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Effect of Integrated Nutrient Management Practices on Various Forms of Soil Phosphorus in a Newly Developed Terraced Land

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Abstract

Different forms of soil phosphorus in a newly developed terraced land under upland rice to which N, P and K (NPK) fertilizers, farmyard manure (FYM), poultry litter, forest litter, *Azospirillum* and Zn either alone or in combinations were added each year for two consecutive years were evaluated. Among treatments, NPK + poultry litter favored significantly highest build up in solution P, available P, inorganic P, organic P and total P. After two years, the rate of build up of available P in various nutrient management practices was estimated to be 0.1 to 3.0 kg P/ha per yr with an average of 1.8 kg p/ha per yr. The rate of build up of organic P was higher than available P and varied from 3.6 to 28.5 kg P/ha per yr with an average of 15.0 kg P/ha per yr. The build up of available P, inorganic P and organic P in different nutrient management practices averaged 56.1, 6.1 and 8.4%, respectively. The accumulation of available P in different treatments caused a change in P fertility status from low to medium in NPK + poultry litter and $^1/_2$N + PK + $^1/_2$ N poultry litter treatments only. On an average, solution P, inorganic P, available P and organic P represented 0.2, 39.0, 1.7 and 61.0% of total P.
Key words : Terraced land, Inorganic P, Available P, Organic P, Total P.

Bench terracing is frequently employed to manipulate surface topography of hill slopes to convert them to suit intensive agriculture. Bench terracing usually exposes infertile and biologically inert subsoil of less desirable properties for crop growth than those of the top soil. The initial production potential of terraced land is generally low. To increase immediate and long term productivity of newly terraced land, sound fertility management practices are obviously needed. These would improve the nutrient status of the exposed subsoil and would also ensures a steady build up of available plant nutrient levels together with other physico-chemical properties of the soil suitable for plant growth. Soil organic matter influences a number of physical, chemical and biological properties of the soil and their combined effect together ensure favorable plant growth conditions in soil. The effect of integrated nutrient management practices on various forms of soil phosphorus in acid soil of newly terraced land in Nagaland has not been studied. The present investigation was carried out to study the effect of nutrient management practices on various forms of soil phosphorus in a newly terraced land under rainfed conditions of Nagaland.

Methods

A hill slope of 22% was bench terraced in 2001 at the experimental farm of the Department of Soil Conservation, School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema, Nagaland. Three bench terraces, each 26.0 m long and 3.5 m wide were constructed manually. These were disked and then final leveling was done. The surface 3.0 cm soil that was scrapped and saved before terracing was uniformly added in equal volumes to the resultant surface soil of each terrace and mixed thoroughly. An experiment on these terraces was conducted in 2001 and 2002. The soil data collected in *kharif* of 2001 and 2002 after harvest of upland rice are reported here.

The experiment was laid out in randomized block design with twelve treatments and replicated thrice. The plots of 2.0 × 3.0 m^2 separated by a bund of 15 cm width were used in the experiment. A border of 25 cm along the riser was left. During each year of experimentation, the plots were manually dug with spade and prepared to ensure good seedbed. The recommended dose of 60 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha for rice was applied for NPK. The farmyard manure (FYM), poultry litter and forest litter was applied at 10.0 t/ha, 3.3 t/ha and 5.0 t/ha, respectively. For $^1/_2$ N (30 kg/ha) through FYM, poultry litter and forest litter, calculated amounts of these organic sources containing 0.5, 1.5 and 0.1% N, respectively were applied (6.0, 2.0 and 30.0 t/ha, respectively) to the soil. Zinc (Zn) was applied at 10 kg/ha in the form of $ZnSO_4.7H_2O$ as basal dose. *Azospirillum* was applied as seed treatment before sowing at 20 g/kg of seed. Nitrogen was applied as urea in three equal split doses at the time of sowing, tillering and panicle initiation stages. The entire doses of P and K (PK) in the form of single super phosphate and muriate of potash, respectively were applied as basal dose. For forest litter burned + $^1/_2$ FYM treatment which resembles farmers' practice in Nagaland, the required amount of forest litter at 5.0 t/ha was evenly spread on the soil surface and burned there. The ash was incorporated thoroughly in the soil. Thereafter, 5 t/ha of FYM ($^1/_2$ FYM) was aplied 30 days before sowing and mixed in the soil. The 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.

