Indian Journal of Agricultural Sciences **89** (1): 79–86, January 2019/Article
https://doi.org/10.56093/ijas.v89i1.86168

Relative impacts of long-term nutrient management practices on nitrogen dynamics in rice (*Oryza sativa*)-based organic cropping systems of Indo-Gangatic Plains

A L MEENA[1], R N PANDEY[2], DINESH KUMAR[3], V K SHARMA[4], S P DATTA[5] and GEETA SINGH[6]

ICAR-Indian Agricultural Research Institute, New Delhi 110 012

Received: 6 July 2018; Accepted: 19 July 2018

ABSTRACT

Limited information is available on the impacts of long-term organic nutrient management practices on different nitrogen pools and urease enzyme activity. Hence, the major objective of this study was to evaluate long-term (12 years) organic nutrient management practices' impact on different nitrogen pools and urease activity. Treatments were two cropping systems, viz. rice (*Oryza sativa* L.) –wheat (*Triticum aestivum* L.)-mungbean [*Vigna radiata* (L.) Wilczek] (RWMCS) and rice-wheat (RWCS) in strips and seven nutrient combinations, i.e. FYM equivalent to 60 kg N/ha, VC equivalent to 60 kg N/ha, FYM + crop residue (CR) of preceding crop @ 3 t/ha for each rice, wheat and mungbean, VC+CR, FYM+CR+BF and VC+CR+BF and control under sub-plots. Available N, microbial biomass N (MBN), mineral N, potential mineralizable (PMN), total N and urease enzyme assay were analysed in 0-15 cm soil depth. Results showed that FYM+CR+BF recorded 5.5% and 7.7% higher available N as compared to the FYM alone in both RWMCS and RWCS, respectively. Similarly, an increment of 4.0% and 7.5% in available N was observed with VC+CR+BF over VC alone in both the cropping systems, respectively. MBN ranged from 47.1 mg/kg (control) to 69.6 mg/kg (FYM) under RWMCS and 43.2 mg/kg (control) to 67.6 mg/kg (FYM) under RWCS. Treatments FYM+CR and FYM+CR+BF showed 5.0% and 30% lower ammonical N as compared to FYM alone treatments in RWMCS. Concurrently, in case of RWCS, the magnitude of decrease in ammonical N content was similar (21.1%) both in FYM+CR and FYM+CR+BF. The total mineral nitrogen (NH_4^+-N + NO_3^- -N) content was significantly influenced by the application of organic manures, crop residues and biofertilizers in both RWMCS and RWCS and their interaction effects. The FYM+CR+BF treatment recorded highest (56.4 mg/kg) potential mineralizable N (PMN) among all the treatments with an increment of 86.4% and 104% the over control in RWMCS and RWCS, respectively. The VC+CR showed 6.1% and 5.5% higher total N content over the control in RWMCS and RWCS, respectively. The content of urease enzyme ranged from 155.1 µg urea/g soil/h (control) to 230.4 µg urea/g soil/h (VC+CR) and 144.3 µg urea/g soil/h (control) to 233.6 µg urea/g soil/h (FYM+CR) in RWMCS and RWCS, respectively.

Key words: Ammonical N, Available N, Crop residues, Farmyard manure, Mineral N, Potential mineralizable N, Total N, Urease enzyme, Vermicompost

Changes in global climate have increased the attention of researchers towards different tillage practices as well as organic versus conventional farming since organic farming has positive effects on long-term sequestration and availability of carbon and nitrogen in soils (Cao *et al.* 2006). Organic farming has gained a wide popularity in the past few decades throughout the world. Study conducted by Pullmeman *et al.* (2003) reported higher amount of soil organic matter, enzymes and microbial biomass in organically managed soils as compared to the conventionally managed ones. Different management practices, viz. N fertilization, tillage, crop rotation and use of organic amendments have been used as an indicator of nitrogen availability in the soils. Thus, studies in many parts of the world have been conducted on effects of organic amendments on N mineralization rate.

Nitrogen is highly deficient nutrient in most of the soils throughout the world and for high crop yields, particularly from rice (*Oryza sativa* L.) – wheat (*Triticum aestivum* L.) cropping system; nitrogen is applied in high amounts through the chemical fertilizers (Pathak *et al.* 2006). This high application of nitrogen in rice-wheat cropping system is leading to lower nitrogen use efficiency and N fertilizer

[1]Scientist (e mail: amrit.iari@gmail.com), ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut 250 110. [2]Principal Scientist (e mail: rnpandeyssaciari@rediffmail.com), [4]Principal Scientist (e mail: vksharma.iari@gmail.com), Division of Soil Science and Agricultural Chemistry, [5]Professor (e mail: spdatta@yahoo.com), Division of Soil Science and Agricultural Chemistry, [3]Principal Scientist (dineshctt@yahoo.com), Division of Agronomy, [6]Principal Scientist (e mail: geetasingh@iari.res.in), Division of Microbiology, ICAR-Indian Agricultural Research Institute, New Dehli 110 012.

