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Effect of Integrated Nutrient Management Practices on Important Soil Properties in Terraced Land Under Continuous Cultivation of Rice Variety Teke in Nagaland

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Abstract A field experiment was carried out for eleven years continuously and local rice variety Teke was used for this research evaluation. The soil samples were collected in *kharif* 2011 from the field to investigate the effect of nutrient management practices on important soil properties in terraced land under continuous cultivation. The experiment was laid down in randomized block design (RBD) with 12 treatments and each treatment was replicated three times. The results revealed that the maximum WHC and hydraulic conductivity was recorded in $^1/_2$ N+ PK + $^1/_2$ N Forest litter with 43.20% and 3.00 cm hr^{-1} while the minimum was recorded in control with 33.20% and 2.30 cm hr^{-1}, respectively. The highest percent aggregates > 0.25 mm and mean weight diameter of the soil was recorded in NPK + FYM + Zn with 72.60% and 2.60 mm while the lowest was recorded in control with 53.30% and 1.20 mm, respectively. The highest organic carbon was recorded in $^1/_2$ N + PK + $^1/_2$ N Forest litter with 3.10% and lowest was recorded in control with 1.60%. The highest pH was recorded in Forest litter burned + $^1/_2$ FYM with 4.90 and lowest was recorded in NPK and $^1/_2$ N + PK + *Azospirillum* with 4.30. The highest CEC was recorded in NPK + Poultry litter with 24.70 cmol (p^+) kg^{-1} and lowest was recorded in control with 18.20 cmol (p^+) kg^{-1}. In terms of the available NPK, the highest available N and P was recorded in NPK + FYM with 568.40 kg ha^{-1} and 21.90 kg ha^{-1} while the lowest was recorded in control with 310.30 kg ha^{-1} and 8.20 kg ha^{-1}, respectively. Available K was recorded maximum in $^1/_2$ N ± PK + $^1/_2$ N Forest litter with soil varied from 298.30 kg ha^{-1} and minimum was recorded in control with 143.70 kg ha^{-1}.

Keywords Continuous cultivation, Important soil properties, Nutrient management.

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Introduction

Integrated Nutrient Management (INM) envisages the use of chemical fertilizers in conjunction with the organic manures, legumes in cropping system, biofertilizers and other locally available sources for sustaining soil health and productivity. Nagaland is a predominantly hilly state occupying an area of 1.65 of which only 11% area is under plain. The rest of the area comprises of mild to steep slopes, rendering the area unsuitable for permanent cultivation without proper management practices. Bench terracing is the most reliable conservation measure frequently employed to manipulate surface topography of hill slopes to convert them to suit intensive agriculture. Bench terracing usually exposed infertile and biologically inert subsoil of less desirable properties for crop growth than those of the top soil. Consequently, the initial production potential of the terraced land is generally low since the development of soil fertility of the exposed subsoil of terraced fields for sustained production however it is a time taking process. To increase the productivity of terraced land, integrated nutrient management practices should be adopted to ensure a steady build up of soil fertility together with other properties suitable for plant growth.

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 addition of N, P, and K fertilizers with organic sources would increase the availability of plant nutrients and favor accumulation of organic matter on surface soil besides improving soil properties. Soil organic matter also influences a number of physical, chemical and biological properties of the soil and their combined effect together ensures favorable plant growth conditions in soil. The integrated application of inorganic fertilizers and organic residue would soil fertility and productivity on a sustainable basis since the system would supply almost all the nutrients in judicious way, besides increasing the nutrient use efficiency and improving the physico-chemical properties of the soil.

The data pertaining to the effect of continuous nutrient management practices on soil fertility and performance of upland rice on terraced land in Nagaland were found scanty. Therefore, the present investigation has been conducted to evaluate the effect of integrated nutrient management practices on soil properties and on available N, P and K in terraced land.

