



# Conjoint Application of Lime, Organics, Inorganic Fertilizers, and Bio-fertilizers Increases Groundnut Productivity, Available Phosphorus and Microbial Biomass Phosphorus in Acidic Soil of Tripura, India

D. Dey <sup>a,b</sup>, M. C. Kundu <sup>b\*</sup>, D. Sen <sup>c</sup> and M. S. Sachan <sup>a</sup>

<sup>a</sup> Krishi Vigyan Kendra, Khowai, Tripura, Chebri, 799207, India.

<sup>b</sup> Department of Soil Science and Agricultural Chemistry, Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan -731236, West Bengal, India.

<sup>c</sup> Department of Agronomy, College of Agriculture, Tripura, Lembuchera-799210, West Tripura, India.

## **Authors' contributions**

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## **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),

\*Corresponding author: E-mail: mckundu@gmail.com;

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 (RD) 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 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<sup>-1</sup> conjointly with lime (@ 1/5<sup>th</sup> LR), PM (@ 5 t ha<sup>-1</sup>), and treating the seeds with Rhizobium @ 20 g kg<sup>-1</sup> 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<sub>2</sub>O<sub>5</sub> content in post-harvest soil.

**Keywords:** Groundnut; yield; lime; organic manure; fertilizers; biofertilizers; soil phosphorus.

## 1. 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, this 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 (P) and microbial biomass phosphorus (MBP) content in the acidic soil of Tripura.

## 2. MATERIALS AND METHODS

The study was carried out at the Chebri Village of Khowai district of Tripura having 23.8974<sup>o</sup> North Latitude, 91.6372<sup>o</sup> 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<sup>2</sup>. 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<sub>1</sub>: Control (only recommended dose of NPK (20:60:40 kg ha<sup>-1</sup>) (RDF); T<sub>2</sub>: Liming @1/10<sup>th</sup> LR (limestone) + RDF; T<sub>3</sub>: Liming @1/5<sup>th</sup> LR (limestone) + RDF; T<sub>4</sub>:Liming @1/10<sup>th</sup> LR (limestone) + RDF + FYM @ 5 t ha<sup>-1</sup> [T<sub>2</sub> + FYM]; T<sub>5</sub>: Liming @1/5<sup>th</sup> LR (limestone) + RDF + FYM @ 5 t ha<sup>-1</sup> [T<sub>3</sub> + FYM]; T<sub>6</sub> : Liming @1/10<sup>th</sup> LR (limestone) + RDF + PM

@ 5 t ha<sup>-1</sup> [T<sub>2</sub> + PM]; T<sub>7</sub>: Liming @1/5<sup>th</sup> LR (limestone) + RDF + PM @ 5 t ha<sup>-1</sup> [T<sub>3</sub> + PM]; T<sub>8</sub> : Liming @1/10<sup>th</sup> LR (limestone) + RDF + Rhizobium (seed treatment @ 20 g kg<sup>-1</sup> seed) [T<sub>2</sub> + Rhizobium]; T<sub>9</sub> : Liming @1/5<sup>th</sup> LR (limestone) + RDF + Rhizobium (seed treatment @ 20 g kg<sup>-1</sup> seed) [T<sub>3</sub> + Rhizobium]; T<sub>10</sub> : Liming @1/10<sup>th</sup> LR (limestone) + RDF + FYM @ 5 t ha<sup>-1</sup> + Rhizobium (seed treatment @ 20 g kg<sup>-1</sup> seed) [T<sub>4</sub> + Rhizobium]; T<sub>11</sub> : Liming @1/5<sup>th</sup> LR (limestone) + RDF + FYM @ 5 t ha<sup>-1</sup> + Rhizobium (seed treatment @ 20 g kg<sup>-1</sup> seed) [T<sub>5</sub> + Rhizobium]; T<sub>12</sub> : Liming @1/10<sup>th</sup> LR (limestone)+ RDF + PM @ 5 t ha<sup>-1</sup> + Rhizobium (seed treatment @ 20 g kg<sup>-1</sup> seed) [T<sub>6</sub> + Rhizobium]; T<sub>13</sub> : Liming @1/5<sup>th</sup> LR (limestone) + RDF + PM @ 5 t ha<sup>-1</sup> + Rhizobium (seed treatment @ 20 g kg<sup>-1</sup> seed) [T<sub>7</sub> + Rhizobium]. Liming material (CaCO<sub>3</sub>) 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<sup>-1</sup>) 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 1<sup>st</sup> and 2<sup>nd</sup> 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 phosphorus (P<sub>2</sub>O<sub>5</sub>) using Brays No. 1 method [6] and microbial biomass phosphorus (MBP) by Fumigation extraction method [7]. The data on seed yield, available P<sub>2</sub>O<sub>5</sub> 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.

