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RESEARCH ARTICLE :

Effect of long term fertilization on soil nitrogen dynamics and balance in an irrigated inceptisol under finger millet-hybrid maize cropping sequence

PRAGYAN PARAMITA ROUT, N. CHANDRASEKARAN, K. RULMOZHISELVAN AND DHANESHWAR PADHAN

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SUMMARY : A field study was conducted in the year 2013-14 at TNAU, Coimbatore as a part of ongoing AICRP-LTFE to assess the effect of long-term fertilization on soil nitrogen (N) dynamics, N uptake and yield of hybrid maize under finger millet-hybrid maize cropping sequence. There were ten treatments each replicated four times in Randomized Block Design *viz.*, T_1 - 50 % NPK, T_2 - 100% NPK, T_3 - 150% NPK, T_4 - 100% NPK + hand weeding, T_5 - 100%NPK + $ZnSO_4$, T_6 - 100% NP, T_7 - 100% N alone, T_8 - 100% NPK + FYM, T_9 - 100% NPK (-S) and T_{10} - Absolute control. Results showed a significant higher value of available N in soil under 100% NPK+FYM treatment irrespective of critical growth stages of hybrid maize. Among N fractions, inorganic fractions *viz.*, NH_4-N, NO_3-N and fixed NH_4-N were significantly affected by the incremental addition of N. Integration of organics with inorganic fertilizers had a complementary effect on all fractions of nitrogen. Grain and straw yield of hybrid maize were significantly higher under 100% NPK + FYM treatment which showed a yield increase of 12.6 % over 100% NPK alone. Hence, integrated nutrient management (100% NPK+ 10 t FYM ha^{-1}) has maximized yield of hybrid maize and improved the soil N pools by facilitating N transformation in soil.

KEY WORDS :
FYM, Hybrid maize, Integrated nutrient management, Nitrogen dynamics, N fractions

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Author for correspondence :
PRAGYAN PARAMITA ROUT
Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, COIMBATORE (T.N.) INDIA
Email: parimita.pragyan 00@gmail.com

BACKGROUND AND OBJECTIVES

Nitrogen is one of the major nutrients affecting soil fertility (Heumann *et al.*, 2002). The soil nitrogen forms available to plants are generally low, and range from 1 to 5% (Bednarek and Tkaczyk, 2002). Inorganic N, mineralizable N and microbial biomass N are active N pools, affecting short-term biological cycling of soil N (Duxbury *et al.*, 1991) and N availability. Inorganic N can be directly absorbed by plants, whereas microbial biomass N is a sensitive indicator of changes in soil quality induced by management practices, and contains the largest portion of the biologically active N in soil (Deng *et al.*, 2000). Organic nitrogen is usually bound to clay and humus particles known as soil colloids, forming stable complexes whose availability to crops depends mainly on soil biological activity and fertilizer type (Smith and Poul, 1990 and Schmidt *et al.*, 2000).

The content of various forms of N in soil depends primarily on the processes of immobilization and organic matter mineralization. Mineralization of soil organic N to inorganic N includes ammonification and nitrification with former providing readily available N for plant uptake and substrates for latter (Weier and MacRae, 1993) and latter influencing plant N uptake and N losses from soil-plant system through leaching and conversion to gaseous N compounds (Yang *et al.*, 2008). In terrestrial ecosystems, N availability is often a limiting factor that controls primary production and C storage (Kruse *et al.*, 2004). A gradual depletion of available nitrogen pool is observed in agricultural ecosystems as a consequence of ammonium and nitrate ion uptake by crops and soil microbes under intensive cropping system (Deng *et al.*, 2000).

In the context of soil fertility management, long-term fertilizer experiments (LTFEs) are valuable assets for determining yield trends, changes in nutrient dynamics and balances, predicting soil carrying capacity, assessing soil quality and system sustainability (Blaise *et al.*, 2005). The study on N dynamics and quantifying N balance under intensive cropping system enables optimal N fertilization management practice for reducing environmental risks and improving N supplying capacity of soil. With this background, a field study was conducted to assess the effect of long term fertilization on soil N dynamics and N uptake by hybrid maize in an irrigated inceptisol under finger millet-hybrid maize cropping sequence.

