended soil (a) rice straw and (b) rice roots during 140 days of incubation time.

the soil. At 56 days of incubation, nitrogen mineralization observed in the case of all the four materials. During 140 days of incubation, nitrogen mineralization rates as per cent of plant residue nitrogen for the four materials were: 20.15% (rice straw), 13.95% (rice roots), 27.50% (wheat straw) and 18.81% (wheat roots) (Figures 2 and 3).

Nitrogen mineralization in amended soil ranged from 1.26 to 7.21% of the plant residue nitrogen at 56 days of incubation (Table 6). At 140 days, the rates of

nitrogen mineralization were relatively higher in rice straw amended soil as compared to that of rice root amended soil. Nitrogen mineralization was found to be greater in straw amended soil (27.96%) as compared to that of roots amended soil (14.21%) (Table 6). Averaged across the sampling dates of the total incubation period of 140 days, the soil microbial biomass nitrogen in different treatments were: 44.89 (wheat roots), 39.48 (rice roots), 45.49 (rice straw), 38.71 (wheat straw) (Table 6).

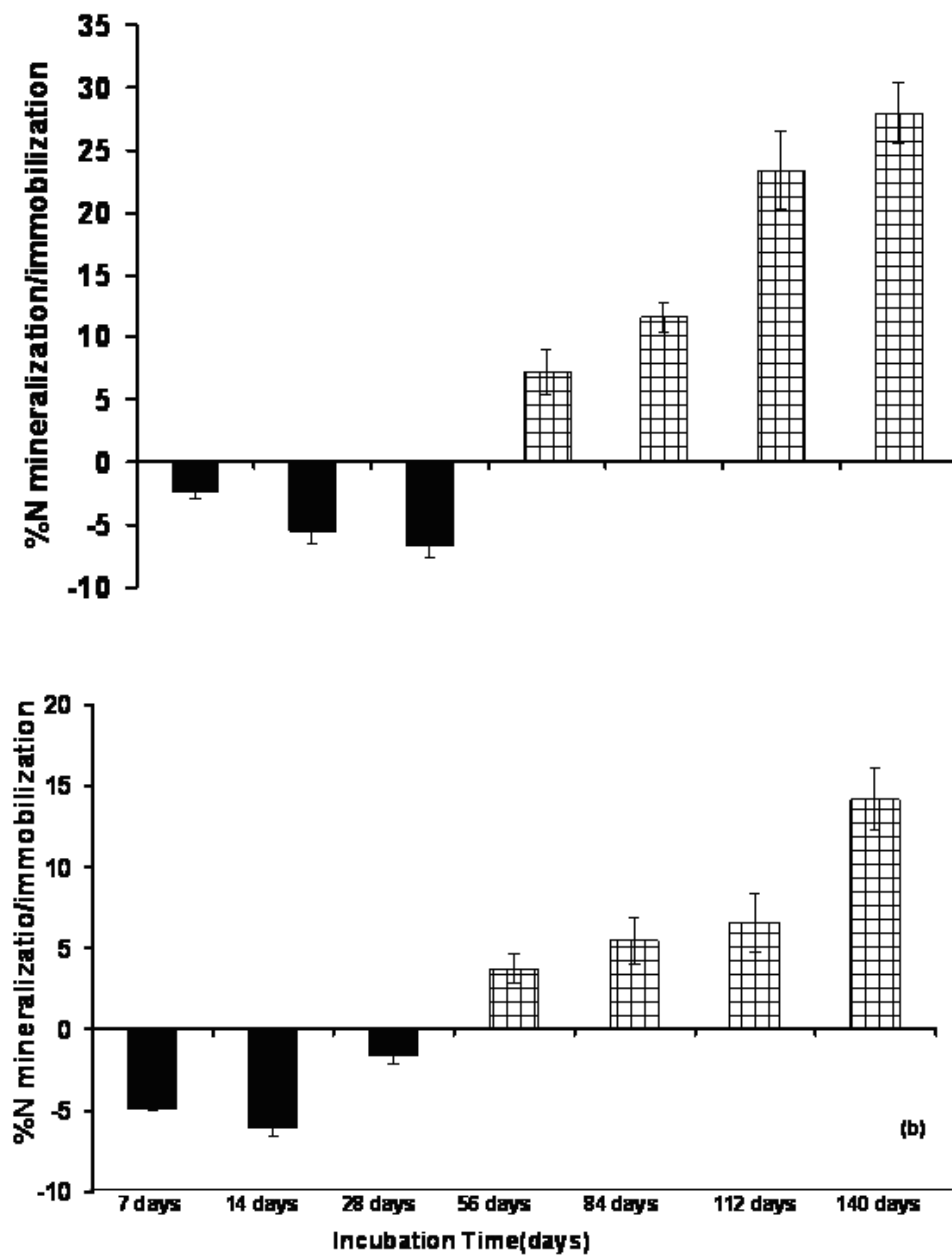


Figure 3. Percent nitrogen mineralization and immobilization in amended soil (a) wheat straw and (b) wheat roots during 140 days of incubation time.

DISCUSSION

Yield of wheat was found to be 6.8 to 11.7% higher in zero-tillage and furrow irrigated raised bed wheat systems. Yields in the rice-wheat (RW) systems of the Indo-Gangetic Plains in South Asia are higher with no-till because of timelier planting and better stands (Hobbs and Gupta 2004). This study revealed that rice roots formed 11 to 13% of the total aboveground and

belowground plant biomass. Uptake of nitrogen in wheat was increased by about 24% in zero-tillage systems as compared to conventional tillage. In zero-tillage rice, the increase in nitrogen uptake was 10 to 12%. A number of studies have shown that tillage and nitrogen fertilization can significantly affect carbon and nitrogen accumulation in different cropping systems (Crozier et al. 1999, Merrill et al. 1996, 2002, Qin et al. 2004).

Carbon and nitrogen were added or recycled from plant roots into the soil in agricultural systems. Several workers have shown that rhizodiposition such as root exudates, mucilage's and sloughed cells could also be significant sources of carbon and nitrogen to soil in agricultural systems (Buyanovsky et al. 1986, Balesdent and Balabane 1996, Allmaras et al. 2004). The nitrogen supplying potential of the soil could increase after long-term application of no-tillage (Franzluebbers et al. 1994a, 1994b). The efficiency of nitrogen uptake in rice crop was 52.30 to 55.69% and that in wheat crop varied from 61.39 to 69.81%. In the rice system, the efficiency of nitrogen is often low due to loss of nitrogen from flooded soil or leaching of nitrogen into ground water (De Datta and Buresh 1989).