### 3. RESULTS AND DISCUSSION

The seed yield 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<sub>13</sub> (2.98 t ha<sup>-1</sup>) imposing 1/5<sup>th</sup> of LR and 5 t ha<sup>-1</sup> of poultry manure (PM), recommended dose of fertilizer (RDF), and biofertilizer, which was, however, statistically at par with T<sub>11</sub> (RDF + 1/5 LR + FYM + Rhiz), T<sub>7</sub> (RDF + 1/5 LR + PM) and T<sub>5</sub> (RDF + 1/5 LR + FYM). There was 85.09% increase in seed yield in T<sub>13</sub> over T<sub>1</sub> (control). Application of RDF along with 1/10<sup>th</sup> of LR with 5 t ha<sup>-1</sup> of FYM and biofertilizer for seed treatment (T<sub>10</sub>) increased the seed productivity over control by 33.54%. In contrast, RDF and 1/10<sup>th</sup> of LR with 5 t ha<sup>-1</sup> of poultry manure and biofertilizer for seed treatment (T<sub>12</sub>) increased the seed productivity over control by 44.10%. Adding the recommended dose of fertilizer and 1/10<sup>th</sup> of LR (T<sub>2</sub>) increased the seed yield over control by 16.77%. It was noted that the addition of FYM @ 5 t ha<sup>-1</sup>, 1/5<sup>th</sup> of LR and RDF (T<sub>5</sub>) increased the seed productivity by 14.76 % over T<sub>3</sub>, where only 1/5<sup>th</sup> of LR with RDF was applied. Similarly, adding 5 t ha<sup>-1</sup> of poultry manure/ha and 1/5<sup>th</sup> of LR with RDF (T<sub>7</sub>) increased the seed yield by 18.98% over T<sub>3</sub>. However, T<sub>13</sub> was found to increase seed yield by 5.67% over T<sub>7</sub>. Similarly, T<sub>11</sub> has increased seed yield by 5.88% over T<sub>5</sub>. However, T<sub>11</sub> had an additional seed yield increase of 18.03% over T<sub>9</sub>. Similarly, T<sub>13</sub> is found to have an additional seed yield increase of 22.13% over T<sub>9</sub>. Adding 5 t ha<sup>-1</sup> of FYM with the recommended dose of fertilizer and 1/10<sup>th</sup> of LR (T<sub>4</sub>) has increased the seed yield by 10.63% over T<sub>2</sub>. In contrast, adding 5 t ha<sup>-1</sup> of PM and the RD of fertilizer with 1/10<sup>th</sup> of LR (T<sub>6</sub>) has increased the seed yield by 19.14% over T<sub>2</sub>. At the same time, the addition of 5 t ha<sup>-1</sup> of FYM with RDF and 1/10<sup>th</sup> of LR and rhizobium as a seed treatment (T<sub>10</sub>) had an additional seed yield increase of 9.13% over T<sub>8</sub>. However, 5 t ha<sup>-1</sup> of PM with RDF and 1/10<sup>th</sup> of LR and rhizobium for seed treatment (T<sub>12</sub>) had an additional seed yield increase of 17.76% over the use of rhizobium as seed treatment with RDF along with 1/10<sup>th</sup> of LR (T<sub>8</sub>). The lowest pooled seed yield (1.61 t ha<sup>-1</sup>) of groundnut was obtained T<sub>1</sub> (control) which was, however, statistically at par with T<sub>2</sub>, T<sub>8</sub>, T<sub>4</sub>, T<sub>10</sub>, T<sub>6</sub>, T<sub>12</sub>, T<sub>3</sub> and T<sub>9</sub>.