RESOURCES AND METHODS

Site description

A field study was conducted in the in the year 2013-2014 as a part of an ongoing All India Co-ordinated Research Project on Long-term Fertilizer Experiment (AICRP-LTFE) with finger millet-hybrid maize cropping sequence which was initiated during 1972 at Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu with hybrid maize as test crop. The soil of experimental site belongs to order-*Inceptisol*, having calcareous mixed black soil with sandy clay loam texture and comes under *Vertic ustropept*. The experimental soil was recorded to have an initial pH of 8.20, electrical conductivity (EC) of 0.20 dSm^{-1}, organic carbon (OC) of 3.0 g kg^{-1}, available N 178 kg ha^{-1}, available P 11 kg ha^{-1}, available K 810 kg ha^{-1}.

Treatment details :

There were ten treatments each replicated four times in Randomized Block Design *viz.*, T_1 - 50 % NPK, T_2-100% NPK, T_3- 150% NPK, T_4 - 100% NPK + hand weeding, T_5 - 100% NPK + $ZnSO_4$ @ of 25 kg $ZnSO_4$ ha^{-1}, T_6 - 100% NP, T_7 - 100% N alone, T_8 - 100% NPK+ FYM @ 10 t ha^{-1}, T_9 - 100% NPK (-S) and T_{10} - Absolute control. The hybrid maize variety *viz.*, CO-6 was used as a test crop in *Rabi* season being 101th crop in finger millet-hybrid maize cropping sequence. The recommended dose of N, P_2O_5 and K_2O based on initial soil test was 250:75:75 kg ha^{-1}. The sources of N, P and K used were urea, single super phosphate (SSP) and muriate of potash. In sulphur free treatment (T_9), diammonium phosphate (DAP) was used instead of SSP as a source of P. All the treatments except T_4 were sprayed with herbicide Atrazine WP at 500 g ha^{-1} at 3rd days after sowing for controlling weeds.

Soil and plant analysis :

Composite surface (0-15 cm) soil samples were collected from each plot during cropping period (at three critical growth stages of hybrid maize *viz.*, knee high, tasselling, milky and harvest). The total N and available N were estimated using macro kjeldahl method (Piper, 1966) and Alkaline $KMnO_4$ oxidation method (Subbiah and Asija, 1956), respectively. Among soil N fractions, inorganic N fraction was quantified using 2M KCl extraction (Bremner, 1965) wherein organic N fractions were estimated by 6N HCl extraction method (Bremner, 1965).

Besides, plant samples were analysed for N content using di-acid extraction followed by micro kjeldahl distillation method (Jackson, 1973). Finally both straw and grain yield of hybrid maize was recorded at harvest stage. The data on analysis of soil and plant samples, dry matter production, yield, N uptake and content of hybrid maize were subjected to analysis of variance (ANOVA) and correlation statistics as suggested by Panse and Sukhatme (1985). For statistical analysis of data, Microsoft Excel (Microsoft Corporation, USA) and Agres window version 7.0 packages were used.

OBSERVATIONS AND ANALYSIS

The results obtained from the present study as well as discussions have been summarized under following heads:

Available nitrogen :

The results of the available N status (Fig. 1) in soil showed a declining trend with the advancement of growth stages of hybrid maize irrespective of the treatments imposed. This might be attributed to the utilisation of soil native N by crop and loss of N due to immobilization by microbes and volatilization (Thilagavathi and Subbiah, 2006). Among treatments, the combined application of FYM with 100% NPK (T_8) recorded highest soil available nitrogen as compared to the plots where only 100% NPK was applied. Such increase in available N might be due to multiplication of microbes leading to mineralization and enhanced conversion of organically bound N into inorganic forms thus, made available to crops (Mairan *et al.*, 2005). Organic manures besides being a store house of nutrients also prevents the loss of nitrate-N by leaching. The above results are in conformity with the findings of Subhendu and Adikari (2005).

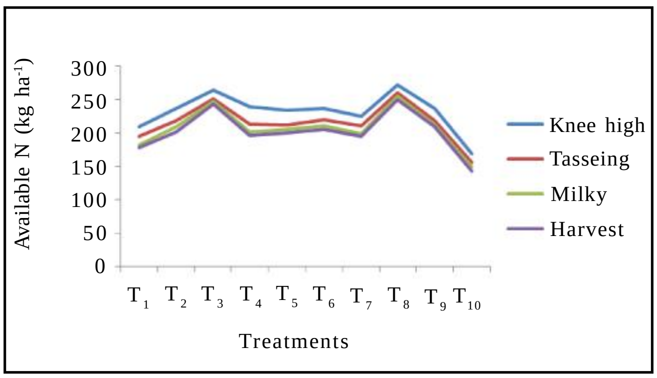

Fig. 1 : Effect of long-term fertilization on soil available N status cropped with hybrid maize

Intensive cropping decreased the soil available N status in the control plots to a much lower magnitude as compared to that of fertilized and manured plots. The decrease in available N status in the absolute control might be due to the continuous removal of soil N in the absence of external supply of N through fertilizers and manures. Sinha *et al.* (1997) and Parmar and Sharma (2002) reported similar finding of depletion of available N due to continuous cropping without fertilization. The increase in soil available nitrogen was observed with increasing levels of nitrogenous fertilizers from 50 to 150% NPK which may probably due to N fertilizers that contributes directly towards the available nitrogen pool (Brar and Brar, 2002).