Soil microbes play an important role in the nitrogen-mineralization and immobilization process. Much of nitrogen is mineralized from nitrogen rich compounds such as proteins, peptides, amino acids and nucleic acids. The soil receiving straw and root residue amendment showed a rapid increase in microbial biomass carbon and nitrogen during 28 days of incubation. Such increase in soil microbial biomass carbon and nitrogen has been reported by Ocio and Brookes (1990), Ocio et al. (1991a, 1991b) and Gupta (1992) in straw amended soils. During the decomposition of organic residues, the soil microbial biomass may obtain some of its N requirement from the straw itself, some from fertilizer inorganic N (Ocio et al. 1991a, 1991b). Soil nitrogen dynamics following straw incorporation has been studied by Ocio and Brookes (1990). They have found that microbial biomass increased by 100% in clay soil and 50% in sandy soil in wheat straw incorporated system. Using ^{15}N labeled wheat straw (Ocio et al. 1991b) and ^{15}N labeled sugarbeet leaves (Gupta 1992), it was found that microbial biomass derived nitrogen preferentially from plant residue N.

The kinetics of nitrogen mineralization showed differences among the four materials depending upon their chemical composition. After 7 days of incubation, there was a sharp decline in soil inorganic N in the soil amended with straw or root residues. The soils amended with straw and roots did not show increase in mineral N even up to 28 days. Several studies have reported that straw addition enhances nitrogen immobilization (Myrold and Tiedje 1986, Ocio and Brookes 1990). An early phase of N immobilization followed by slow net nitrogen mineralization was observed in the case of all the four materials. Wienhold

and Halvorson (1999) have reported that during the decomposition of the high C:N ratio residue, nitrogen is immobilized. The rapidly growing microbial biomass in amended soil has a high demand for soil inorganic nitrogen. Thus, the observed fluxes of immobilization and mineralization of nitrogen in amended soils could be associated with the microbial turnover of nitrogen during the decomposition of straw and roots over the incubation period.

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