RESEARCH ARTICLE Agricultural Science Digest, Volume 45 Issue 4: 606-612 (August 2025)

# Nutrient Composition, Uptake, Yield and Phosphorus Use Efficiency of Black Gram as Influenced by Soil Amendments and Phosphorus in Acidic Soil of Nagaland

Temsusangla I. Jamir[1], Y.K. Sharma[1], Albert Uchoi[1]

10.18805/ag.D-6214


## ABSTRACT

**Background:** Nutrient availability is impaired by soil acidity limiting its accessibility to plants especially phosphorus get immobilized by $Fe^{3+}$ and $Al^{3+}$ in acid soil, thereby, resulting in poor growth, seed development and yield. Liming is an imperative soil management practices to keep in check the soil acidity-induced fertility constraints, along with integrated use of fertilizers and organic fertilizers.

**Methods:** The experiment consist of four soil amendments levels [$SA_0$ (control), $SA_1$ (5% LR), $SA_2$ (PSB) and $SA_3$ (5% LR+PSB)] and four phosphorus levels (0, 20, 40 and 60 kg $P_2O_5$ $ha^{-1}$) laid out in randomized block design with three replications. Lime ($CaCO_3$) was applied in furrows 10 days prior to sowing and seed was treated with PSB a day before sowing. Phosphorus levels and the recommended dose of nitrogen and potassium were applied as basal.

**Result:** $SA_3$ (5% LR+PSB) significantly increased the seed yield by 29.9% and stover yield by 35.7% over control. Among P levels application of 60 kg $P_2O_5$ $ha^{-1}$ significantly increased the seed and stover yield and was found highest over preceding P levels but was found at par with $P_{40}$; application of 40 kg $P_2O_5$ $ha^{-1}$ increased the seed yield by 44.9% and stover yield by 55.9% over control. Interaction effect of soil amendments and phosphorus was significant on seed and stover yieldand nutrient uptake. Phosphorus use efficiency (PUE) decreased with increase in phosphorus levels while P uptake efficiency (PUPE), fertilizer P uptake efficiency (FPUPE), fertilizer P utilization efficiency (FPUTE) and fertilizer P use efficiency (FPUE) were highest at $P_{40}$.


**Key words:** Black gram, Phosphorus, Soil amendments, Yield.

## INTRODUCTION

Black gram, also known as *urd* bean, is one of the important pulse crops grown throughout India. It is cheapest source of food protein thereby considered as the poor men's meat. In India, according to first advance estimates of production of major *kharif* crops (Anonymous, 2023-24), area under *urd* is estimated to be 30.73 lakh hectares with a production of 15.05 lakh metric tonnes during *kharif* season. The states of Madhya Pradesh, Uttar Pradesh, Rajasthan, Karnataka and Andhra Pradesh are the major producers of black gram in India during *kharif* season. North Eastern regions of India account less than 5% in pulse production. In Nagaland, black gram (during 2022-23) occupies with 310 hectares with a production of 255 metric tonnes, (Directorate of Economics and Statistics, 2023). Being a legume and a drought resistant crop, it fixes atmospheric nitrogen enriching the soil also exhibits great resilient to long period of water scarcity. However, inadequate utilization of both macro and micro plant nutrients are among the major factors accountable for poor yield in the state.

Soils of North Eastern Regions (NER) of India are strongly acidic in nature with special reference to the state of Nagaland (Sharma *et al*., 2006). In Nagaland, 83.6% of the total geographical area comprised of degraded acidic soils (with pH<5.5), out of which, 16.9% belonged to extremely acidic, 39.4% of TGA under very strongly acidic and 27.3% of TGA was under strongly acidic soils (Bandypadhyay *et al*., 2016). In acid soil, phosphorus is deficient because soluble inorganic P is fixed by Al and Fe (Adnan *et al*., 2003) resulting in less availability of P for crop. Soil acidity and phosphorus deficiencies limit crop production in North east region. Proper soil acidity management practices on such soils are therefore imperative for improving food security globally and regionally. Liming is the most desirable practice of amelioration of acidic soils having pH of less than 5.5. Lime application declines the concentration of $H^+$, solubility of Fe, Al and Mn and increase in soil pH. It also helps reduce to the toxicity effect of Al; enhances the efficiency of applied fertilizers (Prochnow, 2014) and facilitates the increase in availability of phosphorus and molybdenum.