Total nitrogen :

The results on total N content (Table 1) showed that among fertilizer treatments imposed, the application of 100% NPK + FYM (T_8) recorded highest magnitude of total N. Such build-up of soil reserve N might be due to the contribution from 10 t of FYM would have supplied an additional dose of about 50 kg N ha^{-1} per annum since the average N content of FYM is around 0.5 per cent. Besides, the N released was reported to get incorporated in the soil humic material thereby accounting for build-up in total N content of soil.

In addition to direct effect of nutrient addition, organic manure also reported to contribute by chelating soil N and thereby conserving it from losses (Santhy *et al.*, 2000). Sharma and Saxena (1994) in their study on silty clay loam soil also reported that the application of FYM at 12.5 t ha^{-1} increased the total N status of soil from 2.8 kg ha^{-1} in control to 3.3 kg ha^{-1} in FYM applied treatment.

With graded levels of fertilizer input, the total N in soil was found to increase. The increases were marked at lower levels (100% NPK) as compared to the high input level (150% NPK). In control plot there was a drastic reduction in total N content to that of optimal NPK. Evidently addition of optimal nutrient had increased the return of crop residues to soil for recycling soil N and a definite decline in N reserve was found in control plots during crop growth. Bhandari *et al.* (2002) also found a decline in total soil N with continuous rice-wheat cropping in unfertilized plots.

Nitrogen fractions:

Inorganic N fractions:

Nitrate-N:

Nitrate-N usually forms 0.7 to 2.7 per cent of total N. As the experimental soil was well-drained and arable in nature, the magnitude of NO_3-N content was higher than NH_4-N content in post-harvest soil of hybrid maize (Table 1). It constituted about 60 to 70% of the total inorganic nitrogen.

The combined application of 100% NPK+ FYM ensured higher NO_3-N content of soil as compared to control which could be due to increased microbial activity and resultant enhanced nitrification process (Khankhane and Yadav, 2000). Increase in the rate of inorganic N added also enhanced the nitrate N possibly due to the conversion of applied inorganic N via nitrification process (Yadav and Singh, 1991). Higher content of NO_3-N in soil as a result of increased N addition has also been reported by Brar and Brar (2002).

Exchangeable NH_4 - N :

The results on exchangeable NH_4-N status (Table 1) showed that its magnitude in soil increased significantly with increase in the levels of NPK fertilizers upto 150% due to direct result of higher amount of applied N and also due to increased organic C content (Prasad and Rokima, 1991). Application of whole of N through urea resulted in a rapid conversion to NH_4-N, which was further enhanced in the presence of optimum amount of P and K. This explains the steep increase in NH_4-N content of soil. Lower exchangeable NH_4-N content was observed in treatments receiving sub optimal dose of fertilizers (50% NPK) as the formation of NH_4-N in soil declined when the amount of N added through fertilizers was reduced from its optimum dose (Duraisami *et al.*, 2001). The NH_4-N decreased substantially in control and in the plots where there was no external addition of N sources. This supports the earlier results of Corbeels *et al.* (1999).

However, a much higher content of NH_4-N was observed when NPK fertilizers were combined with 10 t FYM ha^{-1}. This may be due to application of FYM that resulted in a higher microbial activity and enhanced mineralization, resulting in the accumulation of NH_4-N in the soil. A positive effect of 25% N substitution through FYM was also observed in terms of improved NH_4-N content of the soil (Santhy *et al.*, 2001).The exchangeable NH_4-N content in other treatments *viz.*,100% NPK+HW, 100% NPK+$ZnSO_4$, 100% NP, 100% N, 100% NPK (S free) did not vary significantly since the same quantity of N was added through different sources and the accompanying management practices found to have no effect on exchangeable NH_4-N.