Soil samples from individual plots were collected after the harvest of the rice each year and air dried at room temperature. The samples were ground to pass through 2 mm sieve and stored for analysis. Solution P as soluble in 1:2 soil water ratio was extracted by shaking the soil suspension for one hour. Soil samples were digested in triacid mixture for total P. The inorganic P was extracted over night with 100 ml 2N H_2SO_4 as suggested by Anderson (1). The available P in soil was extracted by Bray's method No. 1 (2). The P content in different extracts and triacid digested material was measured using ascorbic acid method (3). 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 Panse and Sukhatme (4).

Results and Discussion

Solution P

The solution P content in the soil ranged from 0.2 to 0.6 mg/kg in 2001, and from 0.2 to 0.7 mg/kg in 2002 with an average of 0.4 mg/kg (Table 1). In 2001, solution P showed a significant increase in NPK + FYM, NPK + poultry litter, $^1/_2$N + PK + $^1/_2$N poultry litter and NPK + FYM + Zn treatments over control. In 2002, solution P increased significantly in all the treatments except in $^1/_2$N + PK and forest litter burned + $^1/_2$ FYM over control. The increase in solution P could be related to the input of inorganic P and mineralization of both added and native organic P. In $^1/_2$N + PK and forest litter burned + $^1/_2$ FYM treatments solution P did not increase perhaps because of the contribution of added fertilizer P and organic P mineralization towards solution P was less than its removal by the plant. In both the years of cultivation, highest solution P was in NPK + poultry litter and lowest was in control and forest litter burned + $^1/_2$ FYM. The solution P in NPK + poultry litter, NPK + FYM and NPK + FYM + Zn showed a significant increase over NPK and NPK + forest litter treatments. The solution P in $^1/_2$N + PK + $^1/_2$N poultry litter and $^1/_2$N + PK + $^1/_2$N FYM was significantly higher as compared to NPK and $^1/_2$N + PK + $^1/_2$N forest litter.

The increase in solution P in different treatments varied from 0 to 0.9 kg/ha with an average of 0.4 kg/ha, and 0 to 1.1 kg/ha with an average of 0.6 kg/ha over control in 2001 and 2002, respectively (Table 1). On an average, addition of NPK + poultry litter caused a significant increase of 87.5% in solution P as compared to NPK. Addition of NPK + FYM, NPK + FYM + Zn and $^1/_2$N + PK + $^1/_2$N poultry litter caused a significant increase of 58.4% in solution P as compared to NPK.

Inorganic P

The inorganic P content in the soil varied from 84.5 to 91.3 mg/kg with an average of 87.6 mg/kg, and 83.1 to 94.9 mg/kg with an average of 89.5 mg/kg in 2001 and 2002, respectively (Table 1). The highest inorganic P was recorded in NPK + poultry litter and the lowest was in control during both the years. The inorganic P content showed a significant increase

Table 1. Effect of nutrient management practices on solution P, inorganic P and available P in soil.

Treatments	Solution P (mg/kg) 2001	2002	Inorganic P (mg/kg) 2001	2002	Available P (mg/kg) 2001	2002
T_1 Control	0.2	0.2	84.5	83.3	2.6	2.5
T_2 $^1/_2$N + PK	0.3	0.3	86.7	91.2	3.3	3.4
T_3 NPK	0.3	0.4	87.5	90.1	3.4	3.6
T_4 NPK + FYM	0.5	0.6	87.5	89.4	4.5	4.8
T_5 $^1/_2$N + PK+$^1/_2$N FYM	0.4	0.5	87.6	90.9	4.1	4.4
T_6 NPK + poultry litter	0.6	0.7	91.3	94.9	4.9	5.2
T_7 $^1/_2$N + PK + $^1/_2$N poultry litter	0.5	0.6	89.5	90.5	4.7	5.0
T_8 NPK + forest litter	0.3	0.4	88.1	91.0	3.3	3.6
T_9 $^1/_2$N + PK + $^1/_2$N forest litter	0.3	0.4	88.7	91.0	3.7	4.1
T_{10} $^1/_2$N+ PK + *Azospirillum*	0.3	0.4	86.9	89.4	3.3	3.5
T_{11} NPK + FYM + Zn	0.5	0.6	88.2	89.2	4.5	4.9
T_{12} forest litter burned+$^1/_2$ FYM	0.2	0.2	84.6	83.1	2.7	2.6
SE ±	0.06	0.07	0.93	1.26	0.24	0.23
CD (P=0.05)	0.16	0.19	2.74	3.70	0.70	0.68

