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RESEARCH PAPER

Effect of twelve years integrated nutrient management practices on soil fertility and performance of upland rice in terraced land

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A long-term field experiment was started in 2001 on newly constructed bench terraces at the Department of Soil and Water Conservation in the experimental farm of School of Agricultural Science and Rural Development (SASRD), Nagaland University (NU), Medziphema, Nagaland to study the long term effects of various nutrients management practices on performance of upland rice and fertility of terraced land under rainfed condition. Twelve treatments involving N, P and K (NPK) fertilizers, farmyard manure (FYM), poultry litter, forest litter, *Azospirillum* and Zn either alone or in combinations were applied continuously for twelve years to evaluate the effect of integrated nutrient management practices on available N, P and K content and performance of upland rice in a terraced land. The available N and K content increased significantly in all the treatments whereas, available P content increased significantly in all the treatments except Forest litter burned+ ½ FYM over control. The highest accumulation of available N, P and K was found in NPK+ Poultry litter, NPK+ FYM and ½N+ PK+ ½N Forest litter treatments, respectively. The rate of build up of available N, P and K in different nutrient management practices varied from 3.57 to 22.5, 0.19 to 1.09 and 3.35 to 13.3 kg ha^{-1} yr^{-1}, respectively. Maximum plant height was recorded in NPK+ FYM+ Zn treatment. The number of productive tillers per plant was also highest in NPK+ FYM+ Zn treatment. The highest straw yield was recorded in NPK+ FYM followed by NPK+ Poultry litter treatment. The highest grain yield was recorded in NPK+ FYM+ Zn followed by NPK+ Poultry litter treatment. Compared with NPK, grain yield in NPK+ FYM+ Zn, NPK+ Poultry litter and NPK+ FYM treatments increased significantly and were 38.1, 34.43 and 32.6 per cent higher, respectively. Among different nutrient management practices, NPK+ FYM+ Zn proved to be the best practices followed by NPK+ Poultry litter and can suitably be recommended for use not only to build up available N, P and K levels but also to produce higher grain yield in terraced land under upland rice cultivation.

Key words : Terraced land, Available N P K, Grain, Straw yield

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INTRODUCTION

Bench terracing is the most reliable conservation measure frequently employed to protect cultivated slopes and make them suitable for intensive agriculture for sustainable production. Bench terracing usually expose infertile and biologically inert subsoil of less desirable properties for crop growth than those of the top soil (Chauhan, 2001). Consequently, the initial production potential of terrace land is generally low. Development of soil fertility of the exposed subsoil of terraced fields for sustained production however, is a time taking process. To develop fertility of the resultant surface soil after bench terracing, and also to increase the immediate as well as long term productivity of terraced land, sound fertility management practices should be adopted. That could ensure a steady buildup of the soil fertility and other physicochemical properties of the soil desirable for the growth of the plants.

Development of soil fertility of the resultant surface soil after terracing can be achieved through the addition of manures, fertilizers and the other amendments either alone or in combinations. Long -term manurial treatments have brought about an improvement in soil aggregates and an increase in availability of N, P and K. The grain yield increased significantly with continuous application of balanced fertilizers and FYM (Mishra and Sharma, 1997). Long-term application of manures and fertilizers either alone or in combination improved soil properties and also increased availability of N, P and K and crop yield (Mathur, 1997).

Organic residues like straw, compost and FYM have been successfully used to improve soil tilth and increase the proportion of water stable crumbs in soil. Most of the phosphate and probably all the potassium FYM contains is as effective as fertilizer phosphate and potassium but only one-quarter of the nitrogen is as effective as fertilizer N (Russell, 1973). Soil fertility must be periodically estimated as there is continuous removal of macro and micro nutrients by the crop intensively grown in every crop season. In order to achieve higher productivity and profitability, every farmer should realize that fertility levels must be measured as these measurements can then be used to manage soil fertility. Fertilizing soils to bring all the deficient elements at high levels as to provide sufficient ionic activity in soil solution for crop uptake is one of the important considerations for maximization of crop yield (Verma *et al.*, 2013). Addition of fertilizer, manures, bio-fertilizers and forest litter either alone or in combinations would not only affect the levels of available nutrients but also the properties of the soil. These changes in turn would affect soil fertility status and crop performance. The levels of available N, P and K together with organic C content and pH of the soil could be considered main soil fertility determinants of acid soils of Nagaland. The effect of continuous additions of N, P and K fertilizers and amendments on the status of soil fertility and performance of upland rice (*Oryza sativa* L.) on terraced land in Nagaland has not been studied in detail.

