

Long-term effects of continuous cropping and different nutrient management practices on the distribution of organic nitrogen in soil under rice-wheat system

J. Kaur^{1,2}, J.P. Singh²

¹Sub Divisional Soil and Water Conservation Department, Ludhiana, India

²Department of Soil Science, CCS Haryana Agricultural University, Hisar, India

ABSTRACT

A long-term experiment was used to evaluate the effects of different nutrient management practices on the distribution of soil organic N fractions and their contribution to N nutrition of a rice-wheat system. Continuous rice-wheat cultivation for 13 years without any fertilization was unable to maintain total soil nitrogen level to its original level and resulted in a decrease at 8.3 mg N/kg/year. Likewise, amino acid N, amino sugar N, ammonia N, hydrolysable unknown N, total hydrolysable N and non-hydrolysable N decreased by 37.2, 29.6, 33.7, 10.4, 26.6 and 20.4%, respectively over their initial status. However, application of inorganic fertilizers alone or in combination with organic manures led to a marked increase in total N and its fractions. The increase in total N with the application of farmyard manure, press mud and green manure along with inorganic fertilizer over treatment with inorganic fertilizer alone was 23.1, 34.4 and 7.0%, respectively. These results imply that integrated use of inorganic fertilizers with organic manures represent a sound practice for sustaining N reserves in soil. On average, amino acid-N, amino sugar-N, ammonia-N and hydrolysable unknown-N constituted about 27.9, 10.7, 28.7 and 32.7% of the total hydrolysable-N, respectively.

Keywords: organic manures; burnt rice husk; hydrolysable N fractions; non-hydrolysable N fractions

The Indo-Gangetic plains are located within the tropical and subtropical regions of India and are among the most agriculturally productive areas in the country. The average soil organic carbon content of the soils in the region is, however, low due to intensive cultivation along with prevailing high temperatures and humidity. Rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping is the dominant cropping sequence in the Indo-Gangetic Plains, and occupies nearly 50% of its cropped area. Nitrogen is the major limiting plant nutrient in this region, with N availability being routinely supplemented through application of fertilizers. Soil organic fractions were found to be affected markedly with nitrogen fertilization directly through changing the composition of soil N and indirectly through affecting crop growth (Bird et al. 2002). González-Prieto et al. (1997) reported that most of the added urea-N was transformed

into hydrolysable organic N fractions which were the major sources of plant available N. Wander et al. (2007) observed that the easily hydrolysable fractions, especially amino acid N, amino sugar N, amine N and hydrolysable $\text{NH}_4\text{-N}$ can provide an assessment of soil organic N changes induced by management such as cropping system and inorganic and organic fertilizations.

In rice-rice cropping systems, application of farmyard manure (FYM) with NPK as balanced fertilization resulted in higher labile N pools after a period of 39 years (Bhattacharyya et al. 2013). The contents of amino sugar and amino acid N were lowest with NPK fertilizers and highest with pig manure + NPK fertilizers treatment (Xu et al. 2003). Huang et al. (2009) observed no change in organic N fractions with inorganic fertilization but increased significantly with the application of organic manures with or without inorganic

fertilizers. Understanding the effect of organic amendments on the transformation of organic N into different forms is a prerequisite for managing N inputs in a given soil. The present study was undertaken to quantify temporal changes in soil organic N fractions over time under continuous cropping with differential nutrient management practices.

MATERIAL AND METHODS

Description of experimental site and crop management. A long-term rice-wheat cropping system experiment was established in 1997 at CCS HAU, Regional Rice Research Station, Kaul, Haryana, India situated at 29.6°51'N latitude and 76°40'E longitude. The soil of the experimental field is clay loam, mixed hyperthermic Typic Ustochrept with a pH of 7.8, electrical conductivity 22 mS/m, organic C 4.2 g/kg, cation exchange capacity 129 mmol₊/kg, available N 136 kg/ha, available P 24 kg/ha and available K 305 kg/ha.