recovery efficiency (Bijay-Singh and Yadvinder-Singh 2003). To meet this challenge, the use of integrated nutrient management particularly through organic nutrient sources, viz. FYM, vermicompost (VC), crop residues (CR) and green manures, etc. not only improve the nitrogen use efficiency but also reduce the dependency on chemical fertilizers (Sharma *et al.* 2014). Use of these organic nutrient sources and use of green manures strongly influence the soil productivity and nitrogen dynamics in soil plant systems. Sharma *et al*. (2014) reported that the use of organic manures not only improves the available N, but also increases the different N pools in which nitrogen occurs and supplies N to plant. Furthermore, addition of residue of summer mungbean provides organic N to the succeeding rice and wheat crops. Zahoor (2013) reported that incorporation of crop residues, particularly return of rice and wheat straw improve soil quality and productivity through increased microbial activities, N mineralization, aggregation and increasing C and N storage in the soil.

In recent years, rice-wheat cropping system (RWCS) has faced a significant slowdown or stagnation in productivity due to decline in soil organic matter induced by low inputs of bio-resources and lack of adequate crop rotation (Shibu *et al.* 2010), depletion of soil fertility and nutrient deficiency due to imbalance use of chemical fertilizers, decline in ground water due to over exploitation (Hira 2009), poor management of crop residues and their burning and finally decreased input use efficiency. Under such scenario, organic farming could be an alternative way to overcome these abiotic interacting constraints of RWCS. It builds up and maintains SOM level, requires less water, improves nutrient use efficiency and finally enhance soil fertility and quality (Prasad 2005). Inclusion of summer mungbean with rice-wheat cropping system in rotation supply nutrients through organic sources, especially nitrogen to sustain the cropping systems (Kumar 2014). Legume crop, like mungbean has short vegetative duration and have many advantages in rice-based cropping systems by its high adaptation capability and ability of nitrogen fixation (Bar *et al.* 2000). Thus, it necessitates understanding the release and availability of nitrogen in different N pools and their inter-relationship under varied combinations of organic nutrient sources. It would, in turn, help in discerning the best combination of organic nutrient sources vis-à-vis crop growth and yields. However, information on these aspects is unavailable, particularly for rice-based cropping systems. Therefore, the present study aimed to understand the effect of organic manures, crop residues and biofertilizers on different nitrogen pools, urease enzyme and inter-relationship of different N pools and urease enzyme with rice yield.

MATERIALS AND METHODS

The present investigation was conducted in an on-going long-term experiment on "Nutrient management in long-term rice-based organic cropping systems" after harvest of rice crop. It is located at New Delhi in the Indo-Gangatic Plains of North India at latitude of 28.4°N and longitude of 77.1°E and an elevation of 228.6 m above the msl. The soil of the experimental field was classified as a typical Ustochrept (sandy clay loam texture) which had 52.06% sand, 22.54% silt and 25.40% clay and medium levels of organic carbon (5.1 mg/kg soil), low levels of available nitrogen (73.1 mg/kg soil), low levels of available phosphorus (8.42 mg/kg soil), available potassium (108.87 mg/kg soil) and pH 8.16 at the beginning of experimentation (Table 1). The experiment was laid out in a strip plot design with three replications which consisted of two rice-based cropping systems, i.e. basmati rice-wheat (RWCS) and basmati rice-wheat-mungbean (RWMCS) in strips and seven combinations of different organic materials and biofertilizers (BF), viz. farmyard manure (FYM) equivalent to 60 kg N/ha, vermicompost (VC) equivalent to 60 kg N/ha, FYM + crop residue (CR) of

Table 1 Physicochemical and biological properties of the initial soil sample collected from the field before start of the experiment

Property	Value
Physical properties	
Mechanical composition	
Sand (%)	52.1
Silt (%)	22.5
Clay (%)	25.4
Textural class	Sandy clay loam
Bulk density (Mg/m^3)	1.50
Water holding capacity (%)	40.4
Mean weight diameter (mm)	0.47
Field capacity at 1/3 atmospheric tension (%)	25.3
Chemical properties	
pH (1:2.5 soil:water ratio)	8.16
Electrical conductivity (dS/m 25^{0}C)	0.37
Cation exchange capacity (Cmol (P$^+$)/kg)	14.7
Organic carbon (g/kg)	5.1
Available N (kg/ha)	163.7
Available P (mg/kg)	8.42
Available S (mg/kg)	15.6
Available micronutrients (mg/kg)	
Fe	26.3
Cu	3.20
Zn	1.24
Mn	10.3
Biological properties	
Microbial biomass carbon (mg/kg)	230
Acid phosphatase (μg pNPP/g soil/h	97.5
Alkaline phosphatase (μg pNPP/g soil/h)	156.8
Arylsulfatase (μg pNP/g soil/h)	44.9
Dehydrogenase (μg TPF/g soil/24 h)	47.3
Urease (μg urea/g soil/h)	130.6
β-glucosidase (μg pNPG/g/soil/h)	13.5

preceding crop @ 3 t/ha for each rice, wheat and mungbean, VC+CR, FYM+CR+BF and VC+CR+BF, and control (no fertilizer applied) were applied in sub-plot. Pusa Basmati 1121, HD 2967 and Pusa Vishal varieties were used for rice, wheat and mungbean, respectively. Combinations of organic sources and biofertilizers were applied to both rice and wheat, whereas mungbean in rice-wheat-mungbean cropping system was grown on residual fertility. For biofertilizers, blue green algae (BGA), phosphate solubilizing bacteria (PSB) (*Pseudomonas striata*) and cellulolytic culture (*Aspergillus awamori*, *Trichoderma viride*, *Phanerochaete chrysosporuim* and *Aspergillus wolulens*) used in rice, *Azotobacter*, PSB (*Pseudomonas striata*) and cellulolytic culture in wheat and *Rhizobium* + PSB in mungbean.