Fixed ammoniacal - N:

The results on effect of fertilizer treatment imposed on fixed NH_4-N (Table 2) revealed a similar trend as noticed in case of exchangeable NH_4-N and NO_3-N. The fixed NH_4-N was found to be highest in treatment T_8 that involves the integrated use of FYM along with inorganic fertilizers (100% NPK). This might be attributed to fixation of excess NH_4-N in the binding sites of organic manure that in serves as short-term storage pool of nitrogen and may be available to crop when N pools declines in soil solution to maintain equilibrium (Sadej and Przekwas, 2008). Besides, the amount of fixed NH_4-N is mostly related to the type and amount of clay minerals being higher in soil rich in micaceous clay minerals (Stevenson, 1982).

The graded fertilizer levels from 50 to 100% NPK also increased the fixed NH_4-N in soil. This might be due to increasing level of N applied to soil that in turn caused the fixation of NH_4-N in clay interlayer lattice (Schulten and Schnitzer, 1998). The lowest fixed NH_4-N was observed in control which might be due to the fact that continuous cropping without N fertilization resulted in release of fixed NH_4-N from clay lattice to meet crop N demand there by causing depletion of fixed

Table 1 : Effect of long-term fertilization on inorganic N fractions (mg kg^{-1}) in post-harvest soil of hybrid maize

Treatments		Total N	Nitrate-N	Exchangeable NH_4-N	Fixed NH_4-N
T_1	50 % NPK	582.3	9.6	5.1	22.9
T_2	100 % NPK	627.0	11.2	6.3	26.3
T_3	150 % NPK	674.3	13.1	7.1	29.4
T_4	100 % NPK + HW	624.4	11.5	6.6	26.7
T_5	100 % NPK + Zn	621.1	11.6	6.4	26.1
T_6	100 % NP	624.5	11.7	6.2	26.6
T_7	100 % N	629.2	11.4	6.5	26.1
T_8	100 % NPK + FYM	681.5	13.9	8.2	29.9
T_9	100 % NPK (- S)	533.6	11.4	6.6	26.4
T_{10}	Control	370.7	8.2	3.2	18.6
	S.E.±	9.64	0.30	0.14	0.50
	C.D. (P=0.05)	19.08	0.58	0.27	1.02

NH_4-N. Similar findings were reported by Jayashree Sankar (1994). Other management practices did not influence the magnitude of fixed NH_4-N as all imposed treatments, had received equal amount of fertilizer N dose.

Organic N fractions :

The results on organic N fractions (Table 2) revealed that among the organic N fractions analysed, total hydrolysable N constituted more than 75 per cent of total N confirming the general trend that major portion of soil N of about 98% is in organic form (Tisdale *et al.*, 1985). Among total hydrolysable N, hydrolysable NH_4-N, amino acid N and unidentified hydrolysable N fractions constituted the dominant fractions wherein hexosamine N was least in magnitude among various organic N fractions evaluated. Kher and Minhas (1992) also stated that total hydrolysable N contributed 75.8 to 82.9 per cent of total N after 13 years of continuous cropping.

The investigation on soil organic N fractions in maize revealed that a considerable build up in all the fractions *viz.*, total hydrolysable N, hydrolysable NH_4-N, amino acid N, hexosamine N, unidentified hydrolysable N, and unidentified hydrolysable N. 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.

The FYM in conjunction with NPK increased the all fractions of organic N in soil over optimal NPK treatment. This may be due to inherent capacity of organic matter in augmenting the rate of added fertilizer N to complexing that would account for higher organic N. In rice-rice cropping systems, application of FYM with NPK as balanced fertilization resulted in higher organic N 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.

The control plot recorded the lowest amount of organic N. Kaur and Singh (2014) reported that cultivation of rice-wheat continuously for 13 years without any fertilization (control) decreased all the four hydrolysable N fractions amino acid N, amino sugar N, ammonia N, unidentified hydrolysable N significantly over their ini- tial status.

It has also been recorded that there is a greater depletion of hydrolysable N when compared to non-hydrolysable fraction in the post-harvest soil of maize. The greater depletion of hydrolysable N fractions under continuous cropping without manuring was also reported by Sammy Reddy *et al*. (2003). The extent of depletion in total hydrolysable N fraction was more than that in non-hydrolysable N fraction over initial status due to continuous cropping. The relatively greater decrease in total hydrolysable N supports the observation that hydrolysable N is more vul- nerable to mineralization and

Table 2 : Effect of long-term fertilization on organic N fractions (mg kg^{-1}) in post-harvest soil of hybrid maize