The experiment included two crops per year, rice (July–October) and wheat (November–April). Both the crops were cultivated as per agronomic practices recommended under irrigated condition by CCS Haryana Agricultural University, Hisar. The six treatments applied to rice consisted of unfertilized control (T_1); 150 kg N + 32.8 kg P + 62 kg K + 5 kg Zn/ha (T_2); 150 kg N + 32.8 kg P + 62 kg K + 5 kg Zn/ha + FYM (T_3); 150 kg N/ha + press mud (T_4); 150 kg N + 16.4 kg P + 31 kg K + 5 kg Zn/ha + green manure (T_5); 150 kg N + 32.8 kg P + 62 kg K + 5 kg Zn/ha + burnt rice husk (T_6). All the treatments were arranged in a randomized complete design with three replications. Farmyard manure and press mud (by product of suphinated sugar factory) were applied at 15 and 7.5 t/ha on fresh weight basis or 7.5 and 6.0 t/ha on dry weight basis, respectively. The burnt rice husk was applied at 7.5 t/ha on dry weight basis. The *Sesbania* green manure was grown in situ for 45 days in the plots of T_5 treatment and fresh biomass amounting to 20 t/ha (containing 750 g water/kg) was incorporated into soil two days before transplanting of rice. On an average, FYM, press mud, green manure and burnt rice husk contained 1.10, 2.22, 1.98 and 0.02% N on dry weight basis, respectively. The organic carbon values for the corresponding organic amendments were 26.8, 40.6, 38.8 and 0.46%, respectively.

Sample collection and analysis. Subsamples of grain and straw of both the crops were dried in hot air oven at 65°C for 3 days. Samples were ground in a Willey mill and stored in paper bags for further chemical analysis. Dried and ground material was digested in a diacid mixture of H₂SO₄ and HClO₄ (4:1, v/v). Grain and straw digests were analyzed for N using standard analytical methods (Jackson 1973). The surface (0–15 cm) soil samples from each treatment were taken at wheat harvest during April 2010 using a 5 cm diameter auger. Organic N fractions viz. total hydrolysable-N, amino acid-N, amino sugar-N, hydrolysable unknown-N and non-hydrolysable-N were determined by the method given by Stevenson (1996).

Statistical analysis. The data were subjected to the randomized block design analysis of variance and the treatment means were compared using the least significant difference at the 5% level of probability.

RESULTS AND DISCUSSION

Nitrogen depletion. Cultivation of rice-wheat continuously for 13 years without any fertilization (control) decreased all the four hydrolysable-N fractions (amino acid-N (AAN), amino sugar-N (ASN), ammonia-N (AMMN), hydrolysable unknown-N (HUN) significantly over their initial status (Table 1). However, the magnitude of decrease varied markedly depending upon the hydrolysable N form and amounted to 37.2, 29.6, 33.7 and 10.4% depletion in AAN, ASN, AMMN and HUN, respectively over their initial status in surface soil (Figure 1). The greater depletion of hydrolysable N forms under continuous cropping without manuring compared to adjacent fallow was also reported by Subba Rao and Ghosh (1980). The extent of depletion in total hydrolysable (THN) N fraction was more (26.6%) than that in non-hydrolysable N (NHN) fraction (20.4%) over their initial status due to continuous cropping (Figure 1). The relatively greater decrease in THN supports the observation that hydrolysable N is more vulnerable to mineralization and could be considered as a major source of potentially available N for plants than non-hydrolysable N (Ferguson and Gorby 1971, González-Prieto et al. 1997). Thirteen years of rice-wheat cropping without any fertilizers or organic amendments (T_1) significantly lowered the initial status of soil N from 432 to 324 mg/kg resulting in 25.1% depletion in surface

Table 1. Effect of different treatments on N content of organic nitrogen fractions

No.	Different N forms (mg/kg soil)						Total N (mg/kg)
	AAN	ASN	AMMN	HUN	THN	NHN	
T ₁	59	19	61	95	234	90	324
T ₂	104	37	106	126	373	124	497
T ₃	134	54	139	138	465	147	612
T ₄	140	62	152	147	501	167	668
T ₅	116	45	112	134	407	130	532
T ₆	105	36	105	129	375	125	500
Initial	94	27	92	106	319	113	432
LSD _{0.05}	16	10	28	12	52	18	58

AAN – amino acid N; ASN – amino sugar N; AMMN – ammonia N; HUN – hydrolysable unknown N; THN – total hydrolysable N; NHN – non-hydrolysable N

soil (Table 1 and Figure 1). Bhandari et al. (2002) also found a decline in total soil N with continuous rice-wheat cropping in unfertilized plots.

