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Impact of Continuous Fourteen Years of Integrated Nutrient Management Practices on Forms of Soil Potassium in Terraced Land

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Abstract An experiment with twelve treatments involving NPK, FYM, poultry litter, forest litter, *Azospirillum* and Zn either alone or in combinations applied continuously for fourteen years was conducted to evaluate the impact of integrated nutrient management practices on various forms of soil potassium in terraced land. The highest amount of water soluble K, exchangeable K, available K, non-exchangeable K and total K were found in ½N + PK +½ N Forest litter treatment. The integrated application of NPK with organic residues caused a significant increase of 37.5, 31.3, 30.2 and 36.6 of water soluble K and 17.1, 14.5, 14.3 and 18.28% of non-exchangeable K in NPK + FYM, NPK + Poultry litter, NPK + Forest litter and NPK + FYM + Zn treatments over NPK, respectively. Exchangeable K in ½ N + PK + ½ N Poultry litter and ½ N + PK + ½ N Forest litter treatments were 18.5 and 34.0% higher as compared to NPK, respectively. The rate of build up of available K in different nutrient management practices was 0.6 to 6.7 kg K ha^{-1} yr^{-1} with an average of 4.0 kg K ha^{-1} yr^{-1}. On an average, water soluble K, exchangeable K, available K and non-exchangeable K represented 0.2, 0.6, 0.7 and 3.9% of total K.

Keywords Water soluble K, Exchangeable K, Available K, Non-exchangeable K, Total K.

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Introduction

Bench terracing is generally employed to convert surface topography of hill slopes to suit intensive agriculture. In the process it exposes infertile and biologically inert subsoil of less desirable properties for plant growth than those of the top soil. The production potential of terraced land is generally low. To increase the long term productivity of terraced land, sound soil management strategies are obviously needed. It ensures a steady build up of soil fertility together with other physico-chemical properties of the soil suitable for plant growth. Crop residues and farm yard manure are excellent material for improving the soil physico-chemical properties when incorporated. Sustainability in crop production is not a viable proposition either through use of organic manures or chemical fertlizers alone [1]. Organic matter influences a number of properties of the soil and their combined effect together ensure favorable plant growth conditions in soil. The information on the impact of long term integrated nutrient management practices on various forms of soil potassium in terraced land of Nagaland are scanty. Therefore the investigation was carried out to study the impact of fourteen years integrated nutrient management practices on various forms of soil K on terraced land under upland rice cultivation in acid soils of Nagaland.

Materials and 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. 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 established in 2001 and has been maintained since then. The soil samples collected in *kharif* of 2014 after fourteen 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. 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^{-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 $ZnSO_4 . 7 H_2O$ as basal dose. *Azospirillum* @ 20 g kg^{-1} of seed was applied as seed treatment before sowing. 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 + 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 (landrace) was sown with a spacing of 20 cm row to row using a seed rate of 75 kg ha^{-1}. Soil samples from individual plots were collected after the harvest of rice crop and air dried at room temperature. Water soluble K was extracted with distilled water and estimated flame photometrically. The available K was extracted from the soil with neutral normal ammonium acetate as described by Jackson [2] and estimated flame photometrically. The difference between available K and water soluble K was considered as exchangeable K. The non-exchangeable K was determined by extracting the soil with l N HNO_3 according to the procedure as described by Black [3]. The total K in the soil was measured flame photometrically in the triacid digest of the soil.

Results and Discussion

Water soluble K

The water soluble K content in the soil ranged from 5.0 to 16.1 mg kg^{-1} with an average of 11.2 mg kg^{-1} (Table 1). After fourteen years of integrated nutrient management, water soluble K content in the soil increased significantly in all the treatments except in Forest litter burned + ½ FYM over control. This might be due to the fact that addition of potassic fertilizer has increased the concentration of K in soil solution, thereby water soluble K content in the soil increased. To maintain dynamic equilibrium, K in solution phase proportionately saturated the exchange site of the clay minerals, resulting an increase in exchangeable K in soil. Water soluble K content was highest in ½ N + PK + ½ N Forest litter treatment and the lowest in control. Addition of FYM, poultry litter or forest litter with NPK or substituting half nitrogen through FYM, poultry litter or forest litter caused a significant increase in water soluble K in soil as compared to addition of NPK alone. Water soluble K in NPK + FYM, NPK + Poultry litter, NPK + Forest litter and NPK + FYM + Zn treatments were 37.5, 31.3, 30.2 and 36.6% higher as compared to NPK, respectively.

