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Impact of continuous fourteen years of integrated nutrient management practices on forms of soil N and P on terraced land

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Summary

An experiment was conducted in the experimental farm at School of Agricultural Sciences and Rural Development, Medziphema, Nagaland to find out the impact of continuous fourteen years integrated nutrient management practices on forms of soil N and P on terraced land. Twelve treatments involving N, P and K fertilizers, farmyard manure, poultry litter, forest litter, *Azospirillum* and Zn either alone or in combinations were applied continuously for fourteen years. The highest NH_4-N content was recorded in NPK+ FYM+ Zn followed by NPK+ FYM treatment, whereas the highest NO_3-N content was in NPK followed by NPK+ FYM and NPK+ FYM+ Zn treatments. After fourteen years, the rate of build up of available N in different nutrient management practices was 0.5 to 10.3 kg N ha^{-1} yr^{-1} with an average of 5.8 kg N ha^{-1} yr^{-1} whereas, the rate of build up of total N in various nutrient management practices was 1 2.8 to 16.1 kg N ha^{-1} yr^{-1} with an average of 11.2 kg N ha^{-1} yr^{-1}. The significant increase in organic N in NPK+ FYM, NPK+ poultry litter and NPK+ FYM+ Zn treatments over NPK was 5.7, 5.0 and 5.4 per cent, respectively. The inorganic P in NPK+ poultry litter, NPK+ FYM+ Zn and NPK+ FYM was 5.8, 3.8 and 2.2 per cent higher as compared to NPK, respectively. The rate of build up of available P in different treatments was 0.01 to 0.76 kg P ha^{-1} yr^{-1} with an average of 0.49 kg P ha^{-1} yr^{-1}. On an average, solution P, inorganic P, available P and organic P represented 0.3, 40.6, 3.3 and 59.6 per cent of total P.

Key words : N fraction, P fraction, Terraced land

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Introduction

Soil fertility development of the resultant surface soil after terracing could be achieved through the addition of manures, fertilizers, bio-fertilizers, organic residues and other amendments either alone or in combinations. The initial production potential of terraced land is generally low. To increase productivity of terraced land, sound fertility management practices are obviously needed. The addition of N, P and K fertilizers with organic sources would increase the availability of nutrients to growing plants and favour accumulation of organic matter in surface soil besides improving soil properties. The soil organic nitrogen fractions are sensitive to management practices, including fertilization (Durani *et al*., 2016). The information on the long term impact of integrated nutrient management practices on various forms of soil nitrogen and phosphorous on terraced land in acid soils of Nagaland are very scanty. Therefore, the present study was carried out to evaluate the impact of long term integrated nutrient management practices on various forms of soil N and P on terraced land under upland rice cultivation in Nagaland.

Resource and Research Methods

A hill slope of 22 per cent was bench terraced in 2001 at the experimental farm of the School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema, Nagaland. A field experiment on these terraces was established in 2001 and has been maintained since then. The soil samples collected in *Kharif* 2014 after fourteen years of nutrient management and continuous cultivation of upland rice forms the basis of this investigation. The experiment was laid out in Randomized Block Design with twelve treatments and replicated thrice in plots of 2.0 x 3.0 m^2 size separated by a bund of 15 cm. A border of 25 cm along the riser was left. During each year, the plots were manually prepared to ensure good seedbed. The recommended dose of 60 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} for rice was applied. The farmyard manure (FYM), poultry litter and forest litter was applied @ 10.0 t ha^{-1}, 3.3 t ha^{-1} and 5.0 t ha^{-1}, respectively. For ½ N (30 kg ha^{-1}) through FYM, poultry litter and forest litter, calculated amounts of these organic sources containing 0.5, 1.5 and 0.1 per cent N, respectively were applied (6.0, 2.0 and 30.0 t ha^{-1}, respectively) to the soil. Zinc (Zn) was applied @ 10 kg ha^{-1} in the form of $ZnSO_4.7H_2O$ as basal dose. *Azospirillum* was used as seed treatment @ 20 g kg^{-1} of seed. For forest litter burned+ ½ FYM treatment that resembles farmers' practice in Nagaland, forest litter @ 5.0 t ha^{-1} was evenly spread on the soil surface and burned. The ash was incorporated thoroughly in the soil. The FYM, ½ FYM, poultry litter and forest litter were applied one month before sowing and mixed well in the soil. Upland rice variety Teke (landrace) was sown with a spacing of 20 cm row to row using a seed rate of 75 kg ha^{-1} each year.