Nitrogen build-up. Contrary to the decrease in unfertilized treatment, all four hydrolysable N fractions and non hydrolysable N registered a significant increase due to inorganic fertilizers or organic amended treatments over their respective initial status (Table 1). The magnitude of increase in all the hydrolysable N fractions over their initial level was more with combined application of inorganic fertilizers and organic manures as compared to inorganic fertilizers alone. Huang et al. (2009) concluded that organic manure had a more significant effect on soil N than inorganic fertilizer alone. The extent of N build-up in hydrolysable N fractions varied with the N fractions and organic manure. There was a build-up of 28.8, 34.6 and 11.6% in AAN under FYM, press mud and green manure amended treatment, respectively over inorganic fertilizer treatment ($N_{150}P_{32.8}K_{62}Zn_5$) (Figure 2a). Farmyard manure, press mud and green manure incorporation along with inorganic fertilizers increased the ASN by 45.9, 67.6 and 21.6%, respectively over inorganic fertilizer treatment (Figure 2b). Application of inorganic fertilizers in combination with organic manures (FYM, press mud and green manure) resulted in build-up of AMMN over $N_{150}P_{32.8}K_{62}Zn_5$ (T₂). However, the effect of FYM and press mud was more pronounced as compared to green manure treatment (Figure 2c). The HUN increased by 9.5, 16.7 and 6.3% over treatment with inorganic fertilizer alone (T₂) due to FYM (T₃), press mud, (T₄) and green manure

treatments (T₅), respectively (Figure 2d). Santhy et al. (1998) also found a positive effect on the accumulation of organic N fractions in soil with the combined application of FYM and inorganic fertilizers. Similarly, Sharma and Verma (2001) found an increase in different forms of organic N with continuous application of both inorganic fertilizers and green manuring.

The amounts of THN increased by 24.7, 34.3 and 9.1% in FYM, press mud and green manure plus inorganic fertilizers treatment, respectively, over that obtained in treatment with inorganic fertilizers alone (Figure 3a). The increase in NHN in the corresponding organic amendments was 18.5, 34.7 and 4.8%, respectively (Figure 3b). Kamat et

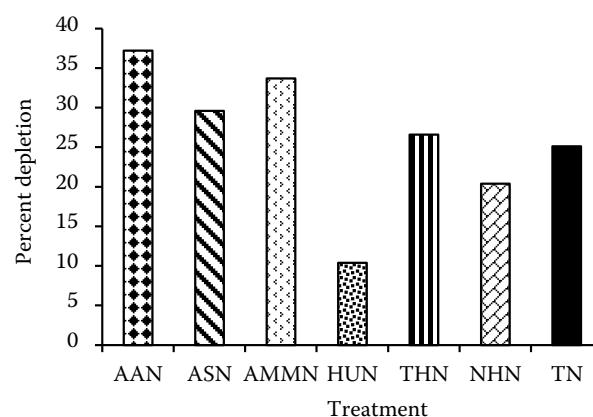


Figure 1. Effect of continuous cropping for 13 years without any N fertilization on the changes in N fractions and total N over their initial status. AAN – amino acid N; ASN – amino sugar N; AMMN – ammonia N; HUN – hydrolysable unknown N; THN – total hydrolysable N; NHN – non-hydrolysable N; TN – total N