[1]Department of Soil Science, School of Agricultural Sciences, Nagaland University, Medziphema-797 106, Nagaland, India.

**Corresponding Author:** Temsusangla I. Jamir, Department of Soil Science, School of Agricultural Sciences, Nagaland University, Medziphema-797 106, Nagaland, India.
Email: asangjamir577@gmail.com
ORCIDs: 0009-0008-9614-7483

**How to cite this article:** Jamir, T.I., Sharma, Y.K. and Uchoi, A. (2025). Nutrient Composition, Uptake, Yield and Phosphorus Use Efficiency of Black Gram as Influenced by Soil Amendments and Phosphorus in Acidic Soil of Nagaland. *Agricultural Science Digest.* **45(4):** 606-612. doi: 10.18805/ag.D-6214.

**Submitted:** 28-09-2024 **Accepted:** 29-11-2024 **Online:** 02-01-2025

In P deficient soils, P-supplementing microorganism, either bacteria or fungi by solubilization, mobilization or mineralization, influence remarkably the three dynamic phenomena P cycle: sorption-desorption, dissolution-precipitation and mineralization-immobilization (Sharma *et al*., 2013). Application of PSB as bioinoculants enhances P availability by employing the mechanism of solubilising and/or mineralization of P through the production of organic acids like lactic, formic, malonic, gluconicand citric etc. Furthermore, PSB also produce phytohormones thereby influences root systems by supplying plants with significant amount of auxin (Bargaz *et al*., 2021). Well-balanced and efficient fertilizer application integrating inorganic and organic fertilizers, also the use of biofertilizers, are crucial in improving yield. Keeping this in consideration the present study was undertaken to investigate the influence of soil amendments and phosphorus on nutrient composition, uptake, yield and phosphorus use efficiency of black gram as influenced by soil amendments and phosphorus in acidic soil of Nagaland.

## MATERIALS AND METHODS

The experiment was carried out in 2021 and 2022 during *kharif* season at research farm at School of Agricultural Sciences, Nagaland University, Medziphema. The experimental site lies at 25°45′30″N latitude and 93°53′04″ E longitude at an elevation of 310 m above mean sea level and humid sub-tropical in nature. The soil was sandy loam in texture with pH 4.42, Organic carbon 21 g $kg^{-1}$, available N, P and K status 209.51, 9.63 and 170.41 kg $ha^{-1}$, respectively, lime requirement 20.9 t $ha^{-1}$, exchangeable $Ca^{2+}$ and $Mg^{2+}$ 0.9 and 0.6 cmol($p^+$) $kg^{-1}$, total potential acidity, pH dependent acidity, exchangeable acidity, exchangeable aluminium and exchangeable hydrogen 20, 16.75, 3.25, 2.75 and 0.5 cmol($p^+$) $kg^{-1}$, respectively. The experiment was laid out in randomized block design with four levels of soil amendments *viz*. $SA_0$: Control, $SA_1$:5% LR, $SA_2$: PSB and $SA_3$: 5% LR+PSB; and four levels of phosphorus *viz*. $P_0$: control, $P_{20}$: 20 kg $P_2O_5$ $ha^{-1}$, $P_{40}$: 40 kg $P_2O_5$ $ha^{-1}$ and $P_{60}$: 60 kg $P_2O_5$ $ha^{-1}$. Lime ($CaCO_3$), as per lime requirement (@5% LR), was applied in furrows 10 days prior to sowing. Four levels of phosphorus 0, 20, 40 and 60 kg $P_2O_5$ $ha^{-1}$ were applied through single super phosphate; recommended dose of nitrogen and potassium (20 kg N and 40 kg $K_2O$ $ha^{-1}$) were applied through urea and muriate of potash. Seed inoculation with phosphate solubilizing bacteria (*Bacillus megaterium* @ 200 g per 10 kg seeds) was done the day before sowing. The seed were sown on last week of July during 2021 and 2022 by line sowing method at 1.5 cm depth. Thinning was done 15 DAS maintaining row to row spacing at 30 cm and plant to plant 10 cm apart. Intercultural operation such as hand weeding was done at time to time when required. Harvesting of pods was done in four to five pickings. After final picking of pods, crop was harvested by cutting from the ground level with sickle to record the stover yield. The harvested pods were then sundried, threshed and cleaned manually. Nitrogen content in seed and stover were analyzed by Kjeldahl method. Phosphorus, potassium, calcium and magnesium content in seed and stover were determined in diacid ($HNO_3$, $HClO_4$) extract by advocating standard procedures (Singh *et al*., 2019). Nutrient uptake was calculated by multiplying the yield with nutrient content. The data were analyzed statistically to compare the treatment effect (Panse and Sukhatme, 1961). The following parameters were calculated to know the nutrition of black gram:

$$\text{Phosphorus uptake efficiency (PUPE)} = \frac{\text{P in plant}}{\text{P in soil}}$$

$$\text{Phosphorus utilization efficiency (PUTE)} = \frac{\text{Yield}}{\text{P in plant}}$$

$$\text{Phosphorus use efficiency (PUPE)} = \frac{\text{Yield}}{\text{P in soil}}$$

$$\text{Fertilization P uptake efficiency (FPUPE)} = \frac{\text{P in fertilized plants - P in control plants}}{\text{P applied}}$$

$$\text{Fertilization P uptake efficiency (FPUPE)} = \frac{\text{Yield of fertilized plots - Yield of control plots}}{\text{p in fertilized plants - P in control plants P applied}}$$

$$\text{Fertilization P use efficiency (FPUE)} = \frac{\text{Yield of fertilized plots - Yield of control plots}}{\text{P applied}}$$

## RESULTS AND DISCUSSION

### Nutrient composition, yield and protein content

The nutrient content in seed and stover of black gram were significantly enhanced with the application of soil amendments (Table 1). Significantly higher N, P, K, Ca and Mg content in seed and stover were recorded with the application of 5% LR in conjunction with PSB ($SA_3$). The response to amendments by nutrient content in seed and stover of black gram were in order as such: $SA_3$>$SA_1$>$SA_2$>$SA_0$. Combine application of 5% LR+PSB ($SA_3$) increased the N, P, K, Ca and Mg content to an extent of 10.4%, 12.1%, 24.2%, 31.2% and 73.6% in seed; 9.9%. 28.5%, 6.5%, 24.1% and 64% in stover over control, respectively. While, solo application of 5% lime ($SA_1$) and PSB ($SA_2$) increased N, P, K, Ca and Mg content by 6.6 and 2.4%, 9.0 and 3.0%, 15.7 and 1.4%, 22.3 and 6.25%, 42.6 and 5.6% in seed; 6.6 and 2.4%, 21.4 and 14.2%, 2.8 and 0.7%, 14.0 and 2.0%, 42.6 and 5.6% in stover over control, respectively. Thus, it could be inferred that nutrient content in seed and stover at amend plots were higher than control, while even among the amended plots nutrient content was more in lime treated plots compared to unlimed plots. Significant improvement in seed and stover yield of black gram were recorded with the application of soil amendments. Maximum seed yield (627.69 kg $ha^{-1}$) and