Materials and Methods

A long term field experiment was started in 2001 on newly developed bench terraces by the Department of Soil and Water Conservation at the experimental farm of School of Agricultural Sciences and Rural Development (SASRD), Nagaland University to study the immediate as well as long term effect of various nutrients management practices on important soil properties of terraced land under rainfed condition. The experiment was maintained for eleven years continuously and local rice variety Teke was used for this research evaluation. The soil samples were collected in *kharif* 2011 from the experimentation field to investigate the effect of nutrient management practices on important soil properties in terraced land under continuous cultivation. The experiment consisted of twelve treatments and replicates three times. The details of the treatment and combinations and the amount of N, P and K added in various treatments each year are given Table 1. A total of 36 plots each having a size of 3.0×2.0 m^2 were used in the experiment.

Field preparation and
treatment application

During the 11^{th} year of experimentation, the plots were manually dug three times with spade. The field was then prepared to ensure the good seedbed. The recommended dose of 60 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} for NPK for rice was applied in various treatments *T_2 to T_{11}). 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. The required amount of FYM (T_5), poultry litter (T_7) and forest litter (T_9) to substitute half recommended dose of N ($^1/_2$N; 30 kg ha^{-1}) was worked out based on the N content of these materials and incorporated in soil one month before sowing. Zinc (Zn) was applied @ 10 kg ha^{-1} in the form of $ZnSO_4.7H_2O$ as basal dose. *Azospirillum* was used as a seed treatment before sowing @ 20 g kg^{-1} of seed. Nitrogen was applied as urea in three equal splits at sowing, tillering and panicle initiation stage. The entire doses of P and K (PK) in the form of single supper phosphate and muriate of potash, respectively

Table 1. Amount of N, P and K added during 11 years of cultivation and managent both from NPK fertilizers and organic residues. The figure in the parentheses indicate the amount of N, P_2O_5 and K_2O added through NPK fertilizers and organic residues–FYM, poultry and forest litter.

Treatments	Amount of NPK added in 11th year (kg ha^{-1}) N	P_2O_5	K_2O
Control: (T_0)	0	0	0
$^1/_2$N+PK: (T_1)	30	60	40
NPK: (T_2)	60	60	40
NPK+FYM: (T_3)	110 (60+50)	80 (60+20)	110 (40+50)
$^1/_2$N+PK+$^1/_2$N FYM: (T_4)	60 (30+30)	72 (60+12)	70 (40+30)
NPK+ Poultry litter: (T_5)	110 (60+50)	113 (60+53)	66 (40+26)
$^1/_2$N+PK+$^1/_2$N Poultry litter: (T_6)	60 (30+30)	92 (60+32)	56 (40+16)
NPK+Forest litter: (T_7)	65 (60+5)	62 (60+2)	75 (40+35)
$^1/_2$N+PK+$^1/_2$N Forest litter: (T_8)	60 (30+30)	72 (60+12)	250 (40+210)
$^1/_2$N+PK+*Azospirillum:* (T_9)	30	60	40
NPK+FYM+Zn: (T_{10})	110 (60+50)	80 (60+20)	90 (40+50)
Forest litter burned+$^1/_2$ FYM: (T_{11})	25	10	25

was applied as basal dose. For forest litter burned + $^1/_2$FYM treatment (T_{12}) 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 ($^1/_2$FYM) was applied 30 days before sowing and mixed in the soil. All the plots were then finally prepared for sowing. After final preparation of the plots, upland rice (*Oryza sativa* L.) variety Teke was sown on 1st June, 2011 with a spacing of 20 cm row to row using a seed rate of 75 kg ha^{-1}. The field was maintained weed, pest and disease free during the entire duration of crop growth.

Collection and preparation of soil samples

Soil samples from individual plots were collected after the harvest of the rice crop and air-dried. Five soil samples from each plot were collected, mixed thoroughly and discarded using quadrat method to retain about 500 g representative soils. Two third of each samples were ground to pass through 2mm sieve and kept in polythene bags for laboratory analysis. The remaining portion of soil samples was preserved for analysis of mean weight diameter and percent aggregation. Undisturbed core soil samples were also collected from each plot in determine bulk density and hydraulic conductivity of the soil.