In view of the above facts, the present investigation was carried out to study the effect of continuous cultivation and integrated nutrient management for twelve years on soil fertility and the performance of upland rice (*Oryza sativa* L.) in terraced land under rainfed conditions.

RESEARCH METHODOLOGY

A hill slope of 22 per cent was bench terraced in 2001 at the experimental farm of the Department of Soil Conservation, School of Agricultural Sciences and Rural Development, Medziphema, Nagaland. Three numbers of bench terraces, 26.0 m long and 3.5 m wide were constructed manually. 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. A field experiment on these terraces was established in 2001 and has been maintained since then. The crop and soil data collected in *Kharif* 2012 after twelve years of integrated 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. A total of 36 plot having individual sizes of 2.0 x 3.0 m^2 separated by a bund of 15 cm width were used in the experiment. 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^{-1} for rice was applied for NPK. 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 $ZnSO_4.7\ H_2O$ as basal dose. *Azospirillum* was used as seed treatment before sowing @ 20 g kg^{-1} 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 form of single super phosphate and muriate of potash, respectively were applied as basal dose. For Forest litter burned+ ½ FYM treatment which resembles farmers' practice in Nagaland, the required amount of forest litter @ 5.0 t ha^{-1} was evenly spread on the soil surface and burned there. The ash was incorporated thoroughly in the soil. Thereafter, 5 t ha^{-1} of FYM (½ FYM) was applied 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 (land race) was sown with a spacing of 20 cm row to row using a seed rate of 75 kg ha^{-1}.

Five plants from each plot were randomly selected for determination of numbers productive tillers and plant height. The grain and straw yield was obtained after the harvest of 1 m^2 area separately and data was used to compute grain and straw yield (q ha^{-1}). Soil samples from individual plots were collected after the harvest of rice crop and air dried at room temperature. The available N content of the soil was estimated by alkaline permanganate method of Subbiah and Asija (1956). The available P in soil was extracted by Bray's method No. 1 (1945) and the P content of the extract was estimated colorimetrically (Jackson, 1973). The available K was extracted from the soil with neutral normal ammonium acetate (Jackson, 1973) and estimated flame photometrically. The statistical analysis of the data was done as per procedure outlined by Gomez and Gomez (1984).

Research Findings and Analysis

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Available N :

The continuous application of fertilizer, FYM, poultry litter, forest litter and *Azospirillum* in different combinations caused a significant increase in available N in all the treatments. The available N content in soil ranged from 320.13 to 590.17 kg ha^{-1} with an average of 478.58 kg ha^{-1} (Table 1). Among different treatments, highest available N was recorded in NPK+ Poultry litter and lowest available N was recorded in control. The available N content in NPK+ FYM, NPK+ FYM+ Zn and NPK+ Poultry litter showed a significant increase over NPK and NPK+ Forest litter treatments. The available N in ½N+ PK+ *Azospirillum* was significantly higher as compared to ½N+ PK+ ½N FYM, ½N+ PK+ ½N Poultry litter, NPK and ½N+ PK treatments. The available N in ½N+ PK+ ½N Forest litter was at par with ½N+ PK+ ½N Poultry litter, but significantly higher as compared to ½N+ PK+ ½N FYM.

The significant increase in available N in NPK+ Poultry litter, NPK+ FYM and NPK+ FYM+ Zn over NPK+ Forest litter and NPK might be due to the variations in the build up of the available N constituents in these treatments. Laxminarayan and Patiram (2006) found that total N content of the soil increased significantly with the integrated applications of NPK and different organic manures over that of NPK alone. Imtilemla *et al.* (2009) also observed that addition of fertilizer alone or in combinations with FYM, poultry litter, forest litter and also with *Azospirillum* resulted in an increase in available N content in the soil on terraced land under continuous cultivation of rice for five years. The combined effect of the processes of transformation of N added through fertilizers and organic sources, mineralization of native organic N compound and loss of N from soil including crop removal may be responsible for the increase in available N pool in these treatments.

