Conjoint application of lime, organics, inorganic fertilizers, and bio-fertilizers increases groundnut productivity, available and microbial biomass phosphorus in acidic soil of Tripura, India

ABSTRACT

In Tripura, India the soil productivity is less due to its light texture, acidic in nature, low fertility status, low microbial activity. Thus, a field experiment on groundnut (*Arachis hypogaea* L.) was carried out on acidic soil of Khowai district of Tripura during 2017 and 2018 to evaluate the impact of the application of various combinations of lime, farm yard manure (FYM), poultry manure (PM), and rhizobium with the recommended doses of NPK on groundnut productivity, available phosphorus (P) and microbial biomass phosphorus (MBP) content of acidic experimental soil. The experiment was conducted using a randomized block design (RBD) with 13 treatments with various combinations of application of lime, farm yard manure (FYM), poultry manure (PM), and rhizobium with the recommended doses of NPK, each having 3 replications. Both initial and post-harvest soil samples were collected and analyzed to estimate the available P and MBP content. Results indicated that the use of the different combinations of the recommended dose (RD) of NPK accompanied by the application of lime, organic manure (FYM or PM) and seed treatment with *Rhizobium* significantly increased available P and MBP content in the post-harvest soil which has resulted in increased seed yield of groundnut compared to the RD of NPK alone. Again, the use of RD of NPK @ 20:60:40 kg ha^{-1} conjointly with lime (@ 1/5th LR), PM (@ 5 t ha^{-1}), and treating the seeds with Rhizobium @ 20 g kg^{-1} of seed might be recommended to the growers in achieving higher groundnut productivity with better return in acid soil of Tripura, India, as it showed maximum enhancement in groundnut productivity as well as available P_2O_5 content in post-harvest soil.

Keywords: Groundnut, yield, lime, organic manure, fertilizers, biofertilizers, soil phosphorus

Introduction

The State Tripura, India characterized by varied physiography and climate is endowed with a variety of land uses and agricultural systems. The state indicates a rise in the area and production of oilseeds and pulses throughout the years. Presently, the yield of major crops in Tripura is generally low. The acid soils occur in 100% geographic area of Tripura. The highly leached soils are generally poor in fertility and water holding capacity. A substantial area with pH value of less than 5.5 is more problematic with severe deficiencies of phosphorus.

Microbial decomposition and transformation of different nutrients are also retarded under acid soil conditions. To produce a better crop yield on acid soils, farmers are recommended to apply alkaline materials such as lime (primarily calcium carbonate) to increase the pH of soil and thus eliminate Al toxicity, and to apply P fertilizer to increase the bioavailability P in soil. Liming is a common method used to increase the productivity of acid soils by reducing their acidity [1]. But farmers find the complete reclamation with lime to the desired level is very expensive. Crops respond differently to lime, generally with varied doses of lime, therefore, amelioration of soil acidity with a minimum amount of lime with a balanced application of all deficient nutrients including micronutrients is required to be popularized amongst the farmers. Applying organic manures in conjunction with lime has been shown by several authors [2, 3] to greatly improve soil quality since it increases the amount of organic matter in the soil. It is possible to economically increase the productivity of acidic red and lateritic soils by using basic slag in conjunction with organic inputs [4]. Given the declining productivity level, increasingly greater emphasis is now given to integrated nutrient management (INM) system, which plays a significant part in sustaining soil health [5]. Under this background, present investigation was undertaken to investigate the impact of concurrent usage of lime, organics, inorganic fertilizers and biofertilizers in enhancing groundnut productivity and also to improve the available phosphorus and microbial biomass phosphorus content in the acidic soil of Tripura.