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 aluminium 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<sup>-1</sup> 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<sup>-1</sup> [14]. Our results support the favourable 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<sub>3</sub> ha<sup>-1</sup> and 63% for its application @ 1000 kg CaCO<sub>3</sub> ha<sup>-1</sup> 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<sup>-1</sup>. 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<sup>-1</sup>) was noted in T<sub>12</sub> (1/10<sup>th</sup> of LR along with 5 t ha<sup>-1</sup> of poultry manure, recommended dose of fertilizer, and biofertilizer) which was, however, at par with T<sub>6</sub> (RDF + 1/10 LR + PM), T<sub>7</sub> (RDF + 1/5 LR + PM), T<sub>8</sub> (RDF + 1/10 LR + Rhiz), T<sub>9</sub> (RDF + 1/5 LR + Rhiz), T<sub>10</sub> (RDF + 1/10 LR + FYM + Rhiz), T<sub>11</sub> (RDF + 1/5 LR + FYM + Rhiz) and T<sub>13</sub> (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<sup>-1</sup>). 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<sub>2</sub>O<sub>5</sub> 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<sub>2</sub>O<sub>5</sub> of experimental soil was 10.65 kg ha<sup>-1</sup>. In all the treatments except control (T<sub>1</sub>), a rise in available P<sub>2</sub>O<sub>5</sub> 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<sup>-1</sup>) available P<sub>2</sub>O<sub>5</sub> content was noted in T<sub>13</sub> (1/5<sup>th</sup> of LR and 5 t ha<sup>-1</sup> of poultry manure, recommended dose of fertilizer, and biofertilizer). The treatment, T<sub>13</sub> has increased the available P<sub>2</sub>O<sub>5</sub> of post-harvest soil over control by 75.21% which was probably due to enhancement in soil health due to the addition of 1/5<sup>th</sup> of LR and 5 t ha<sup>-1</sup> of poultry manure, the recommended dose of fertilizer, and biofertilizer. The application of RDF and 1/10<sup>th</sup> of LR (T<sub>2</sub>) has increased the post-harvest soil's available P<sub>2</sub>O<sub>5</sub> over control by 14.19%. However, T<sub>11</sub> i.e., application of RDF along with 1/5<sup>th</sup> of LR, 5 t ha<sup>-1</sup> of FYM, and biofertilizer for seed treatment, has increased the post-harvest available P<sub>2</sub>O<sub>5</sub> content over control by 66.15%. Application of RDF along with 1/10<sup>th</sup> of LR, 5 t ha<sup>-1</sup> of poultry manure, and biofertilizer for seed treatment (T<sub>12</sub>) has increased the post-harvest soil's available P<sub>2</sub>O<sub>5</sub> over control by 54.94% which was probably due to enhancement in soil health due to the addition of 1/5<sup>th</sup> of LR and 5 t ha<sup>-1</sup> 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<sub>2</sub>O<sub>5</sub> 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.

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

Treatment	Seed Yield (t ha <sup>-1</sup> )			% increase in pooled seed yield over control
	2017	2018	Pooled	
T <sub>1</sub> : RDF	1.60 <sup>c</sup>	1.62 <sup>c</sup>	1.61 <sup>c</sup>	
T <sub>2</sub> : RDF + 1/10 LR	1.87 <sup>c</sup>	1.88 <sup>c</sup>	1.88 <sup>c</sup>	16.77
T <sub>3</sub> : RDF + 1/5 LR	2.35 <sup>b</sup>	2.38 <sup>bc</sup>	2.37 <sup>bc</sup>	47.20
T <sub>4</sub> : RDF + 1/10 LR + FYM	2.06 <sup>bc</sup>	2.09 <sup>bc</sup>	2.08 <sup>bc</sup>	29.19
T <sub>5</sub> : RDF + 1/5 LR + FYM	2.70 <sup>ab</sup>	2.73 <sup>ab</sup>	2.72 <sup>ab</sup>	68.94
T <sub>6</sub> : RDF + 1/10 LR + PM	2.23 <sup>bc</sup>	2.25 <sup>bc</sup>	2.24 <sup>bc</sup>	39.13
T <sub>7</sub> : RDF + 1/5 LR + PM	2.80 <sup>a</sup>	2.83 <sup>ab</sup>	2.82 <sup>ab</sup>	75.16
T <sub>8</sub> : RDF + 1/10 LR + Rhiz	1.96 <sup>c</sup>	1.98 <sup>c</sup>	1.97 <sup>c</sup>	22.36
T <sub>9</sub> : RDF + 1/5 LR + Rhiz	2.42 <sup>b</sup>	2.45 <sup>b</sup>	2.44 <sup>bc</sup>	51.55
T <sub>10</sub> : RDF + 1/10 LR + FYM + Rhiz	2.14 <sup>bc</sup>	2.16 <sup>bc</sup>	2.15 <sup>bc</sup>	33.54
T <sub>11</sub> : RDF + 1/5 LR + FYM + Rhiz	2.85 <sup>a</sup>	2.90 <sup>ab</sup>	2.88 <sup>a</sup>	78.88
T <sub>12</sub> : RDF + 1/10 LR + PM + Rhiz	2.30 <sup>bc</sup>	2.33 <sup>bc</sup>	2.32 <sup>bc</sup>	44.10
T <sub>13</sub> : RDF + 1/5 LR + PM + Rhiz	2.96 <sup>a</sup>	2.99 <sup>a</sup>	2.98 <sup>a</sup>	85.09
<b>SD</b>	<b>0.397</b>	<b>0.403</b>	<b>0.400</b>	
<b>Sem</b>	<b>0.12</b>	<b>0.14</b>	<b>0.14</b>	
<b>CD (0.05)</b>	<b>0.36**</b>	<b>0.41**</b>	<b>0.40**</b>	
<b>CV (%)</b>	<b>9.09</b>	<b>10.27</b>	<b>10.22</b>	

