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Integrated Nutrient Management on Performance of Rice in Terraced Land

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Abstract

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 ten years to evaluate the effect of integrated nutrient management practices on performance of upland rice in a terraced land. The plant height, numbers of tillers and productive tillers increased significantly in all the treatments whereas, grain yield increased significantly in all the treatments except ½N+PK and Forest litter burned+½ FYM over control. Among different nutrient management practices, NPK+Poultry litter produced maximum grain and straw yield. The grain yield in NPK+Poultry litter, NPK+FYM+Zn, NPK+FYM and NPK+Forest litter increased significantly (55.9, 45.7, 37.0 and 29.8%, respectively) as compared to addition of NPK alone. Increase in straw yield in different nutrient management practices ranged from 22.0 to 130.0%. The uptake of N, P and K was significantly higher in treatments where NPK was added with FYM and poultry litter. The average contribution towards apparent recovery of N, P and K from FYM was 36.4, 56.2 and 69.2%; from poultry litter 43.5, 27.7 and 85.9%; and from forest litter 80.4, 98.8 and 44.7%, respectively. After a decade of continuous cultivation, NPK+Poultry litter was found to be the best nutrient management practice that can be adopted for cultivation of upland rice on terraced land followed by NPK+FYM+Zn and NPK+FYM.

1. Introduction

Bench terracing is the most reliable conservation measure frequently employed to manipulate surface topography of hill slopes to convert them to suit intensive agriculture. To increase immediate as well as long term productivity of newly terraced land, sound fertility management practices are obviously needed not only for the immediate improvement of nutrient status of the resultant surface soil but also to ensure a steady build up of soil fertility together with other soil properties suitable for plant growth. Mechanical soil and water conservation technique like bench terracing is one of most reliable conservation measure frequently employed to manipulate surface topography of hill slopes to convert them to suit intensive agriculture. To increase long term productivity of resultant surface soil, sound soil fertility management practices are obviously needed to ensure a steady build up of soil fertility together with other soil physical properties suitable for plant growth. Soil organic matter is an important soil quality determinant as it affects soil fertility and plant growth conditions as well as environment quality parameters by influencing a number of physical, chemical and biological properties of the soil. Fertilizers, manures and other amendments either alone or in combinations could be used to develop nutrient supplying capacity of the resultant surface soil after terracing. The data pertaining to the long term effect of integrated nutrient management practices on the performance of upland rice in respect of plant height, number of tillers and productive tillers, grain and straw yield, and uptake of N, P and K on terraced land in acid soils of Nagaland has not been studied. The present investigation was carried out to evaluate the effect of integrated nutrient management practices and continuous cropping for a decade on performance of upland rice in a terraced land under rainfed conditions of Nagaland.

2. Materials and Methods

A virgin hill slope (22%) was bench terraced in 2001 at the institutional farm. Three numbers of bench terraces, 26.0 m long and 3.5 m wide were constructed manually. A field experiment on these terraces was established in 2001 and has been maintained since then. The soil samples collected in *kharif* 2010 after ten 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 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 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% 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 in all treatments 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}.

Five plants from each plot were randomly selected for determination of numbers of tillers, numbers of productive tillers and plant height. The numbers of tillers of these selected plants were recorded at 60 days after sowing (DAS) and average number of tillers was computed from the data. Similarly, numbers of productive tillers were recorded at maturity stage and average was computed. The plant height (cm) was measured at 115 DAS (maturity stage) from the ground base to the tip of the ear of the selected plants and average height computed. Plant samples collected from each plot were first washed with ordinary water to remove soil and dust adhering to plant parts. These were then finally washed with distilled water. Then grain and straw were separated and dried first in the air and finally dried in an oven at 55 to 60º C till a constant dry weight. These samples were grinded in a grinder and used for N, P and K analysis. The grain and straw yield was obtained after the harvest of 1 m^2 area separately. The grain and straw were dried after thrashing and yield (g m^{-2}) recorded. The plants of this area were harvested from the ground base. The data was used to compute grain and straw yield (q ha^{-1}). The nitrogen content of the plant parts was estimated colorimetrically using Nessler reagent (Jackson, 1973) in H_2SO_4 and H_2O_2 digested plant materials. The P and K content in plant were determined in triacid digested plant material (Jackson, 1973). Phosphorous was estimated colorimetrically and K content was determined flame photometrically (Jackson, 1973). The nutrient content of Grain and straw (g kg^{-1}) together with dry matter (straw+grain) yield was used to compute uptake of N, P and K (kg ha^{-1}) by the plant. The apparent nutrient recovery and percent contribution of organics towards nutrient recovery were calculated as follows as described by Laxminarayana and Patiram (2006).