Soil samples collected after the harvest of 14th year rice were air dried, prepared and analyzed for various forms of N and P. The NH_4-N and NO_3-N was determined using procedure of Chopra and Kanwar (1991). The available N was determined by alkaline permanganate method of Subbiah and Asija (1956). Organic N was determined by using sodium carbonate and concentrated sulphuric acid as described by Chopra and Kanwar (1991). The total N in soil was determined by modified Kjeldahl digestion and distillation method (Jackson, 1973). The inorganic P was extracted over night with 100 ml 2N H_2SO_4 as suggested by Anderson (1960). The available P in soil was extracted by Bray's method No. 1 (Bray and Kurtz, 1945). The P content in different extracts and triacid digested material was measured using ascorbic acid method (Watanabe and Olsen, 1965). The difference between total and inorganic P was taken as organic P. The statistical analysis of the data was done as per procedure outlined by Gomez and Gomez (1984).

Research Findings and Discussion

The findings of the present study as well as relevant discussion have been presented under following heads:

NH_4-N, NO_3-N, available N, organic N and total N content in soil :

The NH_4-N content in the soil varied from 24.0 to 66.5 mg kg^{-1} with an average of 50.2 mg kg^{-1} (Table 1). After fourteen years of integrated nutrient management NH_4-N content in the soil increased significantly in all the treatments except forest litter burned+ ½ FYM over control. The highest NH_4-N was recorded in NPK+ FYM+ Zn and the lowest in control. The NH_4-N in NPK+ FYM, NPK+ poultry litter, NPK+ forest litter and NPK+ FYM+ Zn showed a significant increase over NPK. Substituting half N either through FYM, poultry litter or forest litter also caused a significant increase in NH_4-N as compared to NPK. Integrated use of NPK fertilizers with organic sources might have resulted accumulation of organic matter of lower C: N and its subsequent decomposition and mineralization could have contribute towards higher NH_4-N accumulation. The increase in NH_4-N in NPK+ FYM+ Zn, NPK+ FYM, NPK+ poultry litter and NPK+ forest litter over NPK was 56.5, 55.8, 53.2 and 48.5 per cent, respectively. Similarly significant increase in NH_4-N in ½N+ PK+ ½N FYM, ½N+ PK+ ½N poultry litter and ½N+ PK+ ½N forest litter over NPK was 36.9, 34.1 and 22.4 per cent, respectively Comparatively lower levels of NH_4-N in control, ½N+ PK, NPK, ½N+ PK+ *Azospirillum* and forest litter burned+ ½ FYM treatments might be either due to low rate of ammonification of organic N as affected by its input or due to NH_4-N use by rice or its transformation to other forms of N. Similar results were also reported by Shilpashree *et al*. (2012). Gupta *et al*. (2005) also recorded higher accumulation of NH_4-N in soil profile with the application of FYM as compared with biogas slurry.

The NO_3-N content in the soil ranged from 5.7 to 16.6 mg kg^{-1} with an average of 12.1 mg kg^{-1} (Table 1). The NO_3-N content in the soil also increased significantly in all the treatments except forest litter burned+ ½ FYM over control. The highest NO_3-N was observed in NPK followed by NPK+ FYM and NPK+ FYM+ Zn. The NO_3-N in NPK, NPK+ FYM, NPK+ FYM+ Zn and NPK+ poultry litter was significantly higher than ½N+ PK, ½N+ PK+ ½N poultry litter, ½N+ PK+ ½N FYM and ½N+ PK+ ½N forest litter treatments. The increase in NO_3-N over control in different nutrient management practices varied from 5.0 to 65.7 per cent with an average of 51.5 per cent. The significant decrease in NO_3-N in ½ N+ PK+ ½N FYM, ½N+ PK+ ½N poultry litter, ½N+ PK+ ½N forest litter and NPK+ forest litter over NPK was 26.5, 21.7, 38.0 and 15.7 per cent, respectively. This decrease might be either due to higher NO_3-N uptake or higher NO_3 immobilization during decomposition of added organic residues. These results are in accordance with those reported by Bharadwaj *et al*. (1994). The highest NO_3-N content in NPK treatment might be due to higher nitrification of urea fertilizer. Duraisami *et al*. (2001) also reported increased NO_3-N content in the soil with the application of increasing doses of fertilizer N. The fact that NH_4-N accumulated on addition of NPK and organic sources as compared to NO_3-N suggested that the process of ammonification dominated the nitrification in treatments where integrated application of fertilizer N and organic residues was made. This may be because of the fact that *Nitrosomonas* and *Nitrobacter* are slow growers (Russell, 1973) and their population in resultant surface soil after terracing might also be low as compared to ammonifiers.