[RDF = N:P:K @ 20:60:40 kg ha<sup>-1</sup>; LR = Lime requirement @ 3.2 t ha<sup>-1</sup>; FYM= Farm yard manure @ 5 t ha<sup>-1</sup>; Rhiz= Seed treatment with Rhizobium @ 20 g kg<sup>-1</sup> 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 <sup>-1</sup> ]			% increase in pooled MBP over control
	2017	2018	Pooled	
<b>Initial soil</b>	<b>21.54</b>			
<b>Post-harvest soil</b>				
T <sub>1</sub> : RDF	27.67 <sup>f</sup>	27.71 <sup>f</sup>	27.69 <sup>f</sup>	
T <sub>2</sub> : RDF + 1/10 LR	28.90 <sup>e</sup>	29.01 <sup>e</sup>	28.95 <sup>e</sup>	4.55
T <sub>3</sub> : RDF + 1/5 LR	29.80 <sup>d</sup>	29.82 <sup>d</sup>	29.81 <sup>d</sup>	7.66
T <sub>4</sub> : RDF + 1/10 LR + FYM	30.76 <sup>c</sup>	30.80 <sup>c</sup>	30.78 <sup>c</sup>	11.16
T <sub>5</sub> : RDF + 1/5 LR + FYM	31.54 <sup>b</sup>	31.58 <sup>b</sup>	31.56 <sup>b</sup>	13.98
T <sub>6</sub> : RDF + 1/10 LR + PM	32.02 <sup>ab</sup>	32.06 <sup>ab</sup>	32.04 <sup>ab</sup>	15.71
T <sub>7</sub> : RDF + 1/5 LR + PM	32.27 <sup>ab</sup>	32.30 <sup>ab</sup>	32.29 <sup>ab</sup>	16.61
T <sub>8</sub> : RDF + 1/10 LR + Rhiz	31.89 <sup>ab</sup>	31.93 <sup>ab</sup>	31.91 <sup>ab</sup>	15.24
T <sub>9</sub> : RDF + 1/5 LR + Rhiz	32.20 <sup>ab</sup>	32.24 <sup>ab</sup>	32.22 <sup>ab</sup>	16.36
T <sub>10</sub> : RDF + 1/10 LR + FYM + Rhiz	31.91 <sup>ab</sup>	31.94 <sup>ab</sup>	31.93 <sup>ab</sup>	15.31
T <sub>11</sub> : RDF + 1/5 LR + FYM + Rhiz	32.12 <sup>ab</sup>	32.16 <sup>ab</sup>	32.14 <sup>ab</sup>	16.07
T <sub>12</sub> : RDF + 1/10 LR + PM + Rhiz	32.45 <sup>a</sup>	32.49 <sup>a</sup>	32.47 <sup>a</sup>	17.26
T <sub>13</sub> : RDF + 1/5 LR + PM + Rhiz	32.32 <sup>a</sup>	32.34 <sup>a</sup>	32.33 <sup>a</sup>	16.76
<b>SD</b>	<b>1.502</b>	<b>1.490</b>	<b>1.496</b>	
<b>SEm</b>	<b>0.26</b>	<b>0.25</b>	<b>0.25</b>	
<b>CD (0.05)</b>	<b>0.75**</b>	<b>0.74**</b>	<b>0.74**</b>	
<b>CV (%)</b>	<b>1.43</b>	<b>1.40</b>	<b>1.41</b>	