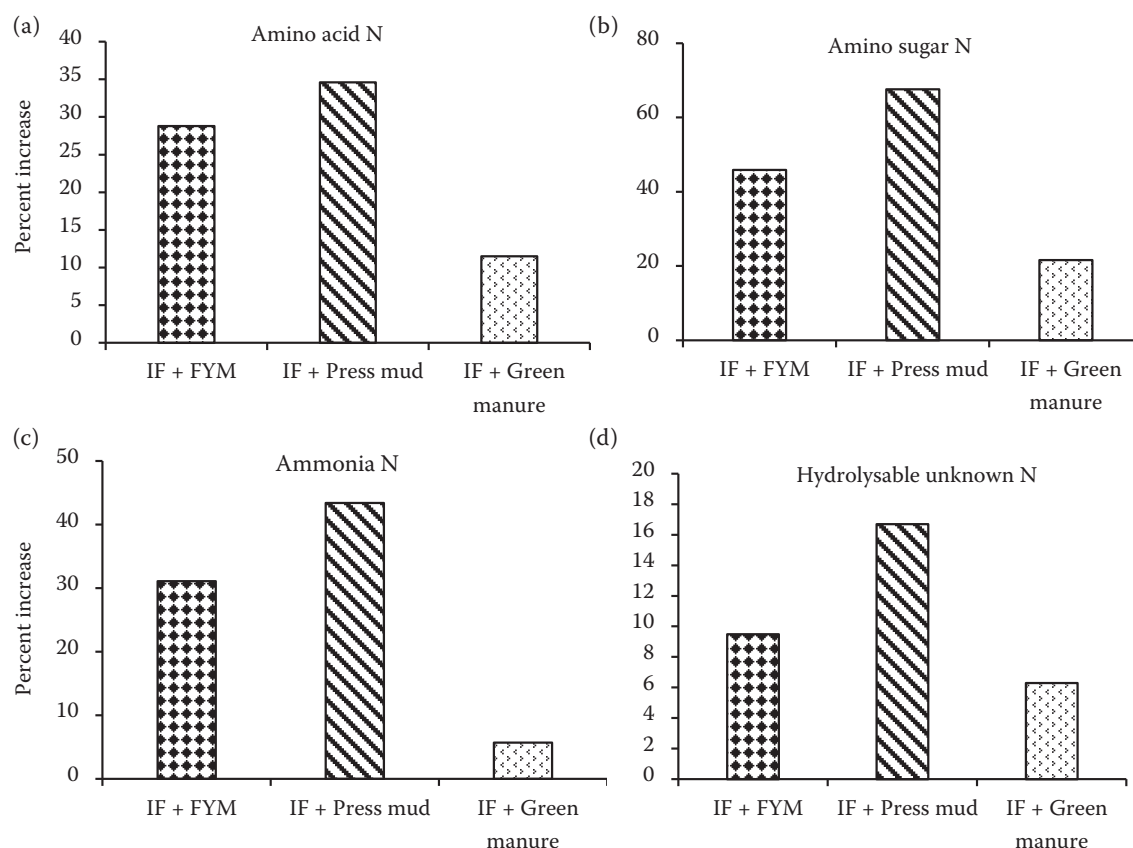


Figure 2. Effect of different organic amendments on the changes in amino acid N (a), amino sugar N (b), ammonia N (c) and hydrolysable unknown N (d) over inorganic fertilizer (NPKZn) treatment after 13 cycles of rice-wheat cropping. IF – inorganic fertilizers

al. (1982) demonstrated that addition of organic manures in the form of FYM enhanced the contents of both hydrolysable and non-hydrolysable-N in the soil. The effect of mineral fertilizers and manures on the interplay between different fractions of organic N is a prerequisite for managing N inputs in a given soil. The changes in these fractions provided an assessment that additional N provided by organic fertilization was primarily concentrated into hydrolysable organic N fractions (AAN, ASN and AMMN) which are considered the major source of plant available N. A large increase in THN and NHN with combined application of manures and mineral fertilizers compared to mineral fertilizers treatment is primarily due to the mineralization and release of N contained in the manures (FYM, press mud and green manure) on their decomposition which was facilitated by the more favourable environment provided by the former compared with the latter.

Addition of inorganic fertilizers alone or their combined use with organic manures continuously for 13 years increased the total N significantly

over control. The increase in total N ranged from 13.3 mg/kg/year in the mineral fertilizer treatment (T_2) to 26.5 mg/kg/year in the press mud amended (T_4) treatment. The total N content was higher by 23.1, 34.3 and 7.0% in FYM, press mud and green manure treatments, respectively compared with the inorganic fertilizer (Figure 3c). It is worthwhile noting that despite the higher input of N by green manure than by FYM or press mud, the total soil nitrogen was higher by 15.0% and 25.6% in FYM press mud amended treatments, respectively over the green manure treatment (T_2). This could be attributed to much slower release of N from FYM or press mud than from green manure, resulting in smaller losses of N and building of a higher concentration of total N.

Relative proportion of hydrolysable N fractions. Amongst various hydrolysable-N fractions, the lowest content of N was recorded in amino sugar-N and highest in hydrolysable unknown-N. The hydrolysable unknown-N was the most dominant fraction of total hydrolysable-N, regardless of treatments applied. On average, amino acid-N,