Soil samples were collected after harvest of rice crop and analyzed for microbial properties, viz. microbial biomass nitrogen (MBN) and urease enzyme. Remaining soil samples were processed and analyzed for different nitrogen pools using standard methods, viz. available N was estimated using procedure given by Subbiah and Asija (1956). Mineral nitrogen (NH_4^+-N and NO_3^- -N) was measured by following the procedure given by Keeney and Nelson (1982). The mineral N was estimated by adding the two mineral nitrogen pools (NH_4^+-N and NO_3^--N). Microbial biomass nitrogen was analysed using method developed by Jenkinson and Powlson (1976). The MBN was calculated as follows.

$$MBN= (ON_F - ON_{UF})/ K_{EC},$$

where ON_F and ON_{UF} are organic nitrogen extracted from fumigated and non-fumigated soils, respectively (expressed on oven dry basis), and K_{EC} is the efficiency of extraction (0.45) as per Bremner and Kessel (1990).

Waring and Bremner (1964) method was followed for measuring potential mineralizable N. Total N content in soil was estimated by Kjeldahl digestion-distillation method. The urease enzyme activity was measured by the 5-hr incubation test described by Bremner and Douglas (1971). Statistical analysis was performed using SAS and SPSS software and the least significant difference (LSD) values were tested at 5% of significance level (*P*=0.05) of significance.

RESULTS AND DISCUSSION

The relative impacts of long-term organic nutrient management practices on nitrogen dynamics in rice-wheat and rice-wheat-mungbean organic cropping systems were studied for available N, mineral N, total mineral N, potential mineralizable N, total N, urease enzyme and correlation among different N pools, urease enzyme with rice yield.

Available N

The available N content was significantly increased by the use of organic nutrient sources in both the cropping systems; however, their interaction effect was non-significant. The available N content varied from 210 kg/ha (control) to 245 kg/ha (VC+CR+BF) and 203 kg/ha (control) to 243 kg/ha (VC+CR+BF) in RWMCS and RWCS, respectively (Table 2). Addition of crop residues and biofertilizers had a significant effect on available N content as compared to manures alone treatments and treatment FYM+CR+BF recorded 5.5% and 7.7% higher available N as compared to FYM alone treatment in RWMCS and RWCS, respectively. Similarly, an increment of 4.0% and 7.5% was observed with VC+CR+BF over VC alone in these cropping systems. Inclusion of summer mungbean (RWMCS) had a significant increase in available N content over its exclusion (RWCS) and it recorded significant higher (244 kg/ha) available N content as compared to RWCS (Table 2). Availability of N in soils amended with organic nutrient sources depends on the amount different organic and inorganic N fractions and their rate of mineralization. In present study combined application of manures, crop residues and biofertilizers resulted in higher amount of available N over other treatments used alone. Biofertilizers induced mineralization of these manures and crop residues caused conversion of other N fractions to plant available N content in these treatments. Nagar *et al.* (2016) also reported

Table 2 Long-term effect of nutrient supply options on available and microbial biomass nitrogen (MBN) in RWMCS and RWCS after harvest of rice crop in an Inceptisols (after 12 years)

Cropping system	Control	FYM	VC	FYM+CR	VC+CR	FYM+CR+BF	VC+CR+BF	Mean
Available N (kg/ha)								
R-W-M	210	231	236	238	243	242	245	244^a
R-W	203	221	226	226	234	238	243	227^b
Mean	207^c	226^b	231^b	232^b	238^a	240^a	244^a	
LSD (P=0.05)	CS = 3.43,	T = 6.42,	CS×T = NS,	T×CS = NS				
Microbial biomass nitrogen (MBN) (mg/kg)								
R-W-M	47.1^h	69.6^a	55.5^{ef}	55.5^{ef}	51.5^g	67.6^{ab}	61.6^c	58.3
R-W	43.2^i	67.6^{ab}	53.5^{fg}	59.5^{cd}	55.5^{ef}	65.6^b	57.5^{de}	57.5
Mean	45.1^d	68.6^a	54.5^c	57.5^{bc}	53.5^c	66.6^a	59.5^b	
LSD (P=0.05)	CS = NS,	T = 4.16,	CS×T = 3.18,	T×CS = 4.62				

* Different lower case letters within rows indicate that they are significant according to LSD Test *(P=0.05)*. * R-W-M = Rice-wheat-mungbean (RWMCS), R-W = Rice-wheat (RWCS)

that combined application of pigeonpea+ blackgram, crop residues and FYM resulted in higher available N content over other treatments. Surekha and Rao (2009) showed that addition of organic amendments attributes to greater multiplication of microorganisms in the soil which causes mineralization of organically bound N to available forms. Inclusion of mungbean in RWMCS and subsequent return of mungbean residues into the soil caused higher available N content in RWMCS as compared to RWCS in our study. Similar results were found by Patra *et al*. (2011).