Table 1. Impact of fourteen years of integrated nutrient management practices on water soluble K, exchangeable K and available K in soil.

Treatment No. and particulars	Water soluble K (mg kg^{-1})	Exchangeable K (mg kg^{-1})	Available K (mg kg^{-1})
T_1-Control	5.0	18.4	23.4
T_2-½ N+PK	8.3	24.2	32.5
T_3-NPK	9.0	32.6	41.6
T_4-NPK+FYM	14.4	43.7	58.1
T_5-½ N+PK+½ N FYM	13.3	38.8	52.1
T_6-NPK+Poultry litter	13.1	40.1	53.2
T_7-½N+PK+½N Poultry litter	12.8	40.0	52.8
T_8-NPK+Forest litter	12.9	42.5	55.4
T_9-½ N+PK+½ N Forest litter	16.1	49.4	65.5
T_{10}-½ N+PK+ *Azospirillum*	8.8	30.8	39.6
T_{11}-NPK+FYM+Zn	14.2	43.4	57.6
T_{12}-Forest litter burned+½ FYM	6.4	20.6	27.0
SEm±	1.01	2.15	2.54
CD (p =0.05)	2.96	6.32	7.46

Table 2. Impact of fourteen years of integrated nutrient management practices on non-exchangeable K and total K in soil.

Treatment No. and particulars	Non exchangeable K (mg kg^{-1})	Total K (mg kg^{-1})
T_1–Control	205.1	5700
T_2–½ N + PK	219.5	5900
T_3–NPK	227.5	6200
T_4–NPK+FYM	266.3	6600
T_5–½ N+PK+½ N FYM	258.7	6400
T_6–NPK+Poultry litter	260.4	6300
T_7–½ N+PK+½ N Poultry litter	252.5	6200
T_8–NPK+Forest litter	260.1	6500
T_9–½ N + PK + ½ N Forest litter	270.3	6700
T_{10}–½ N + PK + *Azospirillum*	232.6	6100
T_{11}–NPK + FYM + Zn	269.0	6500
T_{12}–Forest litter burned+ ½ FYM	208.7	5800
SEm±	4.89	63.00
CD (p = 0.05)	14.34	184.81

Exchangeable K

The exchangeable K content in the soil varied from 18.4 to 49.4 mg kg^{-1} with an average of 35.4 mg kg^{-1} (Table 1). After fourteen years of integrated nutrient management and continuous cropping, exchangeable K content in the soil increased significantly in all the treatments except in ½ N + PK and Forest litter burned + ½ FYM treatments over control. Addition of FYM, poultry litter or forest litter with NPK, or substituting half nitrogen through poultry litter or forest litter also caused a significant increase in exchangeable K in soil as compared to addition of NPK alone. The highest exchangeable K found in ½N + PK + ½N Forest litter might be due to higher input of K through forest litter in this treatment. Yaduvanshi and Swarup [4] also reported that the distribution of water soluble and exchangeable K content of the top soil in the treatments receiving K fertilizer (150% NPK, 100% NPK and 100% NPK + FYM or GM) was higher as compared with 100% N or 100% NP treatments. Exchangeable K in ½ N + PK + ½ N Poultry litter and ½ N + PK+½ N Forest litter treatments were 18.5 and 34.0% higher as compared to NPK, respectively. Addition of *Azospirillum* with ½ N + PK caused a significant increase in exchangeable K as compared to ½ N+ PK alone.