Material and Methods

The study was carried out at the Chebri Village of Khowai district of Tripura having 23.8974^{0} North Latitude, 91.6372^{0} East Longitude, at elevation of 23m (75ft) from mean sea level (MSL) during the two consecutive Rabi Seasons of the year 2017-18 and 2018-19. The study was conducted using a Randomized Block Design (RBD) with 13 treatment combinations each of which was replicated thrice. There were 39 plots each having plot size of 2.7x1.8 m^2. Soil sampling was done from seven randomly selected sites up to a depth of 0-15 cm before the layout of the field and were mixed together to draw a composite sample and were analyzed for different physico-chemical properties following the standard procedure. The following treatment combinations were undertaken: T_1: Control (only recommended dose of NPK (20:60:40 kg/ha) (RDF); T_2: Liming @1/10th LR (limestone) + RDF; T_3: Liming @1/5th LR (limestone) + RDF; T_4:Liming @1/10th LR (limestone) + RDF + FYM @ 5t/ha [T_2 + FYM]; T_5: Liming @1/5th LR (limestone) + RDF + FYM @ 5t/ha [T_3 + FYM]; T_6 : Liming @1/10th LR (limestone) + RDF + PM @ 5t/ha [T_2 + PM]; T_7: Liming @1/5th LR (limestone)

+ RDF + PM @ 5t/ha [T_3 + PM]; T_8 : Liming @1/10th LR (limestone) + RDF + Rhizobium (seed treatment @ 20g/kg seed) [T_2 + Rhizobium]; T_9 : Liming @1/5th LR (limestone) + RDF + Rhizobium (seed treatment @ 20g/kg seed) [T_3 + Rhizobium]; T_{10} : Liming @1/10th LR (limestone) + RDF + FYM @ 5t/ha + Rhizobium (seed treatment @ 20g/kg seed) [T_4 + Rhizobium]; T_{11} : Liming @1/5th LR (limestone) + RDF + FYM @ 5t/ha + Rhizobium (seed treatment @ 20g/kg seed) [T_5 + Rhizobium]; T_{12} : Liming @1/10th LR (limestone)+ RDF + PM @ 5t/ha + Rhizobium (seed treatment @ 20g/kg seed) [T_6 + Rhizobium]; T_{13} : Liming @1/5th LR (limestone) + RDF + PM @ 5t/ha + Rhizobium (seed treatment @ 20g/kg seed) [T_7 + Rhizobium]. Liming material ($CaCO_3$) was used based on Lime Requirement (LR) 15 days prior to the sowing. Prior to seeding, organic manures were used according to treatments. Bio-fertilizers (*Rhizobium*) were applied as seed treatment before sowing. Row-to-row and plant-to-plant spacing of 45 cm and 15 cm were maintained. Prior to field preparation, initial soil samples were collected from 0-15 cm soil depth as indicated above. All the weeds including the previous crop residues were cleaned from the field. The field was ploughed in order to loosen the soil and make it friable to ensure better seed germination. Then in each of 39 plots, groundnut var. ICGS-76 was sown on 20.11.2017 and 18.10.2018 in first and second year respectively. The recommended dose of N:P:K (20:60:40 kg ha^{-1}) was applied during the last ploughing. All the recommended packages of practice were followed in both the years of study period. The crops were harvested on 30.3.2018 in 1st and 2nd year respectively. The seed yield of groundnut was noted as per treatment. The collected soil samples from each plot were dried, processed and analyzed for available P_2O_5 using Brays No. 1 method [6] and microbial biomass phosphorus (MBP) by Fumigation extraction method [7]. The data on seed yield, available P_2O_5 and MBP content were statistically analyzed following the procedures as described by Gomez and Gomez [8]. The level of significance used in “F” and “t” test was p=0.05. Critical difference values were calculated wherever the “F” test was significant.

RESULTS AND DISCUSSION:

The seed yield (t ha^{-1}) of groundnut as impacted by lime, organics, inorganic fertilizers, and biofertilizer was recorded and is indicated in Table 1. Statistical analysis of the results indicated that in most of the treatments seed yield differed significantly. The highest pooled seed output was noted in T_{13} (2.98 t ha^{-1}) imposing 1/5th of LR and 5 t ha^{-1} of poultry manure