Microbial biomass nitrogen

All the manures treatments (FYM and VC) either alone or in combination with crop residues and biofertilizers recorded significantly higher microbial biomass N (MBN) over control in both the cropping systems. MBN ranged from 47.1 mg/kg (control) to 69.6 mg/kg (FYM) and 43.2 mg/kg (control) to 67.6 mg/kg (FYM) in RWMCS and RWCS, respectively (Table 2). FYM alone or in combination with crop residues (FYM+CR) and biofertilizers (FYM+CR+BF) showed higher magnitude of increases in MBN over respective VC treatments. An increment of 47.8%, 17.8% and 43.5% was recorded with FYM, FYM+CR and VC+CR+BF combinations over control in RWMCS. However, in case of RWCS, the magnitude of increase was 56.5%, 37.7% and 51.9%, respectively. Crop residues incorporation along with manures did not improve the MBN over manures alone treatments in both the cropping systems, but significant higher MBN was observed when these crop residues were added along with biofertilizers (Table 2). The MBN content in soil was considerably affected by amount of organic matter added to the soil and subsequently mineralization/immobilization of this organic matter by diversified microbial community. Addition of crop residues and biofertilizers in treatments VC+CR+BF and FYM+CR+BF significantly enhanced the density of soil bacteria, fungi and actinomycetes which positively increased the MBN content in these treatments as compared to other treatments (Singh *et al*. 2015). Zhen *et al*. (2014) also reported higher MBN content with addition of manure compost along with bacterial fertilizers in their study. Relatively higher rate of mineralization of FYM treatments resulted in higher content of MBN over VC treatments in these treatments in the present study.

Mineral and total mineral N

In RWMCS, nutrient source FYM+CR and FYM+CR+BF recorded an increment of 36% and 43% in ammonical N content over FYM alone, respectively (Table 3). Concurrently, in case of RWCS, the magnitude of increase in ammonical N content in FYM+CR+BF was 27% while FYM+CR was at par with FYM alone treatment. Similarly, combination of VC+CR and VC+CR+BF showed an increment of 36% and 15% over VC alone in RWMCS, while VC+CR and VC+CR+BF resulted in 25% and 28% increased ammonical N over VC alone in RWCS (Table 3). This might be result of the association of highly active microflora in these sources due to availability of high substrate for microbial degradation and mineralization as compared to manures alone treatments (Verma *et al.* 2018). Growing of summer mungbean in RWMCS increase crop diversity, heterogeneity and chemical complexity of microbial substrate which expand the breadth and depth of microbial niche and rise the more diversified

Table 3 Long-term effect of nutrient supply options on ammonium nitrogen (NH_4^+-N), nitrate nitrogen (NO_3^--N) and mineral nitrogen in RWMCS and RWCS after harvest of rice crop in an Inceptisols (after 12 years)

Cropping system	Control	FYM	VC	FYM+CR	VC+CR	FYM+CR+BF	VC+CR+BF	Mean
Ammonium nitrogen (NH_4^+-N) (mg/kg)								
R-W-M	18.8^{d}	28.2^{bc}	28.2^{bc}	38.3^{a}	38.3^{a}	40.3^{a}	32.3^{b}	32.0^{a}
R-W	15.7^{d}	30.2^{b}	24.2^{c}	30.2^{b}	30.2^{b}	38.3^{a}	31.0^{b}	28.3^{b}
Mean	17.3^{f}	29.2^{cd}	26.2^{de}	34.3^{b}	34.3^{b}	39.3^{a}	31.7^{c}	
LSD (P=0.05)	CS = 4.94,	T = 2.08,	CS×T = 6.36,	T×CS = 4.05				
Nitrate nitrogen (NO_3^--N) (mg/kg)								
R-W-M	14.1^{e}	22.2^{bc}	22.2^{bc}	20.2^{bcd}	22.2^{bc}	28.2^{a}	24.2^{ab}	21.9^{a}
R-W	16.1^{de}	20.2^{bcd}	18.1^{cde}	18.1^{cde}	24.2^{ab}	22.2^{bc}	18.1^{cde}	19.6^{b}
Mean	15.1^{d}	21.2^{bc}	20.2^{c}	19.1^{c}	23.2^{ab}	25.2^{a}	21.2^{bc}	
LSD (P=0.05)	CS = 2.16,	T = 2.45,	CS×T = 4.28,	T×CS = 3.82				
Mineral nitrogen (mg/kg)								
R-W-M	32.9^{g}	50.4^{d}	50.4^{d}	58.5^{b}	60.5^{b}	68.5^{a}	56.5^{bc}	54.0
R-W	31.8^{gh}	50.4^{d}	42.3^{f}	48.3^{e}	54.4^{c}	60.5^{b}	49.1^{de}	48.1
Mean	32.4^{f}	50.4^{d}	46.4^{e}	53.4^{c}	57.5^{b}	64.5^{a}	52.8^{cd}	
LSD (P=0.05)	CS = NS,	T = 2.56,	CS×T = 9.03,	T×CS = 5.20				