Treatments	Total hydrolysable N	Hydrolysable NH_4-N	Hexosamine N	Amino acid N	Non-hydrolysable N
T_1	251.5	106.3	23.9	79.0	101.1
T_2	269.0	125.5	27.5	94.3	181.2
T_3	291.4	131.7	28.7	99.5	212.3
T_4	265.7	122.3	27.2	93.8	183.4
T_5	263.6	123.4	26.9	91.2	184.7
T_6	269.9	117.4	25.9	87.1	178.1
T_7	264.6	112.9	25.1	84.9	128.5
T_8	311.1	136.2	29.3	102.7	217.9
T_9	263.2	121.1	26.8	91.7	171.8
T_{10}	213.3	95.3	21.4	71.2	74.6
S.E.±	5.59	2.4	0.55	2.08	16.57
C.D. (P=0.05)	11.08	5.04	1.08	4.12	8.06

could be considered as a major source of potentially available N for plants than non-hydrolysable N (González-Prieto *et al.*, 1997).

Contrary to the decrease in unfertilized treatment, all four hydrolysable N and non-hydrolysable N registered a significant increase due to inorganic fertilizers or organic amended treatments over their respective initial status. The magnitude of increase in all the hydrolysable N fractions over their initial level was more with combined application of inor- ganic fertilizers and organic manures as compared to inorganic fertilizers alone. Huang *et al.* (2009) concluded that organic manure had a more sig- nificant effect on soil N than inorganic fertilizer alone. The extent of N build-up in hydrolysable N factions varied with the N fractions and organic manure.

Yield and K uptake :

Grain yield:

The economic biomass in terms of grain yield of hybrid maize ranged from 3012 to 6057 kg ha^{-1} (Table 3). The maize grain yield was significantly affected by organic and inorganic fertilizer treatments. However, the conjoint application of 100% NPK along with FYM @10 t ha^{-1} registered significantly higher grain yield of maize (6057 kg ha^{-1}) followed by treatment T_3-150% NPK which recorded a grain yield of 5492 kg ha^{-1}. The integrated application of 100% NPK along with FYM @ 10 t ha^{-1} showed an increase in grain yield of 12.6 % over 100% NPK. Such yield improvement might be attributed to controlled release of nutrients in soil through mineralization of organic manures which in turn would have facilitated better crop growth (Archarya *et al.*, 2012 and Shahid *et al.*, 2013).

Progressive increase in grain yield was observed with application of graded levels of NPK addition from 50% NPK to 150% NPK. Such significant increases in maize yield at high levels of NPK fertilization (Berzsenyi *et al.*, 2000) and due to balanced fertilizer treatments (Belay *et al.*, 2002) under long term crop rotation has been reported in earlier studies.

The continuous application of N and P fertilizers (100% NP) considerably increased the grain yield (5213 kg ha^{-1}) compared to application of N alone (T_7). Such yield increase might be due to the prolific root growth, enhanced water and nutrient absorption associated with P. This clearly emphasized the need for P addition for maintaining soil productivity. Similar responses of yield to addition of P in combination with N have been reported by Gebrekiden and Seyoum (2006). The application of N alone has resulted in a conspicuous reduction of 20.9 % in yield than 100% NPK that in turn emphasizes the essentiality of balanced fertilization to achieve higher productivity (Jia-yin *et al.*, 2013). Withdrawal of S from fertilizer schedule (T_9) showed no reduction in grain yield as compared to 100 % NPK plot. The lowest grain yield of 3012 kg ha^{-1} was registered in control (T_{10}) clearly reflected the adverse effect of imbalanced fertilization.

Straw yield:

The straw yield of hybrid maize followed similar trend to that of grain yield (Table 3). Benefits accruing from the integrated use of FYM with 100% NPK might

Table 3 : Effect of long-term fertilization on yield and potassium uptake in hybrid maize (kg ha^{-1})

Treatments		Yield (kg/ha)		N uptake (kg/ha)		
		Straw	Grain	Straw	Grain	Total
T_1	50 % NPK	7029	5132	55.0	36.7	91.7
T_2	100 % NPK	8271	5378	63.8	45.5	109.3
T_3	150 % NPK	8514	5492	71.1	52.6	123.7
T_4	100 % NPK + HW	8149	5311	64.5	46.2	110.8
T_5	100 % NPK + Zn	8458	5432	65.6	47.3	112.6
T_6	100 % NP	8134	5213	64.4	46.1	110.1
T_7	100 % N	6933	4256	63.5	45.2	108.5
T_8	100 % NPK + FYM	9379	6057	73.4	55.1	128.4
T_9	100 % NPK (- S)	8221	5349	62.5	44.2	106.7
T_{10}	Control	5242	3012	49.2	30.9	80.1
	S.E.±	165.78	114.32	1.35	1.02	
	C.D. (P=0.05)	328.25	232.52	2.68	2.03	

be attributed to better supply of nutrients through incorporation of organic manures along with conducive physical environment leading to better root activity and higher nutrient absorption which resulted in better crop growth and superior yield attributes responsible for high yield (Thakur *et al.*, 2011 and Mishra *et al.*, 2008).