Apparent nutrient recovery (%) = {(Uptake in treated plot – Uptake in control plot)/ Fertilizer dose} x 100

Contribution of organics to nutrient recovery (%) = {(Uptake in organic sources treated plot – Uptake in NPK plot)/ Nutrient applied through organic manure} x 100

The statistical analysis of the data was done as per procedure outlined by Gomez and Gomez (1984).

3. Results and Discussion

3.1. Plant height

The plant height of rice ranged from 92.5 to 118.8 cm with an average of 107.5 cm (Table 1). After a decade of integrated nutrient management and continuous cropping the plant height in all the treatments showed a significant increase over control. The plant height in NPK+FYM, NPK+Poultry litter, NPK+Forest litter and NPK+FYM+Zn were significantly higher over ½N+PK and NPK treatments. Substituting ½N through poultry litter also brought about a significant increase in plant height over NPK. The increase in plant height in NPK+FYM, NPK+Poultry litter, NPK+Forest litter and NPK+FYM+Zn over NPK was 11.2, 14.6, 8.1 and 13.2%, respectively. These results are in conformity to the observations made by Verma et al. (2006).

3.2. Number of tillers

The number of tillers per plant in different treatments varied from 2.3 to 5.2 with an average of 4.1 (Table 1). The number of tillers in all the treatments showed a significant increase over control. The maximum number of tillers was recorded in NPK+Poultry litter and NPK+FYM+Zn treatments where as the minimum was recorded in control. The number of tillers in NPK+Poultry litter, NPK+FYM+Zn, NPK+FYM and NPK+Forest litter showed a significant increase over NPK treatment. The increase in number of tillers in different treatments over control ranged from 40.6 to 127.5% with an average of 83.4%. The increase in number of tillers in NPK+FYM+Zn, NPK+Poultry litter, NPK+FYM and NPK+Forest litter over NPK was 37.7, 36.8, 32.5 and 22.8%, respectively. The increase in number of tillers on addition of N is expected, as N is essential part of cell constituents and has been reported to favour vegetative growth (Russell, 1973).

3.3. Number of productive tillers

The number of productive tillers per plant in different treatments varied from 2.0 to 5.1 with an average of 3.8 (Table 1). The

Table 1: Effect of integrated nutrient management practices on plant height, tillers, productive tillers, grain yield and straw yield of rice

Treatment	Plant height (cm)	Tillers plant^{-1}	Productive tillers plant^{-1}	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})
Control	92.5	2.3	2.0	20.0	35.7
½N+PK	99.2	3.2	2.8	21.1	46.5
NPK	103.7	3.8	3.3	30.3	55.3
NPK+FYM	115.3	5.0	4.9	41.5	81.5
½N+PK+½N FYM	107.6	3.9	3.7	30.7	69.0
NPK+Poultry litter	118.8	5.2	5.1	47.2	82.0
½N+PK+½N Poultry litter	109.7	4.1	3.9	38.2	66.7
NPK+Forest litter	112.1	4.7	4.5	39.3	60.8
½N+PK+½N Forest litter	106.6	3.8	3.7	33.1	58.3
½N+PK+*Azospirillum*	107.3	4.1	3.8	34.3	62.8
NPK+FYM+Zn	117.4	5.2	5.0	44.1	80.3
Forest litter burned+½ FYM	99.7	3.3	3.1	24.4	43.5
SEm+	1.84	0.11	0.12	1.73	3.08
CD (p=0.05)	5.38	0.33	0.36	5.09	9.08