Soil sample analysis

For the determination of water holding capacity (WHC), soil sample were packed in Keen Rackzowaski boxes with uniform tapping and saturated overnight. After saturation the samples were weighed and kept in oven for 48 hours at equilibrium temperature of 105°C. The samples were then cooled and weighed. The water holding was calculated by the weight difference. Summation of all the fractions > 0.25 mm in wet sieving gave percent macro-aggregates.

For the determination of Mean weight diameter (MWD), air-dried natural clod samples were broken into gentle pressure and passed through 8 mm mesh sieve and retained on 5 mm sieve. Fifty grams of soil retained on 5 mm mesh sieve were transferred on the topmost sieve of the nest of the sieves arranged in the order of 5, 2, 1, 0.5 and 0.25 mm, respectively. The nest of the sieves was then emerged under water for 30 minutes in Yoder's apparatus for 30 minures. Fractions retained in each sieve was collected, over dried at equilibrium temperature for 24 hours, weighed and percent aggregation (of various sizes) was calculated. MWD was then calculated.

The particle density of the soil was determined by the pycnometer method and the bulk density of the soil was determined by the core method. Saturated hydraulic conductivity was then calculated from Darcy's equation.

Organic carbon was determined by the Wet Digestion Method. Soil pH was determined in 1:2.5 soil water suspension using glass electrode pH meter. The cation exchange capacity (CEC) of NH_3 distillation method. The available N content of the soil was estimated by the alkaline parmanganate method. The

Table 2. Effect of integrated nutrient management practices on physical properties of soil under continuous cultivation.

Treatments	WHC (%)	Aggregates > 0.25 mm (%)	Mean weight diameter (mm)	Particle density (g cm^{-3})	Bulk density (g cm^{-3})	Hydraulic conductivity (cm hr^{-1})
Control: (T_0)	33.20	53.30	1.20	2.10	1.38	2.30
$^1/_2$N + PK: (T_1)	34.50	57.40	1.80	2.10	1.34	2.40
NPK: (T_2)	35.00	65.30	1.90	2.10	1.36	2.40
NPK + FYM: (T_3)	40.30	72.40	2.50	2.00	1.24	2.90
$^1/_2$N + PK + $^1/_2$N FYM: (T_4)	39.30	69.30	2.20	1.90	1.26	2.80
NPK + Poultry litter: (T_5)	42.30	71.30	2.30	2.00	1.23	2.70
$^1/_2$N + PK + $^1/_2$N Poultry litter: (T_6)	40.50	70.30	2.40	1.90	1.27	2.70
NPK + Forest litter: (T_7)	38.70	69.30	2.00	2.20	1.25	2.90
$^1/_2$N + PK + $^1/_2$N Forest litter: (T_8)	43.20	72.30	2.50	2.10	1.17	3.00
$^1/_2$N + PK + *Azospirillum*: (T_9)	37.00	68.20	1.90	2.00	1.28	2.60
NPK + FYM + Zn: (T_{10})	42.00	72.60	2.60	2.00	1.23	2.90
Forest litter burned + $^1/_2$ FYM: (T_{11})	35.70	64.10	1.80	2.10	1.32	2.50
SEm ±	1.09	1.68	0.12	–	0.04	0.06
CD (p=0.05)	3.22	4.97	0.37	NS	0.12	0.18

available P in soil was extracted by Bray's method No. 1. The available potassium was determined by flame photometer after extracting the soil with neutral normal ammonium acetate (pH 7.0). Ther available K was extracted from the soil with neutral normal ammonium acetate and estimated flame photometrically.

Data collected were subjected to one way analysis of variance (ANOVA) by randomized block design (RBD) and each treatment was replicated three times. Fisher Shedecor *F* test was used to determine the significance and non-significance of the variance due to different treatments at 0.05 level of significance.