N uptake :

The N uptake by maize in both straw and grain (Table 3) was found to be highest in 100% NPK + FYM treatment and lowest in control. Higher N uptake in FYM treated plots was due to increased fertilizer use efficiency and slow mineralization and release of N from FYM which might have satisfied the N requirement of crop during critical growth period. An increased biomass coupled with higher N content resulted in higher N uptake by maize. Singaram and Kamalakumari (2000) in their study on an inceptisol reported that the increased N uptake in treatments receiving 100% NPK+ FYM may be due to beneficial effects of organic manure in increasing and sustaining the availability of nutrients in soil.

N uptake in straw and grain increased with progressive increase in the supply of NPK to crop, because of higher availability of N and higher biomass yield. Thakur *et al.* (2011) also reported that N uptake by crop increased significantly with nitrogen rates upto 150 kg ha^{-1}. The treatment which has supplied with 100% N also resulted in lower N uptake compared to 100% NPK treatment. This may be attributed to the fact that the exclusion of P from fertilizer schedule has resulted in improper development of roots and consequent reduction in the yield. However, withholding of K from fertilizer schedule did not show any nutrient reduction in N uptake.

Conclusion:

It may be concluded from the present study that the application of 10 t FYM ha^{-1} along with 100% NPK not only produced the higher yield of hybrid maize, but also could able to improve the N dynamics in soil as compared to application of inorganic fertilizers alone. Thus, optimum mineral nutrition in conjunction with organic manures can play a vital role in exploiting high yield potential of hybrid maize through its favourable effect on N transformation and uptake.

Authors' affiliations :

N. CHANDRASEKARAN AND K. RULMOZHISELVAN, Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, COIMBATORE (T.N.) INDIA

DHANESHWAR PADHAN, Department of Agricultural Chemistry and Soil Science, Bidhan Chandra Krishi Viswavidyalaya, NADIA (W.B.) INDIA

REFERENCES

Archaya, R., Dash, A.K. and Senapati, H.K. (2012). Effect of integrated nutrient management on microbial activity influencing grain yield under rice-rice cropping system in an acid soil. Asian *J. Microbiol. Biotechnol. & Environ. Sci.*,**14**: 36-368.

Bednarek, W. and Tkaczyk, P. (2002) The influence of mineral fertilization on the content of some nitrogen forms in soil. *Zesz. Probl. Post. nauk rol.,* **484** : 55–60.

Belay, A., Claassens, A. and Wehner, F. (2002). Effect of direct nitrogen and potassium and residual phosphorus fertilizers on soil chemical properties, microbial components and maize yield under long-term crop rotation. *Biol.& Fertil. Soils,* **35**(6): 420-427.

Berzsenyi, Z., Gyorffy, B. and Lap, D.Q. (2000). Effect of crop rotation and fertilisation on maize and wheat yields and yield stability in a long-term experiment. *European J. Agron.*, **13**(2-3) : 225-244.

Bhandari, A.L., Ladha, J.K., Pathak, H. , Padre, A.T., Dawe, D. and Gupta, R.K. (2002). Yield and soil nutrient changes in a long-term rice-wheat rotation in India. *Soil Sci. Soc. America J.,* **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. and 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 manage- ment in tropical rice*Soil & Tillage Res.,* **129**: 93-105.

Bird, J.A., Kessel, C. Van and Horwath, W.R. (2002). Nitrogen dynamics in humic fractions under alternative straw management in tem- perate rice.*Soil Sci. Soc. America J.,* **66**: 478–488.

Blaise, D., Singh, J.V., Bonde, A.N., Tekale, K.U. and Mayee, C.D. (2005). Effects of farmyard manure and fertilizers on yield, fibre quality and nutrient balance of rainfed cotton (*Gossypium hirsutum*). *Bioresour. Technol.,* **96**: 345-349.

Brar, M.S. and Brar, B.S. (2002). Assessment of soil nutrients depletion in Punjab. *Fert. News.*, **47** (2) : 33- 35.