productive tillers in all the treatments showed a significant increase over control. The maximum number of productive tillers was recorded in NPK+Poultry litter and minimum was recorded in control. The productive tillers in NPK+Poultry litter, NPK+FYM+Zn and NPK+FYM treatments showed a significant increase over NPK+Forest litter and NPK treatments. The productive tillers in NPK+Forest litter treatment were also significantly higher than NPK treatment. Substituting ½N through poultry litter, FYM or forest litter also brought about a significant increase in number of productive tillers over NPK. The percentage of tillers turning to productive tillers in different nutrient management practices ranged from 85.8 to 98.2% with an average of 93.6%. Chauhan et al. (2010) also reported that on an average 75.8% of tillers transformed into productive tillers in upland rice on terraced land. The significant increase in productive tillers in NPK+Poultry litter, NPK+FYM+Zn, NPK+FYM and NPK+Forest litter over NPK was 53.5, 52.5, 49.5 and 36.4%, 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. The significant decrease in productive tillers in farmers practice (Forest litter burned+½ FYM) over NPK was 6.1%. This might be due to the loss of organic C and N in burning that in turn, affected the nutrient availability and other soil conditions particularly water holding characteristic causing a reduction in number of tillers and productive tillers. Sharma and Mishra (2001) also reported total loss of organic matter and nitrogen due to residue burning.

3.4. *Grain yield*

The grain yield of rice in different treatments varied from 20.0 to 47.2 q ha^{-1}, with an average of 33.7 q ha^{-1} (Table 1). The grain yield in all the treatments showed a significant increase over control except in ½N+PK and Forest litter burned+½FYM. The highest grain yield was recorded in NPK+Poultry litter treatment and minimum was in control. The grain yield in NPK+Poultry litter, NPK+FYM, NPK+Forest litter and NPK+FYM+Zn treatments showed a significant increase over NPK. The grain yield in ½N+PK+½N Poultry litter also showed a significant increase over ½N+PK+½N Forest litter, ½N+PK+½N FYM and NPK treatments. The grain yield in ½N+PK+*Azospirillum*, ½N+PK+½N Forest litter and ½N+PK+½N FYM treatments was significantly higher than ½N+PK treatment. The increase in grain yield over control in different treatments varied from 5.1 to 135.0% with an average of 73.9%. Increase in grain yield on addition of fertilizer N has also been reported by Dutta et al. (2007). The significant increase in grain yield in NPK+Poultry litter, NPK+FYM+Zn, NPK+FYM and NPK+Forest litter over NPK was 55.9, 45.7, 37.0 and 29.8%, respectively. The grain yield in ½N+PK+*Azospirillum* was 62.6% 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 that significant increase in grain yield in ½N+PK+*Azospirillum* as compared to ½N+PK. Singh et al. (2006) reported that application of *Azospirillum* individually or in combinations with chemical fertilizer and FYM significantly increased the yield and yield attributes of rice over control.

3.5. *Straw yield*

The straw yield varied from 35.7 to 82.0 q ha^{-1} with an average of 61.9 q ha^{-1} (Table 1). The addition of fertilizers, FYM, poultry litter, forest litter and *Azospirillum* in different combinations caused a significant increase in straw yield of all the treatments over control except in Forest litter burned+½FYM. The maximum straw yield was recorded in NPK+Poultry litter treatment and minimum was recorded in control. The straw yield in NPK+Poultry litter, NPK+FYM and NPK+FYM+Zn treatments increased significantly over NPK+Forest litter and NPK treatments. The straw yield in ½N+PK+½N FYM and ½N+PK+½N Poultry litter treatments showed a significant increase over NPK, ½N+PK and Forest litter burned+½FYM treatments. The increase of straw yield over control in different treatments varied from 7.8 to 46.4 q ha^{-1} (22.0 to 130.0%) with an average of 28.6 q ha^{-1} (80.2%). The significant increase in straw yield in NPK+Poultry litter, NPK+FYM and NPK+FYM+Zn over NPK was 48.3, 47.4 and 45.2%, 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 Laxminarayana and Patiram (2006) and Singh et al. (2006). Treatments receiving ½N+PK+½N FYM, ½N+PK+½N Poultry litter, ½N+PK+*Azospirillum* and ½N+PK+½N Forest litter brought about an increase of 26.3, 21.5, 13.0 and 6.0% 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, poultry litter or forest litter to substitute half of the N. The significant decrease of 21.4% in straw yield in Forest litter burned+½FYM as compared to NPK might be due to burning induced changes in soil properties together with likely loss of nutrients in burning.