After twelve years of continuous cultivation the rate of build up of available N in various nutrient management

Table 1 : Effect of various nutrient management practices on soil available N, P and K

Treatment No.	Treatment particulars	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1	Control	320.13	8.87	143.50
T_2	½N+ PK	363.00	14.13	183.70
T_3	NPK	365.57	19.27	186.47
T_4	NPK+ FYM	575.93	22.17	268.33
T_5	½N+ PK+ ½ FYM	521.50	21.07	236.00
T_6	NPK+ Poultry litter	590.17	21.13	271.37
T_7	½N+ PK+ ½ N Poultry litter	536.80	19.77	262.83
T_8	NPK+ Forest litter	459.90	19.60	239.80
T_9	½N+ PK+ ½ Forest litter	547.07	18.27	303.43
T_{10}	½N+ PK+ *Azospirillum*	563.77	18.57	207.90
T_{11}	NPK+ FYM+ Zn	553.43	22.00	270.60
T_{12}	Forest litter burned+ ½FYM	345.80	11.17	192.47
S.E.±		6.63	0.90	6.39
C.D. (P=0.05)		19.46	2.64	18.75

practices was estimated to be 3.57 to 22.5 kg N ha^{-1} yr^{-1} with an average of 14.4 kg N ha^{-1} yr^{-1}. These findings are in agreement with those reported by Humtsoe and Chauhan (2005).

Available P :

The available P content in soil ranged from 8.87 to 22.17 kg ha^{-1} with an average of 18.0 kg ha^{-1} (Table 1). The addition of fertilizer, FYM, poultry litter, forest litter and *Azospirillum* in different combinations continuously for twelve years caused a significant increase in available P in all the treatments except in Forest litter burned+ ½ FYM over control. The highest available P was recorded in NPK+ FYM and lowest was recorded in control. The available P in NPK+ FYM and NPK+ FYM + Zn was significantly higher than the levels present in NPK and NPK+ Forest litter treatments. Available P in ½N+ PK+ ½N FYM was significantly higher as compared to ½N+ PK+ ½N Forest litter, but it did not differed significantly when to ½N+ PK+ ½N Poultry litter, ½N+ PK+ *Azospirillum* and NPK treatments.

The higher available P accumulation in treatments where NPK fertilizers were applied in combinations with FYM and poultry litter might be due to additional P input through FYM and poultry litter. These results are in accordance with those reported by other workers Lal *et al*. (2000); Tolanur and Badanur (2003) and Laxminarayana (2006). Singh *et al*. (2006) 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. After twelve years of continuous cultivation and nutrient management the rate of build up of available P in different nutrient management practices was estimated to be 0.19 to 1.09 kg P ha^{-1} yr^{-1} with an average of 0.83 kg P ha^{-1} yr^{-1}. Imtilemla *et al*. (2009) also estimated the rate of build up of available P ranged from 0.1 to 2.9 kg P ha^{-1} yr^{-1} with an average of 1.2 kg P ha^{-1} yr^{-1} after five years of terraced cultivation.

The accumulation of available P in different treatments after twelve years caused a change in P fertility status from low to medium in all the treatments except control. The fact that highest amount of available P accumulated in NPK+ FYM followed by NPK+ FYM+ Zn, NPK+ Poultry litter, ½N+ PK+ ½N FYM and ½N+ PK+ ½N Poultry litter treatments suggested that besides amount and source of P input, other factors were also affecting available P levels in soil. The increase in available P may be ascribed to 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. These findings are in agreement with those reported by Banerjee *et al*. (2006) and Faujadar and Sharma (2013).

Available K :

The available K content in soil varied from 143.50 to 303.43 kg ha^{-1} with an average of 230.53 kg ha^{-1} (Table 1). Continuous application of fertilizer, FYM, poultry litter, forest litter and *Azospirillum* in different combinations caused a significant increase in available K in all the treatments. The available K content in NPK+ Poultry litter, NPK+ FYM and NPK+ FYM+ Zn showed a significant increase over NPK+ Forest litter and NPK treatments. The highest available K content recorded in ½N+ PK+ ½N Forest litter showed a significant increase over all other treatments. The available K content in ½N+ PK+ ½N Poultry litter, ½N+ PK+ ½N FYM and ½N+ PK+ *Azospirillum* was increased significantly as compared to NPK and ½N+ PK treatments. The available K in ½N+ PK+ ½N Poultry litter was also found to be significantly higher as compared to ½N+ PK+ ½N FYM and ½N+ PK+ *Azospirillum* treatments.

The increase in available K on addition of NPK with FYM or poultry litter was perhaps related to the input and uptake of K in these treatments. A significant increase in available K in Forest litter burned+ ½ FYM over control might be the effect of burning which caused a significant increase in extractable K levels in the soil.