Results and Discussion

Effect of integrated nutrient management practices on physical properties of soil under continuous cultivation

Water holding capacity (WHC)

After 11 years of continuous addition of fertilizer, FYM, poultry litter, forest litter and *Azospirillum* in different combinations showed a significant increase in WHC in all the treatments except in $^1/_2$N + PK, NPK and Forest litter burned + $^1/_2$FYM treatments over control (Table 2). The maximum WHC was recorded in $^1/_2$ N + PK + $^1/_2$ N Forest litter with 43.20% and minimum was recorded in control with 33.20%. The WHC recorded in NPK + FYM, NPK + Poultry litter, NPK + FYM + Zn was at par and increased significantly as compared to NPK. Further, WHC recorded in NPK + Poultry litter and NPK + FYM + Zn had significant increase over NPK + Forest litter. The WHC in $^1/_2$N + PK, NPK, $^1/_2$ N + PK + *Azospirillum* and Forest litter burned + $^1/_2$ FYM was found to be par.

The increase in water holding capacity of the soil with integrated application of inorganic fertilizers with organic sources might be related to both the increase in organic matter content of the soil and improvement in its physical properties. These findings are in accordance with the findings reported by other workers (Laxminarayana [1] and Singh et al. [2] showed that the application of organic manures either alone or in combinations with inorganic fertilizers progressively improved the water holding capacity of the soil.

Percent aggregation

The addition of fertilizer, FYM, poultry litter, forest litter and *Azospirillum* in different combinations continuously for eleven years caused a significant increase in aggregates > 0.25 mm in all the treatments except in $^1/_2$ N + PK over control (Table 2). The highest percent aggregates > 0.25 mm was recorded in NPK + FYM + Zn with 72.60% while the lowest was in control with 53.30%. The aggregates > 0.25 mm in

NPK + FYM, NPK + Poultry litter and NPK + FYM + Zn was at par and showed a significant increase over NPK. Further aggregates>0.25 mm in $^1/_2$ N+ PK + $^1/_2$ N Poultry litter and $^1/_2$ N + PK + $^1/_2$ N Forest litter was at par with $^1/_2$ N + PK + $^1/_2$ N FYM but showed a significant increase as compared to NPK.

The increase in percent aggregates in NPK + FYM + Zn, NPK + FYM, NPK + Poultry litter and NPK + Forest litter over NPK was 11.20%, 10.90%, 9.10% and 6.10%, respectively. The higher percent aggregation in these treatments might be because of higher organic matter content in these treatments that together with clay and other soil constituents favor particle aggregation. It was reported that application of FYM along with NPK fertilizers caused significant increase in the water stable aggregates.

Table 3. Effect of integrated nutrient management practices on chemical properties of soil under continuous cultivation.

Treatments	Organic C (%)	pH	CEC [cmol (p^+) kg^{-1}]
Control: (T_0)	1.60	4.60	18.20
$^1/_2$N+PK: (T_1)	2.20	4.60	18.70
NPK: (T_2)	2.40	4.30	21.20
NPK+FYM: (T_3)	2.90	4.40	23.50
$^1/_2$N+PK+$^1/_2$N FYM: (T_4)	2.40	4.50	21.40
NPK+Poultry litter: (T_5)	2.80	4.50	24.70
$^1/_2$N+PK+$^1/_2$N Poultry litter: (T)	2.70	4.40	23.40
NPK+Forest litter: (T_7)	2.60	4.70	22.60
$^1/_2$N+PK+$^1/_2$N Forest litter: (T_8)	3.10	4.70	23.10
$^1/_2$N+PK+*Azospirillum*: (T_9)	2.50	4.30	23.30
NPK+FYM+Zn: (T_{10})	2.80	4.40	24.30
Forest litter burned+ $^1/_2$FYM: (T_{11})	2.30	4.90	18.60
SEm ±	0.098	0.057	0.72
CD (p=0.05)	0.29	0.17	2.13

Mean weight diameter (MWD) of soil

The mean weight diameter of soil in all the treatments showed a significant increase over control (Table 2). The highest MWD was recorded in NPK + FYM + Zn with 2.60 mm and the lowest was in control with 1.20 mm. The MWD in NPK + FYM + Zn, NPK + FYM and NPK + Poultry litter was at par and showed a significant increase over NPK. The MWD in $^1/_2$ N + PK + $^1/_2$ N Poultry litter and $^1/_2$ N + PK + $^1/_2$ N Forest litter was at par with $^1/_2$ N + PK + $^1/_2$ N FYM but showed a significant increase over NPK. However, MWD in NPK, Forest litter burned + $^1/_2$ FYM and $^1/_2$ N + PK was at par to each other.