over control in all the treatments except in $^1/_2$N + PK, $^1/_2$N + PK + *Azospirillum* in 2001 and forest litter burned + $^1/_2$ FYM in both the years of the cultivation. Sihag et al. (5) 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 under FYM followed by green manuring and press mud treatments.

The build up of inorganic P in different nutrient management practices ranged from 0.1 to 8.1% (0.2 to 15.2 kg/ha) with an average of 4.0% (7.6 kg/ha), and 7.1 to 13.9% (13.2 to 26.0 kg/ha) with an average of 9.0% (16.7 kg/ha) over control in 2001 and 2002, respectively (Table 1). On an average, inorganic P recorded in NPK + poultry litter was 5.2, 5.0, 4.0 and 4.8% higher as compared to inorganic P in NPK + FYM, NPK + FYM + Zn, NPK + forest litter and 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 (6).

Available P

The available P content in the soil ranged from 2.6 to 4.9 kg/kg with an average of 3.7 mg/kg, and 2.5 to 5.2 mg/kg with an average of 4.0 mg/kg in 2001 and 2002, respectively (Table 1). In both the years of cultivation, available P showed a significant increase in all the treatments except in forest litter burned + $^1/_2$ FYM over control. The highest available P was recorded in NPK + poultry litter followed by $^1/_2$N + PK + $^1/_2$N poultry litter and the lowest was in control. The available P in NPK + poultry litter, NPK + FYM and NPK + FYM + Zn was at par and was significantly higher than the levels present in NPK and NPK + forest litter. The available P content in $^1/_2$N + PK + $^1/_2$N poultry litter showed a significant increase over $^1/_2$N + PK + $^1/_2$N forest litter and NPK. Further, available P in $^1/_2$N + PK + $^1/_2$N FYM also showed a significant increase over NPK. The available P content in NPK, $^1/_2$N + PK and $^1/_2$N + PK + *Azospirillum* did not show any significant difference. Available P in NPK was significantly higher than forest litter burned+ $^1/_2$ FYM. Further, in 2002, available P in $^1/_2$N + PK and $^1/_2$N + PK + *Azospirillum* also showed a significant increase over forest litter burned + $^1/_2$ FYM.

The data revealed that relatively higher available P levels accumulated in treatments where NPK fertilizers were applied in combinations with poultry litter and FYM. Higher available P content in these integrated treatments might be due to relatively higher input of P through fertilizer and poultry litter or FYM. Available P content in NPK + poultry litter, NPK + FYM, NPK + FYM + Zn was 44.1 (3.4 kg/ha), 32.4 (2.5 kg/ha) and 32.4% (2.5 kg/ha), and 44.4 (3.6 kg/ha), 33.3 (2.7 kg/ha) and 36.1% (2.9 kg/ha) higher as compared to NPK treatment in 2001 and 2002, respectively. Laxminarayana (7) observed highest available P (12.15 kg/ha) with the application of 100% NPK + poultry manure. Singh et al. (8) also reported 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.

Comparisons of the treatments receiving half N from fertilizer and other half from organic sources showed that available P in $^1/_2$N + PK + $^1/_2$N poultry litter, $^1/_2$N + PK + $^1/_2$N FYM, $^1/_2$N + PK + $^1/_2$N forest litter treatments was 38.2 (2.9 kg/ha), 20.6 (1.6 kg/ha) and 8.8% (0.7 kg/ha), and 38.9 (3.1 kg/ha), 22.2 (1.8 kg/ha) and 13.9% (1.1 kg/ha) higher over NPK in 2001

Table 2. Effect of nutrient management practices on organic P and total P in soil.