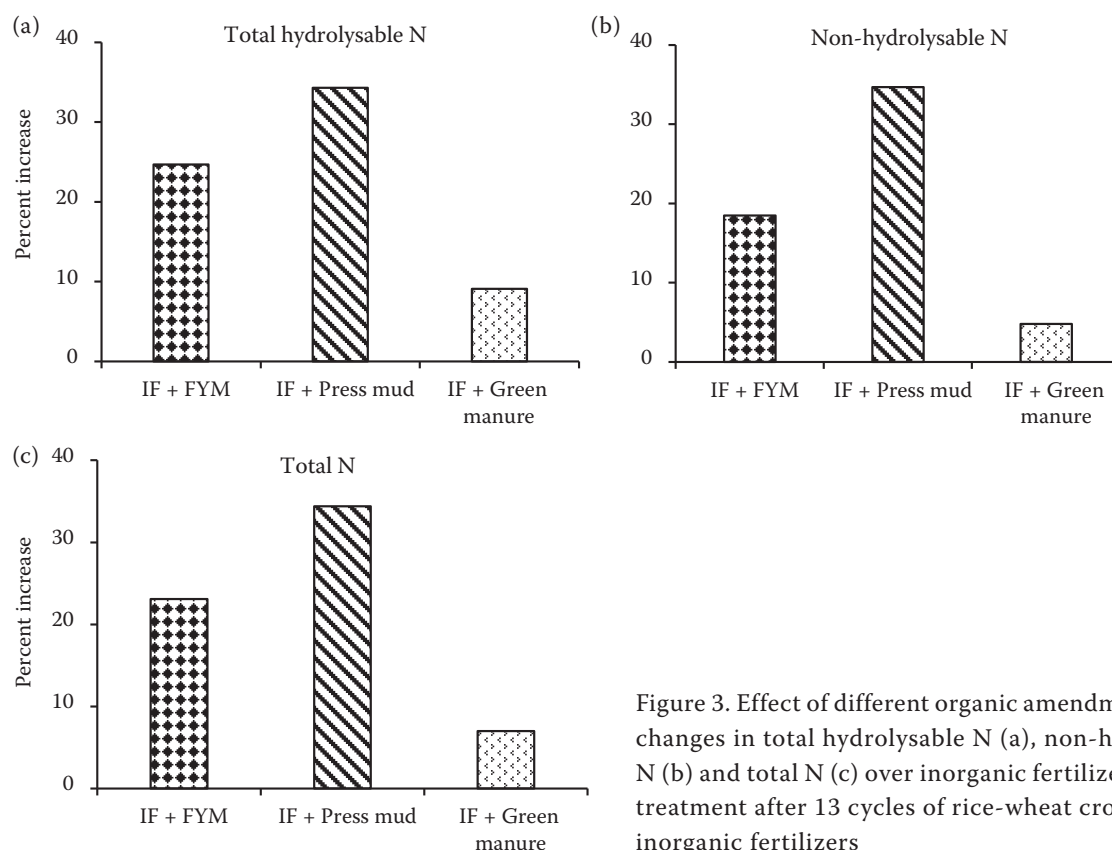


Figure 3. Effect of different organic amendments on the changes in total hydrolysable N (a), non-hydrolysable N (b) and total N (c) over inorganic fertilizer (NPKZn) treatment after 13 cycles of rice-wheat cropping. IF – inorganic fertilizers

amino sugar-N, ammonia-N and hydrolysable unknown N constituted ~ 27.9, 10.7, 28.7 and 32.7% of total hydrolysable-N, respectively (Table 1). As was reported by Pathak and Sarkar (1995), the major portion of total hydrolysable N was found in hydrolysable unknown N fraction.

Relationship of crop yield and N uptake with organic N fractions. Results of simple correlation analysis (Table 2) showed that all the organic N fractions except amino sugar-N and non-hydrolysable N fractions were significantly correlated with grain yield and N uptake of rice and wheat crops. Reddy

et al. (2003) reported that amino acid-N was highly correlated to mineralizable N and the least with the non-hydrolysable. The significantly highest correlation of hydrolysable unknown N and non-significant correlation of non-hydrolysable N with grain yield and N uptake of rice and wheat crops imply that hydrolysable N fractions are the potential contributors towards plant available N. Amino acid N, amino sugar N and hydrolysable $\text{NH}_4\text{-N}$ were also found to be the most active N pools and the major source of N potentially available to plants (Khan et al. 2001, Sharma and Verma 2001).

Table 2. Correlation of organic N with grain yield and N uptake of rice and wheat crops

N fractions	Rice grain yield	Rice N uptake	Wheat grain yield	Wheat N uptake
Amino acid-N	0.868*	0.883*	0.892*	0.889*
Amino sugar-N	0.755	0.777	0.789	0.786
Ammonia-N	0.805*	0.822*	0.833*	0.829*
HUN	0.908*	0.923**	0.932**	0.931**
THN	0.842*	0.859*	0.870*	0.867*
NHN	0.769	0.791	0.803	0.801

* $P = 0.05$; ** $P = 0.01$; HUN – hydrolysable unknown N; THN – total hydrolysable N; NHN – non-hydrolysable N