3.6. *N uptake*

The N uptake by rice plant as affected by different nutrient management practices varied from 24.1 to 71.5 kg ha^{-1} with an average of 46.4 kg ha^{-1} (Table 2). The highest N uptake was observed in NPK+Poultry litter followed by NPK+FYM and NPK+FYM+Zn. The N uptake in these treatments showed a significant increase over rest of the treatments. The N uptake in ½N+PK+½N poultry litter was significantly higher than NPK and ½N+PK+½N Forest litter. The N uptake in NPK+Forest litter was also significantly superior over NPK. The N uptake in NPK was significantly higher than ½N+PK and Forest litter burned+½ FYM. The N uptake in all the treatments increased from 16.2 to 196.7% (3.9 to 47.4 kg ha^{-1}) with an average of 100.9% (24.3 kg ha^{-1}) over control. Rice plant utilized 71.9, 60.3 and 59.9% more N in NPK+Poultry litter, NPK+FYM and NPK+FYM+Zn treatments as compared with NPK, respectively. This might be due to the improved physical conditions of the soils with better availability of N and also other essential nutrients added with these organic sources to rice crop. The combined effect of these produced higher grain and straw yield as observed in these treatments. These findings are in accordance with the findings reported by Laxminarayana and Patiram (2006) and Singh et al. (2006). The N uptake in ½N+PK+½N Poultry litter and NPK+Forest litter was significantly higher by 19.7 and 19..2%, respectively as compared with NPK whereas, it was 27.6 and 32.7% lower in ½N+PK and Forest litter burned+½ FYM treatments. This lower N uptake might be due to lower availability of N and relatively less favourable conditions of plant growth in these treatments resulting in lower grain and straw yield and lower content of N in grain and straw in these treatments.

3.7. *P uptake*

The P uptake by rice ranged from 4.7 to 15.1 kg ha^{-1} with an average of 9.9 kg ha^{-1} (Table 2). A significant increase in P uptake was recorded in all the treatments except ½N+PK and Forest litter burned+½ FYM over control. The P uptake in NPK+Poultry litter, NPK+FYM+Zn and NPK+FYM showed a significant increase over NPK+Forest litter and NPK treatments. The P uptake in ½N+PK+½N Poultry litter and ½N+PK+½N FYM was significantly superior over NPK. The increase in P uptake over control in all the treatments varied from 23.4 to 221.3% (1.1 to 10.4 kg ha^{-1}) with an average of 121.7% (5.7 kg ha^{-1}). The P uptake by rice plant in NPK+Poultry litter, NPK+FYM+Zn and NPK+FYM was 79.8, 70.2 and 64.3% higher as compared with NPK, respectively. This might be due to favourable effect of combined application of NPK with poultry litter or FYM resulting in higher availability and uptake of P to meet the need of growing plants in these treatments which produced higher grain and straw yield. Similar observations were also reported by Laxminarayana and Patiram (2006), Laxminarayana (2006) and Baskar (2003). Transformation of added P to relatively less available forms in treatments receiving inorganic fertilizers without organic sources affecting P availability might have resulted significantly lower P uptake (Singh et al., 2006). Further, the absence of contribution of mineralization of added organic P towards the P nutrition of plant in treatments without organic sources may also be partly responsible for low P uptake.

3.8. *K uptake*

The K uptake in rice ranged from 32.1 to 87.1 kg ha^{-1} with an average of 59.4 kg ha^{-1} (Table 2). The highest K uptake was observed in NPK+FYM followed by NPK+FYM+Zn. The K uptake recorded in these two treatments was significantly superior over rest of the treatments. The K uptake in NPK+Poultry litter and NPK+Forest litter was significantly

Table 2: Effect of integrated nutrient management practices on N, P and K uptake by rice and apparent recovery of nutrients from fertilizers and organic sources in treatments of integrated application