After fourteen years of continuous cropping and integrated nutrient management, the available N content in the soil varied from 100.6 to 165.0 mg kg^{-1} with an average of 134.1 mg kg^{-1} (Table 1). The available N content in the soil increased significantly in all the treatments except ½ N+ PK and forest litter burned+ ½ FYM over control. The maximum available N was recorded in NPK+ forest litter treatment, whereas, lowest available N was recorded in control. The available N in NPK+ FYM, NPK+ FYM+ Zn, NPK+ poultry litter, NPK+ forest litter, ½N+ PK+ ½N FYM and ½ N+ PK+ ½ N poultry litter was significantly higher than NPK. The significant increase in available N on addition of NPK fertilizers with different organic residues are in agreement with those reported by Duraisami *et al*. (2001); Bajpai *et al*. (2006); Shilpashree *et al*. (2012) and Durani *et al*. (2016). After fourteen years, the rate of build up of available N in various nutrient management practices was estimated to be 0.5 to 10.3 kg N ha^{-1} yr^{-1} with an average of 5.8 kg N ha^{-1} yr^{-1}. Humtsoe and Chauhan (2005) also found similar build up of available N in terraced land. The accumulation of available N in various integrated nutrient management practices after fourteen years brought about a change in soil fertility status from low to medium in all the treatments except in control, ½N+ PK, ½N+ PK+ *Azospirillum* and forest litter burned+ ½ FYM treatments. This suggested that addition of NPK in combination with organic residues

Table 1 : Impact of integrated nutrient management practices on forms of soil N (mg kg^{-1})

Treatments No. and particulars	NH_4- N	NO_3- N	Available N	Organic N	Total N
T_1-Control	24.0	5.7	100.6	1371.1	1710.1
T_2-½N+ PK	40.3	10.4	107.1	1460.2	1736.5
T_3-NPK	42.5	16.6	128.9	1543.4	1770.4
T_4-NPK+ FYM	66.2	16.3	163.4	1630.8	1805.4
T_5-½N+ PK+ ½N FYM	58.2	12.2	140.3	1578.0	1793.3
T_6-NPK+ Poultry litter	65.1	14.5	165.0	1627.3	1810.7
T_7-½N+ PK+ ½N Poultry litter	57.0	13.0	142.5	1575.6	1791.5
T_8-NPK+ Forest litter	63.1	14.0	140.5	1590.4	1799.4
T_9-½N+ PK+ ½N Forest litter	52.0	10.3	133.6	1585.1	1793.3
T_{10}-½N+ PK+ *Azospirillum*	41.1	10.9	118.5	1504.5	1747.4
T_{11}-NPK+ FYM+ Zn	66.5	15.8	164.7	1620.7	1808.3
T_{12}-Forest litter burned+ ½ FYM	26.1	6.0	103.8	1436.6	1727.3
S.E. ±	2.75	0.77	3.15	10.30	5.51
C.D. (P=0.05)	8.07	2.26	9.24	30.23	16.18

favoured comparatively higher build up of available N.

The organic N content in the soil varied from 1371.1 to 1630.8 mg kg^{-1} with an average of 1543.6 mg kg^{-1} (Table 1). The organic N content in the soil increased significantly in all the treatments over control. The organic N in NPK+ FYM, NPK+ FYM+ Zn, NPK+ poultry litter, NPK+ forest litter, ½N+ PK+ ½N FYM, ½ N+ PK+ ½N poultry litter and ½N+ PK+ ½N forest litter was significantly higher than NPK. The significant increase in organic N in NPK+ FYM, NPK+ poultry litter, NPK+ forest litter and NPK+ FYM+ Zn over NPK was 5.7, 5.0, 5.4 and 3.1 per cent, respectively. The significant increase in organic N content in integrated treatments over NPK might be due to the variation in N content in these organic residues and its influence on the rate of decomposition and synthesis of microbial metabolites and their C: N, combine effect of which would result variation in the cumulative build up of organic N in these treatments. Similar results were also reported by Sihag *et al*. (2005) and Durani *et al.* (2016).