(PM), recommended dose of fertilizer (RDF), and biofertilizer, which was, however, statistically at par with T_{11} (RDF + 1/5 LR + FYM + Rhiz), T_7 (RDF + 1/5 LR + PM) and T_5 (RDF + 1/5 LR + FYM). There was 85.09% increase in seed yield in T_{13} over T_1 (control). Application of RDF along with 1/10th of LR with 5 t ha^{-1} of FYM and biofertilizer for seed treatment (T_{10}) increased the seed productivity over control by 33.54%. In contrast, RDF and 1/10th of LR with 5 t ha^{-1} of poultry manure and biofertilizer for seed treatment (T_{12}) increased the seed productivity over control by 44.10%. Adding the recommended dose of fertilizer and 1/10th of LR (T_2) increased the seed yield over control by 16.77%. It was noted that the addition of FYM @ 5 t ha^{-1}, 1/5th of LR and RDF (T_5) increased the seed productivity by 14.76 % over T_3, where only 1/5th of LR with RDF was applied. Similarly, adding 5 t ha^{-1} of poultry manure/ha and 1/5th of LR with RDF (T_7) increased the seed yield by 18.98% over T_3. However, T_{13} was found to increase seed yield by 5.67% over T_7. Similarly, T_{11} has increased seed yield by 5.88% over T_5. However, T_{11} had an additional seed yield increase of 18.03% over T_9. Similarly, T_{13} is found to have an additional seed yield increase of 22.13% over T_9. Adding 5 t ha^{-1} of FYM with the recommended dose of fertilizer and 1/10th of LR (T_4) has increased the seed yield by 10.63% over T_2. In contrast, adding 5 t ha^{-1} of PM and the RD of fertilizer with 1/10th of LR (T_6) has increased the seed yield by 19.14% over T_2. At the same time, the addition of 5 t ha^{-1} of FYM with RDF and 1/10th of LR and rhizobium as a seed treatment (T_{10}) had an additional seed yield increase of 9.13% over T_8. However, 5 t ha^{-1} of PM with RDF and 1/10th of LR and rhizobium for seed treatment (T_{12}) had an additional seed yield increase of 17.76% over the use of rhizobium as seed treatment with RDF along with 1/10th of LR (T_8). The lowest pooled seed yield (1.61 t ha^{-1}) of groundnut was obtained T_1 (control) which was, however, statistically at par with T_2, T_8, T_4, T_{10}, T_6, T_{12}, T_3 and T_9.

The results suggest that the conjoint usage of lime, organics, fertilizers and biofertilizer has improved the soil conditions for optimum uptake of nutrients and plant growth which ultimately resulted in an increased seed yield over control plot where only recommended dose chemical fertilizers were applied. The increase in seed yield upon liming and INM was also observed by several researchers [9, 10]. Dosani et al. [11] also observed that applying lime in-furrow at one-tenth, one-half, and equal to the lime requirement to groundnut increased soil pH, exchangeable calcium, and reduced different forms of acidity, exchangeable aluminum and iron, and thereby increased seed yield of different genotypes of groundnut in Alfisols of Konkan. Singh et al. [12] also opined that the addition of Lime + FYM + 50% NPK increased seed yield over other nutrient levels in groundnut. Jat and Ahlawat [13] noted that the use of FYM @ 5 t ha^{-1} markedly improved yield, yield attributed to groundnut over no FYM because of improvement in soil fertility and microbial population and their activity. For rice beans, a comparable increase in crop yield was noted following the application of lime in furrows at a rate of 600 kg ha^{-1} [14]. Our results support the favorable effects of lime application in soils with acidity on groundnut yield, as demonstrated by Basu et al. [15], Basu et al. [16], and Raychaudhury et al. [17]. According to Lungmuana et al. [18], the percentage increase in pooled pod yield as a result of applying lime was 26.5% for lime applications @ 500 kg $CaCO_3$ ha^{-1} and 63% for its application @ 1000 kg $CaCO_3$ ha^{-1} those applications.