* Different lower case letters within rows indicate that they are significant according to LSD Test (P=0.05). * R-W-M = Rice-wheat-mungbean (RWMCS), R-W = Rice-wheat (RWCS)

decomposer community that increase the mineralization and ultimately ammonical N content in soil (Parihar *et al.* 2018). In RWMCS significantly higher (28.2 mg/kg) NO_3^- - N content was recorded under FYM+CR+BF treatment with an increment of 100% over the control, followed by VC+CR+BF (71.6%) > VC+CR ~ VC ~FYM (57.4%) ~FYM+CR (43.3%). Contradictorily, in case of RWCS, VC+CR treatment showed the higher (24.2 mg/kg) NO_3^- - N with the magnitude of 50.3% increment over the control, followed by FYM+CR+BF (37.9%) > FYM (25.5%) > VC+CR+BF ~ FYM+CR ~ VC (12.4%). In the present study, lower NO_3^- - N content was recorded among all the treatments as compared to ammoniacal N, which may be due to the anaerobic conditions of paddy soils. Parihar *et al.* (2018) reported higher mineral N content due to addition of manures, crop residues, reduced tillage and incorporation of legumes in rice-wheat cropping system in India.

Manurial treatments recorded significantly higher mineral N content over control in both the cropping systems (Table 3). Mineral N content varied from 32.9 mg/kg (control) to 68.5 mg/kg (FYM+CR+BF) and 31.8 mg/kg (control) to 60.5 mg/kg (FYM+CR+BF) in RWMCS and RWCS, respectively. Addition of CR+BF along with FYM showed a significant increase in mineral N content in both the cropping systems. Treatment FYM+CR recorded an increment of 16% over FYM alone in RWMCS but contrarily in RWCS, a decrease of 4.2% was recorded with FYM+CR over FYM alone treatment. Organic sources such as VC+CR and VC+CR+BF recorded higher mineral N content over VC alone, in both the cropping systems. Among all the treatments, the amount of mineral N was found significantly higher with FYM+CR+BF treatment in both the cropping systems. Conjoint use of manures, crop residues and biofertilizers provided higher organic substrate for microbial degradation and release of mineral N from complex organic N substrates. Our results were in line with the findings of Porpavai *et al*. (2009) and Kumar *et al*. (2012).

Potential mineralizable N

The combined use of FYM and CR along with BF produced highest (56.4 mg/kg) potential mineralizable N (PMN) content among all the treatments with an increment of 86.4% and 104% over the control in RWMCS and RWCS, respectively (Table 4). Crop residue used with combination of manures recorded no-significant improvement in PMN content and it was decreased 18.8% and 9.6% decreased with FYM+CR over FYM alone under RWMCS and RWCS, respectively. Similarly, treatment VC+CR also showed a decrease of 12.6% in PMN over VC alone in RWMCS, whereas it was at par with VC in RWCS. Incorporation of biofertilizers with manures and crop residues significantly improved the PMN content over manures alone treatments in both the cropping systems (Table 4). Mohanty (2008) also reported that after addition of manures and crop residues in soil due to higher C:N the native N mineralized during the initial period but in subsequent crops these treatments release mineral N. Inclusion of mungbean in RWMCS and subsequent incorporation of its residues in this cropping system provided easily decomposable organic matter to the microbial community which may have resulted in higher PMN as compared to RWCS. The similar findings were reported by Srinivas *et al.* (2006) and Vityakon and Dangthaisong (2005).

Total N

Treatment VC+CR showed 6.1% and 5.5% higher total N content over the control in RWMCS and RWCS, respectively (Table 4). The combined application of manures and crop residues recorded significantly higher total N over other treatments. Application of biofertilizers along with crop residues and manures did not improve total N content in soil. The reduction in total N content was 1.1% and 1.6% in FYM+CR+BF treatment over FYM alone treatment in RWMCS and RWCS, respectively. Similarly, VC+CR+BF recorded 1.4% and 1.6% reduction in total N content as compared to VC alone treatment in both cropping

Table 4 Long-term effect of nutrient supply options on potential mineralizable nitrogen (PMN) and total nitrogen in RWMCS and RWCS after harvest of rice crop in an Inceptisols (after 12 years)