The total N content in the soil ranged from 1710.1 to 1810.7 mg kg^{-1} with an average of 1774.5 mg kg^{-1}, respectively (Table 1). The total N content in the soil also increased significantly in all the treatments over control. After fourteen years of continuous integrated nutrient management, highest total N was recorded in NPK+ poultry litter treatment. The total N in NPK+ FYM, NPK+ FYM+ Zn, NPK+ poultry litter and NPK+ forest litter showed a significant increase over NPK. The treatments receiving half N from fertilizer and other half from organic sources also recorded significantly higher total N content as compared to NPK. After fourteen years, the rate of build up of total N in various integrated nutrient management practices was estimated to be 1 2.8 to 16.1 kg N ha^{-1} yr^{-1} with an average of 11.2 kg N ha^{-1} yr^{-1}. These results are in agreement with those reported by Laxminarayana and Patiram (2006) and Sekhon *et al.* (2011). An analysis of data established that on an average, NH_4-N, NO_3-N, available N and organic N represented 2.8, 0.7, 7.6 and 87.0 per cent of total N. Durani *et al.* (2016) also reported that organic N fraction constituted about 94.2 per cent of total N. Xu *et al.* (2007) reported that combination of no tillage and application of pig manure was the best way to sustain soil fertility status.

Solution P, inorganic P, available P, organic P and total P content in soil :

The solution P in the soil varied from 0.2 to 1.0 mg kg^{-1} with an average of 0.7 mg kg^{-1} (Table 2). Solution P showed a significant increase in all the treatments except in ½ N+ PK and Forest litter burned+ ½ FYM over control. After fourteen years of continuous nutrient management the solution P in NPK+ poultry litter, NPK+ FYM, NPK+ FYM+ Zn and ½ N+ PK+ ½N poultry litter was significantly higher than NPK. The inorganic P content in the soil ranged from 72.2 to 110.3 mg kg^{-1} with an average of 100.9 mg kg^{-1} and showed a significant increase in all the treatments over control (Table 2). The inorganic P in NPK+ poultry litter and NPK+ FYM+ Zn showed a significant increase over NPK. Sihag *et al.* (2005) reported that the amount of inorganic P recovered as saloid-P, Al-P and Ca-P forms increased significantly with the application of inorganic fertilizers and their combined use with organic materials over control and the highest amount of all the forms of P was recorded

Table 2 : Impact of integrated nutrient management practices on forms of soil P (mg kg^{-1})

Treatments No. and particulars	Solution P	Inorganic P	Available P	Organic P	Total P
T_1-Control	0.2	72.2	1.9	120.4	192.6
T_2-½N+ PK	0.4	100.3	3.8	140.3	240.6
T_3-NPK	0.6	104.3	7.4	145.1	249.4
T_4-NPK+ FYM	0.9	106.6	10.6	163.3	269.9
T_5-½N+ PK+ ½N FYM	0.7	107.4	9.9	153.9	261.3
T_6-NPK+ Poultry litter	1.0	110.3	12.5	164.5	275.8
T_7-½N+ PK+ ½N Poultry litter	0.9	107.5	11.8	160.7	264.4
T_8-NPK+ Forest litter	0.7	105.1	9.2	150.6	255.7
T_9-½N+ PK+ ½N Forest litter	0.7	104.9	9.4	152.8	257.7
T_{10}-½N+ PK+ *Azospirillum*	0.6	104.0	8.2	142.2	246.2
T_{11}-NPK+ FYM+ Zn	0.9	108.3	11.7	161.0	269.3
T_{12}-Forest litter burned+ ½ FYM	0.2	79.4	2.0	123.6	203.0
S.E. $\pm$	0.08	1.30	0.42	3.17	3.81
C.D. (P=0.05)	0.23	3.82	1.23	9.31	11.19

under FYM followed by green manuring and press mud treatments. The inorganic P recorded in NPK+ poultry litter, NPK+ FYM+ Zn and NPK+ FYM was 5.8, 3.8 and 2.2 per cent higher as compared to inorganic P in NPK, respectively. This may be attributed to the higher input of P as in NPK+ Poultry litter as compared to other treatments and also mineralization of native organic P as well as that added to the soil. Increase in inorganic P fraction with long term application of organic manures along with fertilizers was reported by Yang and Lijuan (2010).