The microbial biomass phosphorus (MBP) of post-harvest soil as influenced by use of the different combinations of lime, organics, inorganic fertilizers, and biofertilizer were recorded and presented in Table 2. It was recorded that the initial value of MBP in the experimental soil was 21.54 µg g^{-1}. In all the treatments, there was always a rise in MBP content in post-harvest soil compared to the control due to applying different combinations of lime, organics, inorganic fertilizers, and biofertilizer in the experimental fields during the two-year study period. As per pooled data, the highest MBP (32.47 µg g^{-1}) was noted in T_{12} (1/10th of LR along with 5 t ha^{-1} of poultry manure, recommended dose of fertilizer, and biofertilizer) which was, however, at par with T_6 (RDF + 1/10 LR + PM), T_7 (RDF + 1/5 LR + PM), T_8 (RDF + 1/10 LR + Rhiz), T_9 (RDF + 1/5 LR + Rhiz), T_{10} (RDF + 1/10 LR + FYM + Rhiz), T_{11} (RDF + 1/5 LR + FYM + Rhiz) and T_{13} (RDF + 1/5 LR + PM + Rhiz) which might be due to increase in microbial population due to favourable soil environment. However, the lowest MBP was noted in control (27.69 µg g^{-1}). The results confirm that the integrated use of lime, organics, inorganic fertilizers, and biofertilizer has improved the status of MBP in the post-harvest soil. The current study's conclusions were in line with those of Stenberg et al. [19] who emphasized that liming didn't really work on soil structure variables but significantly increased the microbial activity and MBP to some extent. The soil biomass P content can be increased by adding C [20] or lime [21].

The available P_2O_5 content of post-harvest soil influenced by lime, organics, inorganic fertilizers, and biofertilizer were recorded and are presented in Table 3. It was recorded that the initial available P_2O_5 of experimental soil was 10.65 kg ha^{-1}. In all the treatments except control (T_1), a rise in available P_2O_5 content due to applying different combinations of lime, organics, inorganic fertilizers, and biofertilizer in the experimental fields was noted. As per pooled data, the highest (17.03 kg ha^{-1}) available P_2O_5 content was noted in T_{13} (1/5th of LR and 5 t ha^{-1} of poultry manure, recommended dose of fertilizer, and biofertilizer). The treatment, T_{13} has increased the available P_2O_5 of post-harvest soil over control by 75.21%

which was probably due to enhancement in soil health due to the addition of 1/5th of LR and 5 t ha^{-1} of poultry manure, the recommended dose of fertilizer, and biofertilizer. The application of RDF and 1/10th of LR (T_2) has increased the post-harvest soil's available P_2O_5 over control by 14.19%. However, T_{11} i.e., application of RDF along with 1/5th of LR, 5 t ha^{-1} of FYM, and biofertilizer for seed treatment, has increased the post-harvest available P_2O_5 content over control by 66.15%. Application of RDF along with 1/10th of LR, 5 t ha^{-1} of poultry manure, and biofertilizer for seed treatment (T_{12}) has increased the post-harvest soil's available P_2O_5 over control by 54.94% which was probably due to enhancement in soil health due to the addition of 1/5th of LR and 5 t ha^{-1} of poultry manure, the recommended dose of fertilizer, and biofertilizer. The results confirm that the integrated use of lime, organics, inorganic fertilizers, and biofertilizer has improved the availability of P_2O_5 in the post-harvest soil. Increased P availability due to liming possibly because of the dissolution of complex Fe and Al phosphates making phosphate available in mono-calcium phosphate [12, 22]. The finding of the present investigation was in good agreement with Sultana et al. [23], who observed that liming can increase P, Ca, and Mg availability in soil.

The current study's findings were in line with those of Kumar [24] who reported that applying lime can enhance the availability nutrient in acid soil (pH around 4.6), reduce Al toxicity, and improve many other soil fertility attributes. Kisinyo et al. [25] opined that applying lime significantly affected the available P, which was increased by 70.2% over unlimed plots. Juo and Uzu [26] observed that optimum P availability decreased between pH 5 and above. Haynes [27] investigated the impact of liming on the availability of phosphate in acidic soils.

Conclusion:

Significant improvement in groundnut productivity, available P_2O_5 and microbial biomass phosphorus (MBP) content of post-harvest experimental soil of Tripura was noted with the conjoint use of different combinations of the recommended dose (RD) of NPK, lime, organic manure (farm-yard-manure, FYM or poultry manure, PM) and seed treatment with Rhizobium compared to only the recommended dose of NPK (control). Again, the use of RD of NPK @ 20:60:40 kg ha^{-1} conjointly with lime (@ 1/5th LR), PM (@ 5 t ha^{-1}), and treating the seeds with Rhizobium @ 20 g kg^{-1} of seed might be recommended to the growers in achieving higher groundnut productivity with better return in acid soil of Tripura, India, as it showed maximum enhancement in groundnut productivity as well as available P_2O_5 content in post-harvest soil.