Cropping system	Control	FYM	VC	FYM+CR	VC+CR	FYM+CR+BF	VC+CR+BF	Mean
Potential mineralizable nitrogen (PMN) (mg/kg)								
R-W-M	30.2^{e}	49.6^{b}	48.4^{b}	40.3^{d}	42.3^{cd}	56.4^{a}	54.4^{a}	46.0
R-W	27.6^{e}	49.0^{b}	44.3^{c}	44.3^{c}	44.3^{c}	56.4^{a}	50.4^{b}	45.2
Mean	28.9^{f}	49.3^{bc}	46.4^{cd}	42.3^{e}	43.3^{de}	56.4^{a}	52.4^{b}	
LSD (P=0.05)	CS = NS,	T = 4.0,	CS×T = 6.68,	T×CS = 4.68				
Total nitrogen (kg/ha)								
R-W-M	426^{e}	441^{c}	441^{c}	443^{bc}	452^{a}	436^{d}	435^{d}	439
R-W	422^{f}	442^{bc}	440^{c}	433^{d}	445^{b}	435^{d}	433^{d}	436
Mean	424^{e}	442^{b}	440^{b}	438^{bc}	448^{a}	435^{cd}	434^{d}	
LSD (P=0.05)	CS = NS,	T = 3.81,	CS×T = 5.12,	T×CS = 4.65				

* Different lower case letters within rows indicate that they are significant according to LSD Test (P=0.05). * R-W-M = Rice-wheat-mungbean (RWMCS), R-W = Rice-wheat (RWCS)

systems. Application of biofertilizers with treatment combinations, viz. FYM+CR+BF and VC+CR+BF induced microbial biomass which ultimately enhanced the process of mineralization/immobilization in added organic matter and released nitrogen to the available form. Results of the study were in line with the findings of Sharma *et al.* (2014).

Urease enzyme

Urease enzyme activity ranged from 155.1 µg urea/g soil/h (control) to 230.4 µg urea/g soil/h (VC+CR) and 144.3 µg urea/g soil/h (control) to 233.6 µg urea/g soil/h (FYM+CR) in RWMCS and RWCS, respectively (Fig 1). Significant higher urease activity was recorded with addition of crop residues along with manures and FYM+CR showed an increment of 9.7% and 11.7% over FYM alone in RWMCS and RWCS, respectively. Similarly, VC+CR exhibited 2.3% and 1.8% higher urease activity over VC alone. On the contrary, biofertilizers did not have any significant impact on urease activity in soil and treatments FYM+CR+BF and VC+CR+BF showed lower activity of urease enzyme as compared to manures alone treatments in both the cropping systems (Fig 1). Incorporation of crop residues along with manures caused higher urease activity in present study which was due to higher microbial biomass and improved microorganism activity under organically amended soils. Similar results were observed by Ramesh *et al.* (2006). On the other hand, biofertilizers addition as treatment combinations FYM+CR+BF and VC+CR+BF caused accelerated decay of manures and crop residues by zymogenous group of microbes for a short duration. Zhang *et al.* (2015) reported that rate of nutrients release was more steady with FMY+CR and VC+CR treatments.

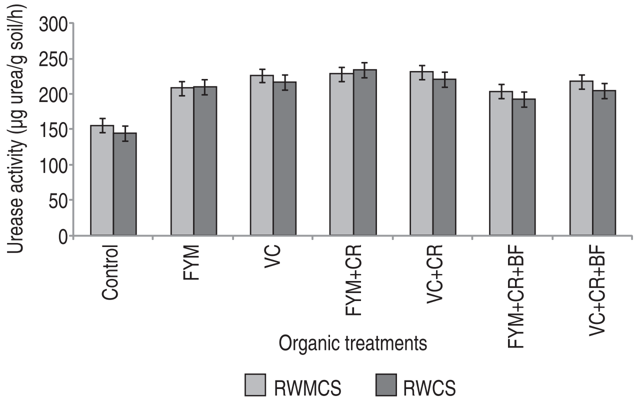

Fig 1 Long-term effect of nutrient supply options on urease enzyme activity (µg urea/g soil/h) in rice-wheat-mungbean and rice-wheat cropping systems after harvest of rice crop in an inceptisol (after 12 years).

Correlation between N pools, urease and rice yield

The correlation coefficients (r) worked out between various nitrogen pools and urease enzyme with rice yield in rice-wheat-mungbean and rice-wheat cropping systems are presented in Table 5 and 6. Available nitrogen content showed a significant and positive correlation with NH_4^+-N (0.521* and 0.461*), NO_3^--N (0.513* and 0.743**), TMN (0.559** and 0.608), PMN (0.662** and 0.761**), total N (0.456* and 0.499*) and rice yield (0.853** and 0.718**) in both the cropping systems. Ammonical nitrogen was found significantly correlated with mineral nitrogen, total N, urease enzyme and rice yield in RWMCS and RWCS at the same time in case of RWCS NH_4-N was significantly correlated with NO_3-N, PMN and MBN. In both the cropping systems NO_3-N concurrently showed significant correlation with mineral nitrogen, total nitrogen and urease enzyme and rice yield, other than this NO_3^--N was positively correlated with PMN and MBN in RWCS (Table 5 and 6). Total mineral nitrogen was found positively correlated with total N, urease enzyme and rice yield (0.663** and 0.690**) in RWMCS and RWCS, respectively. Microbial biomass carbon was significantly correlated with total N, urease enzyme and rice yield (0.582**) in RWMCS, similarly in RWCS MBN was correlated with rice yield (0.468*). Urease enzyme showed a significant correlation with rice yield in both the