Available K

The available K content in the soil ranged from 23.4 to 65.5 mg kg^{-1} with an average of 46.6 mg kg^{-1} (Table 1). After fourteen years of integrated nutrient management practices, available K content in the soil increased significantly in all the treatments except in forest litter burned + ½ FYM over control. Available K content was highest in ½ N + PK+ ½ N Forest litter treatment and the lowest in control. The available K in NPK + FYM, NPK + Poultry litter, NPK + Forest litter and NPK + FYM + Zn was significantly higher than NPK. Substituting half nitrogen through FYM, poultry litter or forest litter caused a significant increase in available K in soil as compared to addition of NPK alone. These results suggested that ½ N+PK+½ N Forest litter, ½ N + PK + ½ N FYM and ½ N+PK+ ½ N Poultry litter could preferably be used to build up available K levels in soil even in situation where fertilizers are adequately available. Available K in NPK+ FYM, NPK+Poultry litter, NPK+ Forest litter and NPK +FYM + Zn treatments were 28.4, 21.8, 24.9 and 27.8% higher as compared to NPK, respectively. The increase in available K was perhaps related to the input and uptake of K in these treatments. Similar results were also reported by Humtsoe and Chauhan [5] and Singh et al. [6]. The rate of build up of available K in different nutrient management practices was 0.6 to 6.7 kg K ha^{-1} yr^{-1} with an average of 4.0 kg K ha^{-1} yr^{-1}. Humtsoe and Chauhan [5] and Imtilemla et al. [7] also reported similar trend of build up of available K in terraced land. After fourteen years of integrated nutrient management, K fertility status changed from low to medium only in NPK+FYM, NPK+Poultry litter, NPK+Forest litter, NPK +FYM+ Zn, ½ N + PK+½ N+FYM, ½ N + PK+½ N Poultry litter and ½ N+PK+½ N Forest litter treatments. K fertility status in other treatments did not change and remained low perhaps because basal dose of 40 kg K_2O ha^{-1} appears to be insufficient to meet the crop requirement.

Non-exchangeable K

The non-exchangeable K content in the soil ranged from 205.1 to 270.3 mg kg^{-1} with an average of 244.2 mg kg^{-1} (Table 2). After fourteen years of integrated nutrient management and continuous cropping, non-exchangeable K content in the soil increased significantly in all the treatments except in Forest litter burned +½ FYM treatment over control. This might be due to addition of K through fertilizer and organic manures increased the concentration of K in soil solution, thereby, redistribution took place among water soluble, exchangeable and non-exchangeable phases in order to maintain the typical dynamic equilibrium. Results of similar variation of non-exchangeable K were also reported by Prasad [8] and Sharma [9]. The highest non-exchangeable K content was recorded in ½ N+PK+½ N Forest litter treatment. The non-exchangeable K in NPK+FYM, NPK+FYM+Zn, NPK+Poultry litter and NPK+Forest litter showed a significant increase over NPK. Similarly, non-exchangeable K in ½ N +PK+½ N Forest litter, ½ N+PK+½ N FYM and ½ N+PK+½ N Poultry litter also showed a significant increase over NPK. This might be due to fixation of applied K as well as residual K balance through addition of organic residues. The non-exchangeable K in NPK+FYM, NPK+Poultry litter, NPK+Forest litter and NPK+FYM+Zn treatments were 17.1, 14.5, 14.3 and 18.28% higher as compared to NPK, respectively.

Total K

The total K content in the soil varied from 5700 to 6700 mg kg^{-1} with an average of 6241.7 mg kg–1 (Table 2). After fourteen years of integrated nutrient management, the total K in soil showed significant increase in all the treatments except in Foerst litter burned+½ FYM over control. Total K in NPK+FYM, NPK+FYM+Zn and NPK+ Forest litter was significantly higher than NPK. Substituting half nitrogen through FYM or forest litter caused a significant increase in total K in soil as compared to addition of NPK alone. A significant build up in total K in ½ N+PK+½ N Forest litter over all other treatments except in NPK+FYM might be due to lower uptake and removal of K by crop as compared to the amount added in ½ N+PK+½ N Forest litter treatment. Yaduvanshi and Swarup [4] from a long term experiment, reported that in all the fertilizer and manure treatments removal of K in the crop exceeded K addition and the total soil K balance was negative. On an average, water soluble K, exchangeable K, available K and non-exchangeable K represented 0.2, 0.6, 0.7 and 3.9% of total K. These results are in conformity with those reported by Sharma et al. [10].

The above results led to conclude that integrated application of NPK fertilizers with FYM, poultry litter and forest litter had pronounced influence in improving the K fertility status of soil as compared to control and NPK alone. These result established addition of NPK with FYM, poltry litter and forest litter, and substituting half N through FYM, poultry litter or forest litter are the best nutrient management practices that can be adopted for improvement of K fertility status for rice cultivation under terrace land.

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