The significant increase in MWD in NPK + FYM, NPK + Poultry litter, NPK + FYM + Zn, $^1/_2$ N + PK + $^1/_2$ N Poultry litter and $^1/_2$ N + PK + $^1/_2$ N Forest litter treatments was higher over NPK with 31.50, 21.10, 36.80, 26.30, and 31.60%, respectively. The higher MWD in these integrated treatments might be due to higher percent aggregates in these treatments as compared to NPK.

Partical density

The highest particle density was recorded in NPK + Forest litter with 2.20 g cm^{-3} and the lowest was recorded in $^1/_2$ N + PK + $^1/_2$ N FYM and $^1/_2$ N + PK + $^1/_2$ N Poultry litter with 1.90 g cm^{-3} each (Table 2). The particle density did not show any variation after eleven years of continuous cultivation and nutrient management. However particle density in $^1/_2$ N + PK, NPK, Forest litter burned + $^1/_2$ FYM, NPK + Forest litter and $^1/_2$ N + PK + $^1/_2$ N Forest litter treatments were comparatively higher than other treatments.

Bulk density

The data revealed that NPK with poultry litter, forest litter and FYM + Zn had a significant decrease in bulk density over control (Table 2). The maximum bulk density was recorded in control with 1.38 g cm^{-3} and minimum was recorded in $^1/_2$ N + PK + $^1/_2$ N Forest litter with 1.17 g cm^{-3}. The bulk density of NPK + FYM and NPK + Forest litter was at par with NPK. The bulk density in NPK + Poultry litter and NPK + FYM + Zn was significantly lower than NPK. The bulk density in $^1/_2$ N + PK + $^1/_2$ N Forest litter decreased significantly as compared to NPK. These might be because of the higher levels of organic C content in these treatments. Bajpai et al. [3] also showed that application of green manure, FYM or crop residue as a substitute of N reduced the bulk density significantly.

Hydraulic conductivity

The addition of fertilizer, FYM, poultry litter, forest litter and *Azospirillum* in different combinations continuously for eleven years caused a significant increase in hydraulic conductivity in all the treatments except in NPK and $^1/_2$ N + PK treatments over control (Table 2). The maximum hydraulic conductivity was recorded in $^1/_2$ N + PK + $^1/_2$ N Forest litter with 3.00 cm hr^{-1} and minimum was recorded in control with 2.30 cm hr^{-1}. The hydraulic conductivity of NPK + Forest litter, NPK + FYM and NPK + FYM + Zn was at par had significant increase over NPK and NPK + Poultry litter. The data established that addition of NPK in combination with FYM, poultry litter or forest litter increased the hydraulic conductivity significantly. The significant increase in hydraulic conductivity in these treatments might be due to increase in organic matter content and resultant increase in the porosity of the soil.

Effect of integrated nutrient management practices on chemical properties of soil under continuous cultivation

Organic carbon

The addition of fertilizer, FYM, poultry litter, forest litter and *Azospirillum* in different combinations continuously for eleven years caused a significant increase in organic C content in all the treatments over control (Table 3). The highest organic C was recorded in $^1/_2$ N + PK + $^1/_2$ N Forest litter with 3.10% followed by NPK + FYM, NPK + FYM + Zn, NPK + poultry litter and $^1/_2$ N + PK + $^1/_2$ N Poultry litter with 2.90%, 2.80%, 2.80% and 2.70%, respectively and lowest was recorded in control with 1.60%.