Treatments	Organic P (mg/kg) 2001	Organic P (mg/kg) 2002	Total P (mg/kg) 2001	Total P (mg/kg) 2002
T_1 Control	129.7	126.9	214.2	210.2
T_2 $^1/_2$N + PK	133.8	133.3	220.5	224.5
T_3 NPK	135.2	136.6	222.7	226.7
T_4 NPK + FYM	140.1	143.2	227.6	232.6
T_5 $^1/_2$N + PK + $^1/_2$N FYM	137.9	139.4	225.5	230.3
T_6 NPK + poultry litter	145.0	152.3	236.3	247.2
T_7 $^1/_2$N + PK + $^1/_2$N poultry litter	142.3	148.1	231.8	238.6
T_8 NPK + forest litter	137.3	139.1	225.4	230.1
T_9 $^1/_2$N + PK + $^1/_2$N forest litter	137.6	140.2	226.3	231.2
T_{10} $^1/_2$N + PK + *Azospirillum*	135.4	136.2	222.3	225.6
T_{11} NPK + FYM + Zn	140.0	144.5	228.2	233.7
T_{12} Forest litter burned + $^1/_2$ FYM	130.7	130.1	215.3	213.2
SE ±	1.80	2.19	2.29	2.67
CD (P=0.05)	5.28	6.44	6.73	7.84

and 2002, respectively. The significantly higher available P in $^1/_2$N + PK + $^1/_2$N poultry litter over $^1/_2$N + PK + $^1/_2$N forest litter and NPK, and in $^1/_2$N + PK + $^1/_2$N FYM over NPK suggested that application of half N through poultry litter and FYM in combination with $^1/_2$N + PK could suitably be used to build up available P levels in situations where fertilizers are not adequately available. The rate of build up of available P in various nutrient management practices was estimated to be 0.1 to 3.0 kg P/ha per yr with an average of 1.8 kg P/ha per yr. These results corroborate the findings of Humtsoe and Chauhan (9) who reported a build up of 1.67, 1.47 and 1.30 kg available P/ha per yr in NPK, NPK + FYM and NPK + FYM + lime treatments, respectively. The accumulation of available P in different treatments caused a change in P fertility status from low to medium only in NPK + poultry litter and $^1/_2$N + PK + $^1/_2$N poultry litter treatments after two years of continuous cultivation and nutrient management. The reason that highest amount of available P accumulated in NPK + poultry litter followed by $^1/_2$N + PK + $^1/_2$N poultry litter, NPK + FYM + Zn, NPK + FYM and $^1/_2$N + PK + $^1/_2$N 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. Further, the capacity factor (b) when computed as the ratio of available P and solution P for different treatments revealed that the availability of P to plants during growth period was highest in NPK + poultry litter as compared to other treatments.

Organic P

The organic P content in the soil varied from 129.7 to 145.0 mg/kg with an average of 137.1 mg/kg, and 126.9 to 152.3 mg/kg with an average of 139.2 mg/kg in 2001 and 2002, respectively (Table 2). In both the years of cultivation, organic P content in the soil increased significantly in all the treatments except $^1/_2$N + PK and forest litter burned + $^1/_2$ FYM over control. The highest organic P was recorded in NPK + poultry litter followed by $^1/_2$N + PK + $^1/_2$N poultry litter and the lowest in control.

In 2001, organic P content in NPK + poultry litter showed a significant increase over NPK and NPK + forest litter treatments. Further, organic P content in $^1/_2$N + PK + $^1/_2$N poultry litter was at par with $^1/_2$N + PK + $^1/_2$N FYM and $^1/_2$N + PK + $^1/_2$N forest litter, but was significantly higher as compared to NPK treatment. In 2002, organic P in NPK + poultry litter showed a significant increase over NPK + FYM, NPK + FYM + Zn, NPK + forest litter and NPK. Further, organic P in NPK + FYM + Zn and NPK + FYM also showed a significant increase over NPK. The organic P content in $^1/_2$N + PK + $^1/_2$N poultry litter was significantly higher as compared to $^1/_2$N + PK + $^1/_2$N FYM, $^1/_2$N + PK + $^1/_2$N forest litter and NPK treatments. Also, organic P in NPK was significantly higher as compared to forest litter burned + $^1/_2$ FYM. The data led to conclude that addition of NPK with poultry litter caused a significant increase in organic P over NPK in both the years.