Bremner, J.M. (1965). Inorganic and organic forms of nitrogen. In: *Methods of soil analysis*. Part II (Ed.) C.A. Black, American

Society of Agronomy, Madison, Wisconsin, pp. 1179-1255.

Corbeels, M., Hofmanand, G. and Cleemput, O.V. (1999). Soil mineral nitrogen dynamics under bare fallow and wheat in Vertisol of semi-arid Mediterranean Morocco. *Biol. & Ferti. Soils.,* **28** : 321-328.

Deng, S.P., Moore, J.M. and Tabatabai, M. (2000). Characterization of active nitrogen pools in soils under different cropping systems. *Biol. Fertil. Soils.,* **32** : 302-309.

Duraisami, V.P., Perumaland, R. and Mani, A.K. (2001). Changes in organic carbon, available nitrogen and inorganic nitrogen fractions under integrated nitrogen management of sorghum in a mixed black soil. *J. Indian Soc. Soil Sci.,* **49**: 133-137.

Duxbury, J.M., Lauren, J.G. and Fruci, J.R. (1991). Measurement of the biologically active soil nitrogen fraction by a ^{15}N technique. *Agric. Ecosyst. Environ.,* **34** : 121-129.

Gebrekiden, H. and Seyoum, M. (2006). Effects of mineral N and P fertilizers on yield and yield components of flooded lowland rice on Vertisols of fogera plain. *J. Agric. & Rural Develop. Trop. & Subtropics.,* **107**: 161-176.

González-Prieto, S.J., Jocteur-Monrozier, L., Hétier, J.M. and 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 & Soil.,* **195** : 151-160.

Heumann, S. and Bottcher, J. (2004). Temperature functions of the rate coefficients of net N mineralization in sandy arable soils and its evaluation via field mineralization measurements. *J. Plant Nutr. Soil Sci.,* **167**: 390-396.

Huang Q.R., Huang, S., Li, H.X., Yuan, Y.H., Pan, G.X. and 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 Private Ltd., NEW DELHI, INDIA,pp. 56-70.

Jayashree Sankar, S. (1994). Investigations on NPK fractions under long term fertilization in an irrigated Inceptisol. Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore, T.N. (INDIA).

Jia-yin, D.U., Mei, R.U. and Wu-zhong, N.I. (2013). Effects of fertilization with reducing nitrogen, controlling phosphorous and stabilizing potassium on rice yield and nutrient accumulation. *Plant Nutr. & Fertil. Sci.,***19** : 523-533.

Kaur, J. and Singh, J.P. (2014). Long-term effects of continuous cropping and different nutrient management practices on the distribution of organic nitrogen in soil under rice-wheat system. *Plant Soil Environ.,* **60** (2): 63-68.

Khankhane, P.J. and Yadav, B.R. (2000). Relative mineralization of nitrogen and phosphorus from farmyard manure, biogas slurry and sewage sludge. *J. Indian Soc. Soil Sci.,* **48**: 793-797.

Kher, Deepak and Minhas, R.S. (1992). Long term effect of liming, manuring and cropping on different hydrolysable N forms in an alfisol. *J. Indian Soc. Soil Sci.,* **40** (4): 840-842.

Kruse, J.S., Kissel, D.E. and Cabrera, M.L. (2004). Effects of drying and rewetting on carbon and nitrogen mineralization in soils and incorporated residues. *Nutr. Cycl. Agroecosyst.,* **69**: 247-256.

Mairan, N.R., Patil, S.G. and Kachhave, K.G. (2005). Physico-chemical properties under sorghum-sunflower cropping sequence in Vertisols. *J. Soils & Crops.,* **15** (2) : 352-355.

Mishra, B., Sharma, A., Singh, S.K., Prasad, J. and Singh, B.P. (2008). Influence of continuous application of amendments to maize-wheat cropping system on dynamics of soil microbial biomass in Alfisol of Jharkhand. *J. Indian Soc. Soil Sci.,* **56**: 71-75.

Panse, V.G. and Sukhatme, P.V. (1985) *Statistical methods for agricultural workers*. Publication and information division. ICAR, NEW DELHI, INDIA.

Parmar, D.K. and Sharma, V. (2002). Studies on long term application of fertilizers and manures on yield of maize-wheat rotation and soil properties under rainfed condition in Western Himalayas. *J. Indian Soc Soil Sci.,* **50** : 311-312.

Piper, C.S. (1966). *Soil and plant analysis*. International Sci. publishres Inc., NEW YORK, U.S.A.

Prasad, B. and Rokima, J. (1991). Integrated nutrient management-I. Nitrogen fractions and their availability in calcareous soil. *J. Indian Soc. Soil Sci.,* **39**: 693-698.