ACKNOWLEDGEMENT

The study is a part of the Ph.D. thesis of the first author. The authors would like to express their sincere gratitude to the Head of the Dept. of Soil Science and Agricultural Chemistry, Palli Siksha Bhavana, Visva-Bharati for the support given for smoothly experimenting.

COMPETING INTERESTS

The authors have declared that no competing interests exist.

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Table 1. Effect of integrated use of lime, organics, inorganic fertilizers and biofertilizers on seed yield of groundnut

Treatment	**Seed Yield (t ha^{-1})**			**% increase in pooled seed yield over control**
	2017	**2018**	**Pooled**	

T_{1}: RDF	1.60^{c}	1.62^{c}	1.61^{c}	
T_{2}: RDF + 1/10 LR	1.87^{c}	1.88^{c}	1.88^{c}	16.77
T_{3}: RDF + 1/5 LR	2.35^{b}	2.38^{bc}	2.37^{bc}	47.20
T_{4}: RDF + 1/10 LR + FYM	2.06^{bc}	2.09^{bc}	2.08^{bc}	29.19
T_{5}: RDF + 1/5 LR + FYM	2.70^{ab}	2.73^{ab}	2.72^{ab}	68.94
T_{6}: RDF + 1/10 LR + PM	2.23^{bc}	2.25^{bc}	2.24^{bc}	39.13
T_{7}: RDF + 1/5 LR + PM	2.80^{a}	2.83^{ab}	2.82^{ab}	75.16
T_{8}: RDF + 1/10 LR + Rhiz	1.96^{c}	1.98^{c}	1.97^{c}	22.36
T_{9}: RDF + 1/5 LR + Rhiz	2.42^{b}	2.45^{b}	2.44^{bc}	51.55
T_{10}: RDF + 1/10 LR + FYM + Rhiz	2.14^{bc}	2.16^{bc}	2.15^{bc}	33.54
T_{11}: RDF + 1/5 LR + FYM + Rhiz	2.85^{a}	2.90^{ab}	2.88^{a}	78.88
T_{12}: RDF + 1/10 LR + PM + Rhiz	2.30^{bc}	2.33^{bc}	2.32^{bc}	44.10
T_{13}: RDF + 1/5 LR + PM + Rhiz	2.96^{a}	2.99^{a}	2.98^{a}	85.09
SD	**0.397**	**0.403**	**0.400**	
Sem	**0.12**	**0.14**	**0.14**	
CD (0.05)	**0.36****	**0.41****	**0.40****	
CV (%)	**9.09**	**10.27**	**10.22**	

[RDF = N:P:K @ 20:60:40 kg/ha; LR = Lime requirement @ 3.2 t/ha; FYM= Farm yard manure @ 5t/ha; Rhiz= Seed treatment with Rhizobium @ 20g/kg seed; Mean values of seed yield followed by different subscript letters within each column are significantly different at ($P < 0.05$) level of probability by LSD. ** indicates F value is significant at 1% level of significance]

Table: 2 Effect of integrated use of lime, organics, inorganic fertilizers, and biofertilizer on microbial biomass phosphorus (MBP) of post-harvest soil

Treatment	**Microbial biomass phosphorus (MBP) [μg g^{-1}]**	**% increase in pooled MBP**