The build up of organic P in different nutrient management practices ranged from 2.2 to 34.3 kg/ha (0.8 to 11.6%) with an average of 18.0 kg/ha (6.2%), and 7.2 to 56.9 kg/ha (2.5 to 20.0%) with an average of

30.0 kg/ha (10.5%) over control in 2001 and 2002, respectively (Table 2). After two years, the rate of build up of organic P in various nutrient management practices was estimated to be 3.6 to 28.5 kg P/ha per yr with an average of 15.0 kg P/ha per yr. Higher build up of organic P in NPK + poultry litter over NPK + forest litter and NPK in 2001, and over NPK + FYM, NPK + FYM + Zn, NPK + forest litter and NPK in 2002 could be due to higher levels of P added through poultry litter and variation in microbial activity and nature of microbial metabolites. Further, in 2002, organic P in NPK + FYM and NPK + FYM + Zn was significantly higher than NPK. These results suggested that addition of NPK in combination with FYM and poultry litter favored higher build up of organic P as compared to application of NPK alone or with forest litter. The significantly higher organic P content in $^1/_2$N + PK + $^1/_2$N poultry litter over NPK in 2001 and over $^1/_2$N + PK + $^1/_2$N FYM, $^1/_2$N + PK + $^1/_2$N forest litter and NPK in 2002, could also be ascribed to relatively higher addition of P through poultry litter. The increase in organic P on addition of chemical fertilizers and organic residues either alone or in combination has also been reported by Humtsoe (10).

Total P

The total P content in the soil ranged from 214.2 to 236.3 mg/kg with an average of 224.7 mg/kg, and 210.2 to 247.2 mg/kg with an average of 228.6 mg/kg in 2001 and 2002, respectively (Table 2). In both the years, highest total P was recorded in NPK + poultry litter and lowest in control. The total P content in various nutrient management practices showed a significant increase in all the treatment except in forest litter burned + $^1/_2$ FYM and $^1/_2$N + PK in 2001, and forest litter burned + $^1/_2$ FYM in 2002 over control.

In both the years, total P content in NPK + poultry litter was significantly higher as compared to NPK + FYM + Zn, NPK + FYM, NPK + forest litter and NPK treatments. The total P content in $^1/_2$N + PK + $^1/_2$N poultry litter showed a significant increase over NPK. The significant increase in total P in NPK + poultry litter and $^1/_2$N + PK + $^1/_2$N poultry litter over NPK was 6.1 and 4.1% in 2001, and 9.0 and 5.2% in 2002, respectively. In 2001, total P in $^1/_2$N + PK + *Azospirillum*, $^1/_2$N + PK, NPK and forest litter burned + $^1/_2$ FYM did not differ significantly, but in 2002, total P in $^1/_2$N + PK, NPK and $^1/_2$N + PK + *Azospirillum* showed a significant increase as compared to forest litter burned + $^2/_2$ FYM. In 2002, total P in $^1/_2$N + PK + $^1/_2$N poultry litter was significantly higher as compared to $^1/_2$N + PK + $^1/_2$N FYM.

The build up of total P in different nutrient management practices varied from 2.5 to 49.5 kg/ha with an average of 25.6 kg/ha, and 6.7 to 82.9 kg/ha with an average of 45.1 kg/ha over control in 2001 and 2002, respectively. The total P in NPK + FYM and NPK + FYM + Zn was 2.2 and 2.5%, and 2.6 and 3.1% higher over NPK in 2001 and 2002, respectively. Santhy et al. (11) reported that inclusion of FYM along with inorganic fertilizer had a positive effect on the build up of total P content. There was no noticeable build up of inorganic and available P in forest litter burned + $^1/_2$ FYM treatment. However, the lowest rate (3.4 kg P/ha per yr) of build up of total P in this treatment was mainly in the form of organic P (3.6 kg P/ha per yr). This may be because of the reason that forest litter burned + $^1/_2$ FYM treatment has not received any inorganic P input and burning of forest litter might have stimulated the transformation of soil P and P in forest litter burned + $^1/_2$ FYM to contribute towards organic P pool. An analysis of data established that on an average, solution P, inorganic P, available P and organic P represented 0.2, 39.0, 1.7 and 61.0% of total P.

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