Sammy Reddy, K., Singh, M., Tripathy, A.K., Singh, M.V. and Saha, M.N. (2003). Changes in amount of organic and inorganic fractions of nitrogen in an Eutrochrept soil after long term cropping with different fertilizers and organic manure inputs. *J. Soil Sci. Plant Nutr.,* **166**: 232-238.

Santhy, P., Selvi, D. and Dhakshinamoorthy, M. (2000). Long term fertiliser experiment-an index of yield and soil sustainability. *Madras Agric. J.,* **87**(1/3): 40-43.

Schmidt, L., Warnstorff, K., Dörfel, H., leinweber, P. , lenge, H. and Merbach, W. (2000). The influence of fertilization and rotation on soil organic matter and plant yields in the long-term rye trial. *Germany. J. Plant Nutr. Soil Sci.,* **163** : 639-628.

Schulten, H.R. and Schnitzer, M. (1998). The chemistry of soil organic nitrogen: a review. *Biol. Fertil. Soils.,* **26**: 1–15.

Sadej, W. and Przekwas, K. (2008). Fluctuation of nitrogen level in soil profile under condition of a long-term fertilization experiment. *Plant Soil Environ.,* **54** (5) : 197-203.

Shahid, M., Shukla, A.K., Tripathy, R., Kumar, A., Mohanty, S., Bhattacharyya, P., Raja, R. and Panda, B.B. (2013) Long-term effects of fertilizers and manure applications on soil quality and yields in a sub humid tropical rice-rice system. *Soil Use & Mgmt.*, **29**: 322-332.

Sharma, J. P. and Saxena, S.N. (1994). Use of crop residues and organic manures for improving the phosphorus availability in rhizosphere zone of maize. *Indian J. Agric. Sci.,* **24**(3):199-202.

Singaram, P. and Kamalakumari, K. (2000). Effect of continuous application of different levels of fertilizers with farm yard manure on enzyme dynamics of soil. *Madras Agric. J.,* **87**(4/6): 364-365.

Sinha, S.K., Singh, V.N. and Singh, P. (1997) Effect of continuous use of fertilizers on physical and physico-chemical properties of an alluvial soil. *J. Res. (BAU).,* **9**(1): 31-34.

Smith, J.L. and Poul, E.A. (1990). The significance of soil microbial biomass estimations. *Soil Biochem*., **6** : 357-348.

Stevenson, F.J. (1982). *Humus chemistry, genesis, composition and reactions*. John Wiley and Sons, New York, U.S.A.pp. 215.

Subbiah, B.V. and Asija, G.C. (1956). A rapid procedure for estimation of available nutrients in soils. *Curr. Sci.,* **25**: 259-260.

Subhendu, M. and Adhikary, J. (2005). Effect of integrated nitrogen management on growth and yield of rice (*Oryza sativa* L.). *Agric. Sci. Dig.,* **25**(2): 136-138.

Thakur, R., Sawarkar, S.D., Vaishya, U.K. and Singh, M. (2011) Impact of continuous use of inorganic fertilizers and organic manure on soil properties and productivity under soybean-wheat intensive cropping of a Vertisol. *J. Indian Soc. Soil Sci.,* **59** : 74-81.

Thilagavathi, T. and Subbiah, S. (2006) Integrated management of sewage sludge and fertilizers for enhanced productivity and nutrient uptake of rice. *Adv. Plant Sci.,* **19** (II): 551-556.

Tisdale, S.L., Nelson, W.L. and Beaton, J.D. (1985). *Soil fertility and fertilizers*. 4thEd. MacMillan Publishing Company, New York, U.S.A.,pp. 251.

Weier, K.L. and MacRae, I.C. (1993). Net mineralization, net nitrification and potentially available nitrogen in the subsoil beneath a cultivated crop and a permanent pasture. *J. Soil Sci.,* **44** : 451-458.

Xu, Y.C., Shen, Q.R. and 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.

Yadav, M.D. and Singh, K.D.N. (1991). Transformation of applied nitrogen in relation to its availability to sugarcane in calcareous soil. *J. Indian Soc. Soil Sci.,* **39** : 292-297.

Yang, L.L.,Zhang, F.S., Mao,R.Z., Ju, X.T., Cai, X.B. and Lu, Y.H. (2008). Conversion of natural ecosystems to cropland increases the soil net nitrogen mineralization and nitrification in Tibet. *Pedosphere.,* **18**: 699-706.