Table 5 Correlations between different nitrogen pools and urease enzyme in rice-wheat-mungbean cropping system (RWMCS) after harvest of rice crop in an Inceptisol

Treatment	N	NH_4-N	NO_3-N	MN	PMN	MBN	Total-N	Urease	RY
N	1								
NH_4-N	.521*	1							
NO_3-N	.513*	.432	1						
MN	.559**	.953**	.599**	1					
PMN	.662**	.334	.308	.357	1				
MBN	.347	.393	.219	.406	.803**	1			
Total-N	.456*	.753**	.545*	.783**	.150	.046	1		
Urease	.547*	.873**	.454*	.865**	.422	.382	.770**	1	
RY	.853**	.614**	.463*	.663**	.731**	.468*	.550**	.688**	1

* Significant at P= 0.05 level; ** Significant at P= 0.01 level (RY= Rice yield; MN= Mineralizable N; PMN= Potential mineralizable N; MBN= Microbial biomass N)

Table 6 Correlations between different nitrogen pools and urease enzyme in rice-wheat cropping system (RWCS) after harvest of rice crop in an Inceptisol

Treatment	N	NH_4_N	NO_3_N	TMN	PMN	MBN	Total_N	Urease	RY
N	1								
NH_4_N	.461*	1							
NO_3_N	.743**	.584**	1						
TMN	.608**	.939**	.773**	1					
PMN	.761**	.757**	.870**	.884**	1				
MBN	.504*	.875**	.669**	.884**	.828**	1			
Total_N	.499*	.554**	.454*	.631**	.571**	.561**	1		
Urease	.395	.728**	.496*	.738**	.593**	.551**	.446*	1	
RY	.718**	.645**	.656**	.690**	.775**	.582**	.635**	.470*	1

* Significant at P= 0.05 level; ** Significant at P= 0.01 level (RY= Rice yield; TMN= Total Mineralizable N; PMN= Potential mineralizable N; MBN= Microbial biomass N)

cropping systems (0.688** and 0.470*). Rice yield in both the cropping systems was significantly correlated with all the nitrogen pools as well urease enzyme (Table 5 and 6). All the nitrogen pools and urease enzyme showed significant and positive correlation with rice yield in present study was as a result of induced mineralization of added organic matter which produced higher amount of plant available nitrogen. Mungbean incorporation further showed additional benefits in the form of higher rice yield in RWMCS as compared to RWCS was due to increased N fixation by mungbean as well as incorporation of mungbean residue in the soil.

Conclusion

From the study, it can be concluded that combined application of manures, crop residues and biofertilizers effectively enhanced the microbial activity in soil irrespective of higher mineralization rate of added organic matter and thus increase the content of various N pools. From soil microbial point of view mungbean residue can be used as an easily decomposable high nutrient supply material for succeeding rice crop.

REFERENCES

Bar A R, Baggie I and Sanginga N. 2000. The use of sesbania (*Sesbania rostrata*) and urea in lowland rice production in Sierra Leone. *Agroforestry Systems* **48**(2): 111–8.

Bijay-Singh and Yadvinder-Singh. 2003. Environmental implications of nutrient use and crop managementin rice–wheat cropping system. (*In*) *Nutrient Management for Sustainable Rice–Wheat Cropping System*, pp398–412. Yadvinder-Singh, Bijay-Singh, Nayyar V K and Singh J (Eds) NATP, Indian Council of Agricultural Research, New Delhi and Punjab Agricultural University, Ludhiana.

Bremner J M and Douglas L A. 1971.Inhibition of urease activity in soils. *Soil Biology and Biochemistry* **3**: 297–307.

Bremner J M and van Kessel C. 1990. Extractability of microbial ^{14}C and ^{15}N following addition of variable rates of labelled glucose and $(NH_4)_2SO_4$ to soil. *Soil Biology and Biochemistry* **22**: 707–13.

Cao B, Roelcke M, Dauck H P, Küsters A, Cai G Xand Nieder R. 2006. Nitrogen mineralization in soils under organic farming and conservation tillage as compared to conventional management. *European Journal of Soil Science* **23**: 1–10.

Hira G S. 2009. Water management in northern states and the food security of India. *Journal of Crop Improvement* **23**:136–57.

Jenkinson D S and Powlson D S. 1976. The effect of biological treatments on metabolism in soil fumigation with $CHCl_3$. *Soil Biology and Biochemistry* **8**: 167–77.

Keeney D R and Nelson D W. 1982. Nitrogen inorganic forms. (*In*) *Methods of Soil Analysis*, 2nd edition, pp 643-98. Agronomy Mongraph part 2, American Society of Agronomy, Madison, Wisconsion.

Kumar D. 2014.Influence of nutrient sources and inclusion of mungbean on productivity, soil fertility and profitability of organic rice-wheat cropping system. (*In*) *Proceedings of the 4th ISOFAR Scientific Conference* on *'Building Organic Bridges,* at the Organic World Congress 2014, 13-15 Oct., Istanbul, Turkey.