Initial soil	21.54			over control
Post-harvest soil	2017	2018	Pooled	
T_1: RDF	27.67[f]	27.71[f]	27.69[f]	
T_2: RDF + 1/10 LR	28.90[e]	29.01[e]	28.95[e]	4.55
T_3: RDF + 1/5 LR	29.80[d]	29.82[d]	29.81[d]	7.66
T_4: RDF + 1/10 LR + FYM	30.76[c]	30.80[c]	30.78[c]	11.16
T_5: RDF + 1/5 LR + FYM	31.54[b]	31.58[b]	31.56[b]	13.98
T_6: RDF + 1/10 LR + PM	32.02[ab]	32.06[ab]	32.04[ab]	15.71
T_7: RDF + 1/5 LR + PM	32.27[ab]	32.30[ab]	32.29[ab]	16.61
T_8: RDF + 1/10 LR + Rhiz	31.89[ab]	31.93[ab]	31.91[ab]	15.24
T_9: RDF + 1/5 LR + Rhiz	32.20[ab]	32.24[ab]	32.22[ab]	16.36
T_{10}: RDF + 1/10 LR + FYM + Rhiz	31.91[ab]	31.94[ab]	31.93[ab]	15.31
T_{11}: RDF + 1/5 LR + FYM + Rhiz	32.12[ab]	32.16[ab]	32.14[ab]	16.07
T_{12}: RDF + 1/10 LR + PM + Rhiz	32.45[a]	32.49[a]	32.47[a]	17.26
T_{13}: RDF + 1/5 LR + PM + Rhiz	32.32[a]	32.34[a]	32.33[a]	16.76
SD	**1.502**	**1.490**	**1.496**	
SEm	**0.26**	**0.25**	**0.25**	
CD (0.05)	**0.75****	**0.74****	**0.74****	
CV (%)	**1.43**	**1.40**	**1.41**	

[RDF = N:P:K @ 20:60:40 kg/ha; LR = Lime requirement @ 3.2 t/ha; FYM= Farm yard manure @ 5t/ha; Rhiz= Seed treatment with Rhizobium @ 20g/kg seed; Mean values of microbial biomass phosphorus (MBP) in post-harvest soil followed by different subscript letters within each column are significantly different at ($P < 0.05$) level of probability by LSD. ** indicates F value is significant at 1% level of significance].

Table 3. Effect of integrated use of lime, organics, inorganic fertilizers, and biofertilizer on available P_2O_5 content of post-harvest soil

Treatment	**Available P_2O_5 content [kg ha^{-1}]**	**% increase pooled available**
Initial soil	**10.65**	

Post-harvest soil	**2017**	**2018**	**Pooled**	**P_2O_5 over control**
T_1: RDF	9.60^{g}	9.85^{e}	9.72^{h}	
T_2: RDF + 1/10 LR	10.87^{f}	11.33^{d}	11.1^{g}	14.20
T_3: RDF + 1/5 LR	11.68^{ef}	12.07^{d}	11.87^{f}	22.12
T_4: RDF + 1/10 LR + FYM	12.43^{de}	12.80^{cd}	12.61^{ef}	29.73
T_5: RDF + 1/5 LR + FYM	13.05^{d}	13.27^{c}	13.16^{e}	35.39
T_6: RDF + 1/10 LR + PM	14.20^{c}	14.43^{b}	14.32^{d}	47.33
T_7: RDF + 1/5 LR + PM	15.28^{b}	15.51^{b}	15.39^{c}	58.33
T_8: RDF + 1/10 LR + Rhiz	11.82^{e}	12.23^{cd}	12.03^{f}	23.77
T_9: RDF + 1/5 LR + Rhiz	14.10^{c}	14.80^{b}	14.45^{d}	48.66
T_{10}: RDF + 1/10 LR + FYM + Rhiz	14.46^{c}	14.69^{b}	14.58^{d}	50.00
T_{11}: RDF + 1/5 LR + FYM + Rhiz	15.97^{ab}	16.33^{ab}	16.15^{b}	66.15
T_{12}: RDF + 1/10 LR + PM + Rhiz	14.80^{bc}	15.32^{b}	15.06^{cd}	54.94
T_{13}: RDF + 1/5 LR + PM + Rhiz	16.75^{a}	17.30^{a}	17.03^{a}	75.21
SD	**2.062**	**2.184**	**2.087**	
Sem	**0.28**	**0.37**	**0.23**	
CD (0.05)	**0.81****	**1.08****	**0.67****	
CV (%)	**3.59**	**4.61**	**2.89**	

[RDF = N:P:K @ 20:60:40 kg/ha; LR = Lime requirement @ 3.2 t/ha; FYM= Farm yard manure @ 5t/ha; Rhiz= Seed treatment with Rhizobium @ 20g/kg seed; Mean values of available P_2O_5 content in post-harvest soil followed by different subscript letters within each column are significantly different at ($P < 0.05$) level of probability by LSD. ** indicates F value is significant at 1% level of significance]