The available P content in the soil ranged from 1.9 to 12.5 mg kg^{-1} with an average of 8.2 mg kg^{-1} and showed a significant increase in all the treatments except in forest litter burned+ ½ FYM over control. The highest available P was recorded in NPK+ poultry litter followed by ½N+ PK+ ½N poultry litter, NPK+ FYM+ Zn and NPK+ FYM. The available P in NPK+ poultry litter, NPK+ FYM, NPK+ FYM+ Zn and NPK+ forest litter was significantly higher than NPK. Substituting half N either by FYM, poultry litter or forest litter also caused a significant increase in available P over NPK treatment. Relatively higher amount of available P levels accumulated in treatments where NPK fertilizers were applied in combinations with poultry litter and FYM might be due to relatively higher input of P through fertilizer and poultry litter or FYM. Laxminarayana (2006) found highest available P (12.15 kg ha^{-1}) with the application of 100% NPK+ poultry manure. Singh *et al*. (2008) also observed that available P content of surface soil increased appreciably with the application of manures along with fertilizers as compared to sole application of NPK fertilizers. After fourteen years of integrated nutrient management, the rate of build up of available P in various nutrient management practices was estimated to be 0.01 to 0.76 kg P ha^{-1} yr^{-1} with an average of 0.49 kg P ha^{-1} yr^{-1}. Dutta and Chauhan (2011) also reported similar build up of available P in terraced land. After fourteen years of continuous nutrient management, the P fertility status in the soil changed from low to medium in all the treatments except in ½ N+ PK and forest litter burned + ½ FYM treatments. The fact that highest amount of available P accumulated in NPK+ poultry litter followed by ½N+ PK+ ½N poultry litter, NPK+ FYM+ Zn, NPK+ FYM and ½N+ PK+ ½N FYM treatments suggested that besides the source and amount of P added, the available P levels in soil may be the result of the combined effect of the processes of transformation of added P through fertilizers and organic sources, mineralization of native and added organic P and loss of P from soil including crop removal. Part of added fertilizer P that is not used by the crop would accumulate in soil in various forms to contribute with varying degree towards different forms of P including available P pool in soil.

The organic P content in the soil ranged from 120.4 to 164.5 mg kg^{-1} with an average of 148.2 mg kg^{-1} and showed a significant increase in all the treatments except Forest litter burned+ ½ FYM over control (Table 2). The highest organic P was recorded in NPK+ poultry litter followed by NPK+ FYM and NPK+ FYM+ Zn. The significant increase in organic P in NPK+ poultry litter, NPK+ FYM and NPK+ FYM+ Zn over NPK was 13.4, 12.5 and 11.0 per cent, respectively. The accumulation of organic P in ½N+ PK+ ½N poultry litter was also significantly higher than NPK. The build up of organic P after fourteen years of integrated nutrient management practices in various treatments was estimated to be 0.23 to 3.15 kg P ha^{-1} yr^{-1} with an average of 2.17 kg P ha^{-1} yr^{-1}. The data revealed that addition of NPK with FYM or poultry litter favoured higher build up of organic P as compared to application of NPK alone or with forest litter. This might be due to higher level of P added through poultry litter and variation in microbial activities.

The total P content in the soil ranged from 192.6 to 275.8 mg kg^{-1} with an average of 248.8 mg kg^{-1}, respectively (Table 2). The total P in the soil increased significantly in all the treatments except forest litter burned+ ½ FYM over control. The highest total P was also recorded in NPK+ poultry litter and the lowest in control. After fourteen years of continuous nutrient management, the total P content in NPK+ FYM, NPK+ poultry litter, NPK+ FYM+ Zn and ½N+ PK+ ½N poultry litter showed a significant increase over NPK. The rate of build up of total P in various nutrient management practices was estimated to be 0.74 to 5.94 kg P ha^{-1} yr^{-1} with an average of 4.38 kg P ha^{-1} yr^{-1}. Dutta and Chauhan (2011) also reported similar build up of total P in terraced land. An analysis of data established that on an average, solution P, inorganic P, available P and organic P represented 0.3, 40.6, 3.3 and 59.6 per cent of total P.

The above results led to conclude that long term application of organic sources with inorganic fertilizers had pronounced influence in improving the soil fertility status as compared to inorganic fertilizers alone. The treatments NPK+ poultry litter, NPK+ FYM and NPK+ FYM+ Zn are the best nutrient management practice that can be adopted for rice cultivation in terraced land.

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