The data revealed that integrated addition of inorganic fertilizers with organic sources in any combinations favored significantly higher build up in organic C as compared to other treatments. Among treatments receiving half N from fertilizer and other half from organic sources, a significant build up in organic C was recorded in $^1/_2$ N + PK + $^1/_2$ N Forest litter and $^1/_2$ N + PK + Poultry litter treatments over NPK. The increases in organic C content in soil on addition of organic sources have been reported by earlier workers (Laxminarayana and Patiram [4]. Similarly, it was also reported maximum organic C content in Alder litter incorporated followed by NPK + FYM and surface soil + FYM treatments. The significant increase in organic C in integrated treatments combining inorganic fertilizers either with forest litter, poultry litter or FYM may be because of the combine effect of the amount of the organic residues C added and its nutrient content, plant residue C return to the soil and efficiency of microbial population in utilizing added organic C.

Soil pH

The addition of NPK alone or in combination with FYM continuously for elevan years caused a significant decrease in pH over control (Table 2). Addition of $^1/_2$ N + PK + $^1/_2$ N FYM, and $^1/_2$ N + PK + $^1/_2$ N Forest litter and Forest litter burned+$^1/_2$ FYM brought about a significant increase in pH over NPK. The highest pH was recorded in Forest litter burned + $^1/_2$ FYM with 4.90 followed by NPK + Forest litter and $^1/_2$ N + PK + $^1/_2$ N Forest litter with 4.70 each and lowest was recorded in NPK and $^1/_2$ N + PK + *Azospirillum* with 4.30.

The reduction in soil pH on addition of N fertilizers has been well established. The significant decrease in soil pH on addition of NPK fertilizer alone by 0.30 units over control are in accordance with earlier. Integrated application of NPK with poultry litter or forest litter, and addition of $^1/_2$ N + PK + $^1/_2$ N FYM and $^1/_2$ N + PK + $^1/_2$ N forest litter caused a significant increase of 0.20 to 0.40 units in soil pH as compared to NPK. Significant increase in soil pH on addition of Forest litter burned + $^1/_2$ FYM are in accordance with those reported earlier.

Cation exchange capacity (CEC)

The addition of fertilizer, FYM, poultry litter, forest litter and *Azospirillum* in different combinations continuously for eleven years caused a significant increase in CEC in all the treatments except in $^1/_2$ N + PK and Forest litter burned + $^1/_2$ FYM treatments over control (Table 3). The highest CEC was recorded in NPK + Poultry litter with 24.70 cmol (p^+) kg^{-1} and lowest was recorded in control with 18.20 cmol (p^+) kg^{-1}. The CEC in NPK + FYM + Zn, NPK + Poultry litter,

Table 4. Effect of integrated nutrient management practices on availability of N, P and K of soil under continuous cultivation.

Treatments	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Control: (T_0)	310.30	8.20	143.70
$^1/_2$N+PK: (T_1)	330.50	13.60	180.20
NPK: (T_2)	363.70	18.50	183.30
NPK+FYM: (T_3)	568.40	21.90	267.30
$^1/_2$N+PK+$^1/_2$N FYM: (T_4)	451.50	20.30	233.70
NPK+Poultry litter: (T_5)	557.80	20.40	265.30
$^1/_2$N+PK+$^1/_2$N Poultry litter: (T_6)	480.10	19.30	260.20
NPK+Forest litter: (T_7)	380.30	18.80	241.40
$^1/_2$N+PK+$^1/_2$N Forest litter: (T_8)	475.20	17.50	298.30
$^1/_2$N+PK+*Azospirillum*: (T_9)	480.30	18.00	204.50
NPK+FYM+Zn: (T_{10})	565.30	21.20	269.80
Forest litter burned+ $^1/_2$FYM: (T_{11})	325.40	10.60	188.70
SEm ±	5.25	0.92	5.61
CD (p=0.05)	15.47	2.73	16.52