After twelve years of continuous cultivation, the rate of build up of available K in various nutrient management practices was estimated to be 3.35 to 13.3 kg K $ha^{-1}yr^{-1}$ with an average of 7.9 kg K ha^{-1} yr^{-1}. Imtilemla *et al.* (2009) also estimated the rate of build up of available K ranged from 3.1 to 15.2 kg K ha^{-1} yr^{-1} with an average of 7.5 kg K ha^{-1} yr^{-1}. The increase in available K may be due to combined effect of addition of K through fertilizers and organic sources, weathering of K minerals and loss of K from soil including crop removal. All the treatments showed a significant increase in available K over control. Similar results were also reported by Sood *et al.* (2008). Further, after twelve years of continuous cultivation and nutrient management, K fertility status remained medium in all the treatments except in ½N+ PK+ ½N Forest litter, where, it changed from medium to high.

Plant height :

The plant height in different treatments varied from 90.80 to 116.80 cm with an average of 105.27 cm (Table 2). After twelve years of continuous cultivation and nutrient management, plant height showed a significant increase only in NPK+ FYM, NPK+ Poultry litter and NPK+ FYM+ Zn treatments over control. The plant height in NPK+FYM, NPK+ Poultry-litter and NPK+ FYM+ Zn treatments were taller, but did not differed significantly as compared to NPK and NPK+ Forest litter. The plant height in ½N+PK+½N-FYM, ½N+PK+½N-Forest-litter and ½N+ PK+ ½N Poultry litter did not differ significantly when compared to NPK and ½N+ PK+ *Azospirillum* treatments. The data revealed that addition of NPK with FYM or poultry-litter brought about a significant increase in plant height as compared to NPK. But substituting ½N through poultry-litter, forest litter or FYM did not result in significant increase in plant height as compared to control. The increase in plant height in different treatments over control varied from 6.5 to 28.63 per cent with an average of 17.38 per cent. The increase in plant height in NPK+ FYM+ Zn, NPK+ Poultry litter, and NPK+ FYM over NPK was 12.96, 12.38 and 10.83 per cent, respectively. Similar results were also made by Verma *et al.* (2006).

Number of productive tillers :

The number of productive tillers per plant ranged from 1.5 to 5.1 with an average of 3.8 (Table 2). The number of productive tillers in all the treatments showed a significant increase over control. The number of productive tillers in NPK+ FYM, NPK+ Poultry litter, NPK+ FYM+ Zn and NPK+ Forest litter showed a significant increase over NPK treatment. The productive tillers in ½N+ PK+ ½N Poultry litter was at par with ½N+ PK+ ½N FYM , ½N+ PK+ *Azospirillum* and ½N+ PK+ ½N Forest litter treatments but showed a significant increase over NPK and ½N+ PK treatments.

The significant increase in productive tillers in NPK+ FYM+ Zn, NPK+ Poultry litter, NPK+ FYM and ½N+ PK+ ½N Poultry litter over NPK was 59.38, 53.13, 50.00 and 40.63 per cent, respectively. The significant increase in productive tillers in these treatments might be due to proportionate higher availability of N, P and K and other essential nutrients in soil particularly during early active period of growth and nutrient uptake and improvement in plant growth conditions in these treatments as compared to NPK treatment.

Straw yield :

The straw yield in different treatments ranged from 35.6 to 82.8 q ha^{-1} with an average of 63.97 q ha^{-1} (Table 2). The straw yield showed a significant increase in all the treatments except Forest litter burned+ ½ FYM over control. The highest straw yield was recorded in NPK+ FYM and the lowest was in control. The straw yield in NPK+ Poultry litter, NPK+ FYM and NPK+ FYM+ Zn showed a significant increase over NPK and NPK+ Forest litter treatments. The straw yield in ½N+ PK+

Table 2 : Effect of various nutrient management practices on performance of upland rice

Treatment No.	Treatment particulars	Plant height (cm)	Productive tillers plant^{-1}	Straw yield (q ha^{-1})	Grain yield (q ha^{-1})
T_1	Control	90.80	1.50	35.60	14.10
T_2	½N+ PK	98.30	2.80	48.20	24.40
T_3	NPK	103.40	3.20	56.50	27.30
T_4	NPK+ FYM	114.60	4.80	82.80	36.20
T_5	½N+ PK+ ½N FYM	104.70	3.60	71.40	30.20
T_6	NPK+ Poultry litter	116.20	4.90	82.20	36.70
T_7	½N+PK+½N Poultry litter	108.50	4.50	66.80	31.80
T_8	NPK+ Forest litter	103.70	4.30	64.10	29.30
T_9	½N+ PK+ ½N Forest litter	107.30	4.00	68.20	28.80
T_{10}	½N+PK+*Azospirillum*	102.20	3.70	70.40	28.40
T_{11}	NPK+ FYM+ Zn	116.80	5.10	80.30	37.70
T_{12}	Forest litter burned+ ½FYM	96.70	3.20	41.20	25.80
S.E.±		6.82	0.31	3.94	2.38
C.D. (P=0.05)		20.02	0.91	11.55	6.97