REFERENCES

- Bhandari A.L., Ladha J.K., Pathak H., Padre A.T., Dawe D., Gupta R.K. (2002): Yield and soil nutrient changes in a long-term rice-wheat rotation in India. *Soil Science Society of America Journal*, 66: 162–170.
- Bhattacharyya P., Nayak A.K., Mohanty S., Tripathi R., Shahid M., Kumar A., Raja R., Panda B.B., Roy K.S., Neogi S., Dash P.K., Shukla A.K., Rao K.S. (2013): Greenhouse gas emission in relation to labile soil C, N pools and functional microbial diversity as influenced by 39 years long-term fertilizer management in tropical rice. *Soil and Tillage Research*, 129: 93–105.
- Bird J.A., Van Kessel C., Horwath W.R. (2002): Nitrogen dynamics in humic fractions under alternative straw management in temperate rice. *Soil Science Society of America Journal*, 66: 478–488.
- Ferguson W.S., Gorby B.J. (1971): Effect of various periods of seed-down to alfalfa and brome grass on soil nitrogen. *Canadian Journal of Soil Science*, 51: 65–73.
- González-Prieto S.J., Jocteur-Monrozier L., Hétier J.M., Carballas T. (1997): Changes in the soil organic N fractions of tropical Alfisol fertilized with ^{15}N -urea and cropped to maize or pasture. *Plant and Soil*, 195: 151–160.
- Huang Q.R., Hu F., Huang S., Li H.X., Yuan Y.H., Pan G.X., Zhang W.J. (2009): Effect of long-term fertilization on organic carbon and nitrogen in a subtropical paddy soil. *Pedosphere*, 19: 727–734.
- Jackson M.L. (1973): *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd., New Delhi.
- Kamat V.N., Mahankar S.T., Puranik R.B., Kohadkar W.S., Joshi R.P. (1982): Effect of long-term application of FYM and NPK on organic nitrogen fractions in Vertisol. *Journal of the Indian Society of Soil Science*, 30: 381–383.
- Khan S.A., Mulvaney R.L., Hoeft R.G. (2001): A simple soil test for detecting sites that are nonresponsive to nitrogen fertilization. *Soil Science Society of America Journal*, 65: 1751–1760.
- Pathak H., Sarkar M.C. (1995): Transformation of soil organic nitrogen with manuring under rice-wheat cropping system. *Fertilizer News*, 40: 33–35.
- Reddy K.S., Singh M., Tripathi A.K., Singh M., Saha M.N. (2003): Changes in amount of organic and inorganic fractions of nitrogen in an Eutrochrept soil after long-term cropping with different fertilizer and organic manure inputs. *Journal of Plant Nutrition and Soil Science*, 166: 232–238.
- Santhy P., Jaysreesankar S., Muthuvel P., Selvi D. (1998): Long term fertilizers experiments status of N, P and K fractions in soil. *Journal of the Indian Society of Soil Science*, 46: 395–398.
- Sharma R.P., Verma T.S. (2001): Dynamics of nitrogen fractions with long-term addition of *Lantana camara* biomass in rice-wheat cropping sequence. *Journal of the Indian Society of Soil Science*, 49: 407–412.
- Stevenson F.J. (1996): Nitrogen-organic forms. In: Sparks D.L., Page A.L., Helmke P.A., Loeppert R.H., Soltanpour P.N., Tabatabai M.A., Johnston C.T., Summer M.E. (eds.): *Methods of Soil Analysis. Part 3. Chemical Methods*. Soil Science Society of America and American Society of Agronomy, Madison, 1185–1200.
- Subba Rao A., Ghosh A.B. (1980): Effect of continuous cropping and fertilizer use on the organic nitrogen fractions in a Typic Ustochrept soil. *Plant and Soil*, 62: 377–383.
- Wander M.M., Yun W., Goldstein W.A., Aref S., Khan S.A. (2007): Organic N and particulate organic matter fractions in organic and conventional farming systems with a history of manure application. *Plant and Soil*, 291: 311–321.
- Xu Y.C., Shen Q.R., Ran W. (2003): Content and distribution of forms of organic N in soil and particle size fractions after long-term fertilization. *Chemosphere*, 50: 739–745.

Received on June 18, 2013

Accepted on January 25, 2014

Corresponding author:

Prof. Jai Pal Singh, Ph.D., CCS Haryana Agricultural University, Department of Soil Science,
Hisar, 125 004 Haryana, India
e-mail: jps6556@gmail.com