Kumar M, Yaduvanshi N P S and Singh Y V. 2012. Effects of integrated nutrient management on rice yield, nutrient uptake and soil fertility status in reclaimed sodic soils. *Journal of the Indian Society of Soil Science* **60** (2): 132–7.

Mohanty M. 2008. Nitrogen mineralization in a vertisol from organic manures, green manures and crop residues in relation to their quality. *Agrochimica* **LII** (2): 1–12.

Nagar R K, Goud V V, Kumar R and Ravindra K. 2016. Effect of organic manures and crop residue management on physical, chemical and biological properties of soil under pigeonpea based intercropping system. *International Journal of Farm Sciences* **6** (1): 101–13.

Parihar C M, Jat S L, Singh A K, Datta A, Parihar M D, Varghese E, Bandyopadhyay K K, Nayak H S, Kuri B R and Jat M L. 2018. Changes in carbon pools and biological activities of a sandy loam soil under long-term conservation agriculture and diversified cropping systems. *European Journal of Soil Science* https://doi.org/10.1111/ejss.12680.

Parihar C M, Parihar M D, Sapkota T B, Nanwal R K, Singh A K, Jat S L, Nayak H S, Mahala D M, Singh L K, Kakraliya S K, Stirling C M and Jat M L. 2018. Long-term impact of conservation agriculture and diversified maize rotations on carbon pools and stocks, mineral nitrogen fractions and nitrous oxide fluxes in inceptisol of India. *Science of the Total Environment* **604-641** (1): 1382–92.

Pathak H, Li C, Wassman R and Ladha J K. 2006.Simulation of nitrogen balance in the rice–wheat systems of the Indo-Gangetic plains. *Soil Science Society of America Journal* **70**: 1612–22.

Patra P S, Sinha A C and Mahesh S S. 2011.Yield, nutrient uptake and quality of groundnut (*Arachis hypogaea*) kernels as affected by organic sources of nutrient. *Indian Journal of Argonomy* **56** (3): 237–41.

Porpavai S, Bama K S and Jayaraj T. 2009. Impact of green manuring on the balance sheet of soil nitrogen in rice (*Oryza sativa* L.).*Advances in Plant Sciences* **22** (2): 439–40.

Ramesh P, Singh M, Panwar N R, Singh A B and Ramana S. 2006. Response of pigeonpea varieties to organic manures and their influence on fertility and enzyme activity of soil. *Indian Journal of Agricultural Sciences* **76**: 252–4.

Sharma S, Chander G and Verma T S. 2014. Nitrogen dynamics under long term *Lantana camara* (L.) residue and fertilizer application in a rice-wheat cropping system. *Journal of Plant Nutrition* **37**: 1804–16.

Shibu M E, Van-Keulen H, Leffelaar P A and Aggarwal P K. 2010. Soil carbon balance of rice-based cropping systems of the Indo-Gangetic Plains. *Geoderma* **160** (2): 143–54.

Singh G, Kumar D and Sharma P. 2015. Effect of organics, biofertilizers and crop residue application on soil microbial activity in rice–wheat and rice-wheat mungbean cropping systems in the Indo-Gangetic plains. *Cogent Geoscience* **1**(1): 1085–296.

Srinivas K, Singh H P, Vanaja M, Sreenivasa R A and Sharma K L. 2006. Effect of chemical composition of plant residues on nitrogen mineralization. *Journal of the Indian Society of Soil Science* **54**: 300.

Subbiah B V and Asija G L. 1956. A rapid procedure for the determination of available nitrogen in soils. *Current Science* **25**: 259–60.

Surekha K and Rao K V. 2009.Direct and residual effects of organic sources on rice productivity and soil quality of Vertisols. *Journal of the Indian Society of Soil Science* **57**(1): 53–7.

Verma N, Chaudhary S and Goyal S. 2018. Long term effects of inorganic fertilizers and organic amendments on ammonification and nitrification activity of soils under cotton-wheat cropping system. *International Journal of Current Microbiology and Applied Science* **7** (4): 718–24.

Vityakon P and Dangthaisong N. 2005. Environmental influences on nitrogen transformation of different quality tree litter under submerged and aerobic conditions. A*groforestry Systems* **63**: 225.

Waring S A and Bremner J M. 1964. Ammonium production in soil under waterlogged condition as index of nitrogen availability. *Nature* **201**: 951–2.

Zahoor A B. 2013. Effect of organic and inorganic sources of nutrition on nitrogen and potassium dynamics in soil. M Sc thesis, Punjab Agriculture University, Ludhyana.

Zhang Q, Zhou W, Liang G, Wang X, Sun J, He P and Li L. 2015. Effects of different Organic manures on the biochemical and microbial characteristics of Albic Paddy Soil in a short-term experiment. *PLoS ONE* **10**(4): 1–19.

Zhen Z, Liu H, Wang N, Guo L, Meng J, Ding N, Wu G and Jiang G 2014. Effects of manure compost application on soil microbial community diversity and soil microenvironments in a temperate cropland in China. *PLoS ONE* **9** (10): 1–10.