½N FYM, ½N+ PK+ ½N Forest litter and ½N+ PK+ *Azospirillum* also showed a significant increase over NPK. Again, straw yield in ½N+ PK+ Poultry litter was at par with NPK, but was significantly higher as compared to ½N+ PK.

The significant increase in straw yield in NPK+ FYM, NPK+ Poultry litter, and NPK+ FYM+ Zn over NPK was 46.55, 45.49 and 42.12 per cent, respectively. This might be due to better utilization of nutrients from the soil in these treatments that resulted proper vegetative growth and increased straw yield as compared to NPK. These findings are in accordance with the findings reported by Singh *et al*. (2006). Treatments receiving half N from fertilizer and half N from FYM or Forest litter or Poultry litter brought about an increase of 26.37, 20.71 and 18.23 per cent straw yield, respectively over NPK. This might be due to improved physico-chemical properties of the soil together with increase in availability of nutrients resulted from addition of FYM or forest litter or poultry litter to substitute half of the N.

Grain yield :

The grain yield in different treatments varied from 14.1 to 37.7 q ha^{-1} with an average of 29.22 q ha^{-1} (Table 2). The grain yield in different treatments showed a significant increase in all the treatments over control. The highest grain yield was recorded in NPK+ FYM + Zn and the lowest was in control. The grain yield in NPK+ FYM+ Zn and NPK+ FYM was at par with NPK+ Poultry litter, but significantly higher as compared to NPK and NPK+ Forest litter. The grain yield in ½N+ PK+ ½N Poultry litter was at par with ½N+ PK+ ½N Forest litter, ½N+ PK+ ½N FYM, NPK and ½N+ PK+ *Azospirillum*, but showed a significant increase over ½N+ PK. Inoculation of *Azospirillum* with ½N+ PK also caused a significant increase in grain yield over control.

The significant increase in grain yield in NPK+ FYM+ Zn, NPK+ Poultry litter, and NPK+ FYM over NPK was 38.1, 34.43 and 32.6 per cent, respectively. Kumar and Singh (2006) also reported that application of organic manures (FYM and poultry manure) significantly improved the growth, yield and yield attributes of rice during two years of experimentation. Similarly many other worker have also reported the superiority of application of FYM along with inorganic fertilizers over sole inorganic fertilizers in increasing yield of rice (Setty and Channabasavanna, 1990; Mathew *et al*., 1993; Prasad, 1994; Swarup and Yaduvanshi, 2000 and Sentivelu and Prapha, 2007). The grain yield in ½N+ PK+ *Azospirillum* was 14.65 per cent higher as compared to ½N+ PK. The atmospheric N fixed by *Azospirillum* might be partly responsible for increase in N uptake and plant growth and consequently the higher grain yield in ½N+ PK+ *Azospirillum* treatment. Chauhan *et al*. (2010) also reported significant increase in grain yield in ½N+ PK+ *Azospirillum* as compared to ½N+ PK.

The computation of relative efficiency of crop production in different treatments based on yield response over NPK (taking NPK as 100) established that the grain yield in NPK+ FYM+ Zn, NPK+ Poultry litter and NPK+ FYM was 138.1, 134.43 and 132.6 per cent, higher over NPK treatment, respectively. Based on the relative efficiency, the treatments could be grouped into three different categories in respect of their productivity. The first category consists of NPK+ FYM +Zn, NPK+ Poultry litter and NPK+ FYM treatments, which produced significantly higher grain yield than NPK. The second category includes ½N+ PK+ ½N Poultry litter, ½N+ PK+ ½N FYM, NPK+ Forest litter, ½N+ PK+ ½N Forest litter and ½N+ PK+ *Azospirillum* which produced grain yield that were higher as well as at par with NPK. The third category consists of ½N+ PK, Forest litter burned+ ½ FYM and control, which produced significantly less than NPK.

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