[RDF = N:P:K @ 20:60:40 kg ha<sup>-1</sup>; LR = Lime requirement @ 3.2 t ha<sup>-1</sup>; FYM= Farm yard manure @ 5 t ha<sup>-1</sup>; Rhiz= Seed treatment with Rhizobium @ 20 g kg<sup>-1</sup> 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<sub>2</sub>O<sub>5</sub> content of post-harvest soil**

Treatment	Available P <sub>2</sub> O <sub>5</sub> content [kg ha <sup>-1</sup> ]			% increase pooled available P <sub>2</sub> O <sub>5</sub> over control
Initial soil	10.65			
Post-harvest soil	2017	2018	Pooled	
T <sub>1</sub> : RDF	9.60 <sup>g</sup>	9.85 <sup>e</sup>	9.72 <sup>h</sup>	
T <sub>2</sub> : RDF + 1/10 LR	10.87 <sup>f</sup>	11.33 <sup>d</sup>	11.1 <sup>g</sup>	14.20
T <sub>3</sub> : RDF + 1/5 LR	11.68 <sup>ef</sup>	12.07 <sup>d</sup>	11.87 <sup>f</sup>	22.12
T <sub>4</sub> : RDF + 1/10 LR + FYM	12.43 <sup>de</sup>	12.80 <sup>cd</sup>	12.61 <sup>ef</sup>	29.73
T <sub>5</sub> : RDF + 1/5 LR + FYM	13.05 <sup>d</sup>	13.27 <sup>c</sup>	13.16 <sup>e</sup>	35.39
T <sub>6</sub> : RDF + 1/10 LR + PM	14.20 <sup>c</sup>	14.43 <sup>b</sup>	14.32 <sup>d</sup>	47.33
T <sub>7</sub> : RDF + 1/5 LR + PM	15.28 <sup>b</sup>	15.51 <sup>b</sup>	15.39 <sup>c</sup>	58.33
T <sub>8</sub> : RDF + 1/10 LR + Rhiz	11.82 <sup>e</sup>	12.23 <sup>cd</sup>	12.03 <sup>f</sup>	23.77
T <sub>9</sub> : RDF + 1/5 LR + Rhiz	14.10 <sup>c</sup>	14.80 <sup>b</sup>	14.45 <sup>d</sup>	48.66
T <sub>10</sub> : RDF + 1/10 LR + FYM + Rhiz	14.46 <sup>c</sup>	14.69 <sup>b</sup>	14.58 <sup>d</sup>	50.00
T <sub>11</sub> : RDF + 1/5 LR + FYM + Rhiz	15.97 <sup>ab</sup>	16.33 <sup>ab</sup>	16.15 <sup>b</sup>	66.15
T <sub>12</sub> : RDF + 1/10 LR + PM + Rhiz	14.80 <sup>bc</sup>	15.32 <sup>b</sup>	15.06 <sup>cd</sup>	54.94
T <sub>13</sub> : RDF + 1/5 LR + PM + Rhiz	16.75 <sup>a</sup>	17.30 <sup>a</sup>	17.03 <sup>a</sup>	75.21
<b>SD</b>	<b>2.062</b>	<b>2.184</b>	<b>2.087</b>	
<b>Sem</b>	<b>0.28</b>	<b>0.37</b>	<b>0.23</b>	
<b>CD (0.05)</b>	<b>0.81**</b>	<b>1.08**</b>	<b>0.67**</b>	
<b>CV (%)</b>	<b>3.59</b>	<b>4.61</b>	<b>2.89</b>	

[RDF = N:P:K @ 20:60:40 kg ha<sup>-1</sup>; LR = Lime requirement @ 3.2 t ha<sup>-1</sup>; FYM = Farm yard manure @ 5 t ha<sup>-1</sup>; Rhiz = Seed treatment with Rhizobium @ 20 g kg<sup>-1</sup> seed; Mean values of available P<sub>2</sub>O<sub>5</sub> 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]

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.

#### 4. CONCLUSION

Significant improvement in groundnut productivity, available phosphorus (P<sub>2</sub>O<sub>5</sub>) 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<sup>-1</sup> conjointly with lime (@ 1/5<sup>th</sup> LR), PM (@ 5 t ha<sup>-1</sup>), and

treating the seeds with Rhizobium @ 20 g kg<sup>-1</sup> 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<sub>2</sub>O<sub>5</sub> content in post-harvest soil.

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#### COMPETING INTERESTS

The authors have declared that no competing interests exist.

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