NPK + Forest litter and NPK + FYM was at par and showed a significant increase over NPK. The data revealed that addition of NPK + Poultry litter, NPK + FYM + Zn and NPK + FYM caused significant increase of 16.50%, 14.60% and 10.80% in CEC as compared to NPK alone. The increase in humus content on decomposition of added organic sources may be responsible for increasing the negative charge on the organic colloid of the soil, which in turn would contribute to increase in CEC of the soil. It was also reported that application of NPK fertilizers along with FYM or organic residues caused significant increase in CEC of soil. The decrease in CEC in NPK and $^1/_2$ N + PK treatments may be the result of continuous application of only chemical fertilizers without organic sources over a long period of time.

Availability of N, P and K of the soil under continuous cultivation

Available N of the soil

The data showed that 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 except in Forest litter burned + $^1/_2$ FYM (Table 4). Among different treatments, highest available N was recorded in NPK + FYM with 568.40 kg ha^{-1} and lowest available N was recorded in control with 310. 30 kg ha^{-1}. The available N content in NPK + FYM, NPK + FYM + Zn and NPK + Poultry litter was at par and showed a significant increase over NPK and NPK + Forest litter treatments. The data revealed that addition of NPK or integrated application of both inorganic and organic sources in different combinations caused as significant build up in available N in soil as compared to control.

The significant increase in available N content in soil on addition of NPK fertilizers, FYM, poultry litter, forest litter and other amendments in different combinations to upland rice are in agreement with those reported by several workers [3, 5]. The significant increase in available N content 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. Laxminarayana [1] also observed a significant increase in available N content in NPK + Poultry litter and NPK + FYM over NPK after three years of continuous cropping and nutrient management. Imtilemla et al. [6] 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.

Available P of the soil

The addition of fertilizer, FYM, poultry litter, forest litter and *Azospirillum* in different combinations continuously for eleven years caused a significant increase in available P content in all the treatments except in Forest litter burned $^1/_2$ FYM over control (Table 4). The highest available P was recorded in NPK + FYM with 21.90 kg ha^{-1} and lowest was recorded in control with 8.20 kg ha^{-1}.

The data revealed that relatively higher available P levels accumulated in treatments where NPK fertilizers were applied in combinations with poultry litter and FYM. A marginal increase in available P was found in Forest litter bunned + $^1/_2$ FYM. These results are in accordance with earlier. These investigators reported that continuous nutrient management of soil with fertilizers, manures and other soil amendments alone or in combinations on a terraced land showed increased available P content in soil except that of Alder litter incorporated and burned. Laxminarayana [1] showed that highest available P (12.25 kg ha^{-1}) with the application of 100% NPK + Poultry manure. Singh et al. [7] also showed 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.

Available K of the soil

The data showed that continuous application of fertilizer, FYM, poultry litter, forest litter and *Azospirillum* in different combinations for eleven years caused as significant increase in available K content in all the treatments (Table 4). The maximum available K was recorded in $^1/_2$ N + PK + $^1/_2$ N Forest litter with soil varied from 298.30 kg ha^{-1} and minimum was recorded in control with 143.70 kg ha^{-1}. The available K content in NPK + FYM, NPK + poultry litter and NPK + FYM + Zn was at par and showed a significant increase over NPK + Forest litter and NPK treatments.

The data established that addition od NPK in combination with FYM, poultry litter or forest litter increased the available K content significantly. These results corroborate the findings of other workers [8]. The significant increase in available K content in the treatments receiving half N from fertilizer in combination with other half from FYM, poultry litter and forest litter suggested that $^1/_2$ N + PK + $^1/_2$ N Forest litter, $^1/_2$ N + PK + $^1/_2$ N Poultry litter and $^1/_2$ N + PK + $^1/_2$ N FYM treatments could preferably be used to build up available K levels in soil even in situation where fertilizers are adequately available. As observed earlier, there was significant increase in available K content of the surface soil with the application of 50% N through organic manure in conjunction with 50% recommended dose of fertilizer under pearl millet-pigeon pea cropping system.

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