Treatment	Uptake (kg ha^{-1})			Apparent nutrient recovery (%)		
Control	N	P	K	N	P	K
½N+PK	24.1	4.7	32.1			
NPK	30.1	6.0	40.5	20.1	4.5	25.3
NPK+FYM	41.6	8.4	51.0	29.2	13.5	56.8
½N+PK+½N FYM	66.7	13.8	87.1	71.0	34.1	165.1
NPK+Poultry litter				(50.1)*	(61.7)	(86.6)
½N+PK+½N Poultry litter	44.5	10.5	60.9	67.9	21.3	86.5
NPK+Forest litter				(9.5)	(39.1)	(39.6)
½N+PK+½N Forest litter	71.5	15.1	75.1	78.9	39.0	128.8
½N+PK+*Azospirillum*				(59.6)	(28.9)	(110.9)
NPK+FYM+Zn	49.8	12.0	59.2	85.7	27.1	81.1
Forest litter burned+½ FYM				(27.3)	(26.4)	(60.9)
SEm+	49.6	9.9	60.3	42.5	19.4	84.6
CD (*p*=0.05)				(159.8)	(175.2)	(31.8)
T_9-½N+PK+½N Forest litter	41.9	9.6	65.5	59.3	18.0	100.2
				(0.9)	(22.3)	(57.5)
T_{10}-½N+PK+*Azospirillum*	42.2	9.2	52.1	60.1	16.6	60.0
T_{11}-NPK+FYM+Zn	66.5	14.3	84.9	70.6	36.1	158.4
				(49.7)	(67.7)	(81.3)
T_{12}-Forest litter burned+½ FYM	28.0	5.8	44.1			
SEm+	3.16	1.02	4.65			
CD (*p*=0.05)	6.22	2.01	9.17			

*Parentheses indicate the per cent contribution of the organic sources over NPK.

higher than NPK. Substituting ½N through FYM or forest litter also brought about a significant increase in K uptake over NPK. The K uptake in different nutrient management practices increased from 26.2 to 171.3% (8.4 to 55.0 kg ha^{-1}) with an average of 92.8% (29.8 kg ha^{-1}) over control. The K uptake by rice plant in NPK+FYM, NPK+FYM+Zn, NPK+Poultry litter and NPK+Forest litter was 70.8%, 66.5%, 47.3% and 18.2% higher as compared with NPK, respectively. This is in conformity with the findings reported by Baskar (2003) and Laxminarayana and Patiram (2006). The significant increase in K uptake in these treatments might be due to the relatively higher K availability, improvement in physical environment of the soil conducive to higher plant growth, grain and straw yield resulting higher K uptake. The significantly higher K uptake in ½N+PK+½N Forest litter treatment may be due to additional amount of K supplied by forest litter and providing conducive physical environment, which might have helped in better root growth and absorption of K from the soil. The K uptake in Forest litter burned+½ FYM was 37.4% higher as compared with control. This may be due to higher K availability, which might probably be either due to the release of K from lattice layer of K bearing minerals present in the soil as was also reported by Surekha et al. (2004) and Serstu and Sanchez (1978) or addition of K through forest litter ash after its burning or both.

3.9. *Apparent N, P and K recovery*

The apparent recovery of N from fertilizers, FYM, poultry litter, forest litter in treatments of various combinations ranged from 20.1 to 85.7% with an average of 58.5% (Table 2). The apparent recovery of P and K varied from 4.5 to 39.0% with an average of 23.0%, and 25.3 to 165.1% with an average of 94.7%, respectively. The data established that the average contribution towards apparent recovery of N, P and K from FYM was 36.4, 56.2 and 69.2%; from poultry litter 43.5, 27.7 and 85.9%; and from forest litter 80.4, 98.8 and 44.7%, respectively. The average contribution of organic sources towards the apparent N and P recovery was highest in Forest litter whereas, apparent K recovery was highest in poultry litter.

4. Conclusion

The above results established that NPK+Poultry litter is the best nutrient management practice that can be adopted for cultivation of upland rice on terraced land followed by NPK+FYM+Zn and NPK+FYM. The data led to conclude that ½N+PK+½N Poultry litter, ½N+PK+½N FYM and ½N+PK+½N Forest litter could be used as an alternative nutrient management practices on terraced land.

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