**Table 1:** Effect of soil amendments and phosphorus on nutrient composition of black gram (Pooled).

| Treatments | Nitrogen (%) | | Phosphorus (%) | | Potassium (%) | | Calcium (%) | | Magnesium (%) | | Seed yield (kg ha$^{-1}$) | Stover yield (kg ha$^{-1}$) | Protein content (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Seed | Stover | Seed | Stover | Seed | Stover | Seed | Stover | Seed | Stover | | | |
| $SA_0$ (Control) | 3.15 | 1.21 | 0.33 | 0.14 | 0.70 | 1.38 | 0.112 | 0.149 | 0.057 | 0.089 | 483.16 | 866.38 | 19.67 |
| $SA_1$ (5% LR) | 3.37 | 1.29 | 0.36 | 0.17 | 0.81 | 1.42 | 0.137 | 0.170 | 0.084 | 0.127 | 577.75 | 1082.75 | 21.06 |
| $SA_2$ (PSB) | 3.26 | 1.24 | 0.34 | 0.16 | 0.71 | 1.39 | 0.119 | 0.152 | 0.058 | 0.094 | 538.15 | 992.94 | 20.36 |
| $SA_3$ (5% LR + PSB) | 3.48 | 1.33 | 0.37 | 0.18 | 0.87 | 1.47 | 0.147 | 0.185 | 0.099 | 0.146 | 627.69 | 1176.39 | 21.75 |
| SEm± | 0.01 | 0.01 | 0.003 | 0.002 | 0.01 | 0.005 | 0.002 | 0.004 | 0.003 | 0.003 | 5.32 | 11.72 | 0.07 |
| CD (P=0.05) | 0.03 | 0.03 | 0.01 | 0.01 | 0.03 | 0.013 | 0.007 | 0.012 | 0.008 | 0.009 | 15.05 | 33.14 | 0.20 |
| **Phosphorus levels** | | | | | | | | | | | | | |
| $P_0$ | 3.11 | 1.19 | 0.32 | 0.14 | 0.73 | 1.40 | 0.122 | 0.154 | 0.075 | 0.113 | 441.55 | 781.05 | 19.43 |
| $P_{20}$ | 3.23 | 1.25 | 0.34 | 0.15 | 0.76 | 1.41 | 0.130 | 0.161 | 0.073 | 0.113 | 503.47 | 924.27 | 20.16 |
| $P_{40}$ | 3.37 | 1.30 | 0.36 | 0.17 | 0.79 | 1.42 | 0.130 | 0.170 | 0.073 | 0.113 | 640.00 | 1194.88 | 21.07 |
| $P_{60}$ | 3.55 | 1.32 | 0.38 | 0.18 | 0.81 | 1.43 | 0.132 | 0.170 | 0.076 | 0.116 | 641.73 | 1218.25 | 22.18 |
| SEm± | 0.01 | 0.01 | 0.003 | 0.002 | 0.01 | 0.005 | 0.002 | 0.004 | 0.003 | 0.003 | 5.32 | 11.72 | 0.07 |
| CD (P=0.05) | 0.03 | 0.03 | 0.01 | 0.01 | 0.03 | 0.013 | NS | NS | NS | NS | 15.05 | 33.14 | 0.20 |
| **Interaction** | | | | | | | | | | | | | |
| $SA_0P_0$ | 2.94 | 1.15 | 0.29 | 0.12 | 0.68 | 1.37 | 0.11 | 0.13 | 0.06 | 0.10 | 401.39 | 689.95 | 18.40 |
| $SA_0P_{20}$ | 3.05 | 1.19 | 0.31 | 0.14 | 0.67 | 1.39 | 0.12 | 0.15 | 0.05 | 0.09 | 446.14 | 780.64 | 19.08 |
| $SA_0P_{40}$ | 3.20 | 1.23 | 0.34 | 0.15 | 0.72 | 1.39 | 0.11 | 0.15 | 0.06 | 0.08 | 542.48 | 988.82 | 19.98 |
| $SA_0P_{60}$ | 3.39 | 1.25 | 0.36 | 0.16 | 0.74 | 1.40 | 0.11 | 0.16 | 0.06 | 0.09 | 542.64 | 1006.10 | 21.21 |
| $SA_1P_0$ | 3.16 | 1.20 | 0.32 | 0.15 | 0.80 | 1.41 | 0.13 | 0.17 | 0.08 | 0.12 | 468.59 | 851.07 | 19.74 |
| $SA_1P_{20}$ | 3.32 | 1.29 | 0.35 | 0.16 | 0.82 | 1.41 | 0.13 | 0.16 | 0.09 | 0.14 | 524.97 | 986.59 | 20.76 |
| $SA_1P_{40}$ | 3.44 | 1.34 | 0.37 | 0.17 | 0.81 | 1.42 | 0.14 | 0.18 | 0.08 | 0.13 | 658.43 | 1239.10 | 21.51 |
| $SA_1P_{60}$ | 3.56 | 1.35 | 0.39 | 0.19 | 0.80 | 1.43 | 0.14 | 0.18 | 0.08 | 0.12 | 658.99 | 1254.24 | 22.25 |
| $SA_2P_0$ | 3.07 | 1.17 | 0.31 | 0.13 | 0.69 | 1.37 | 0.11 | 0.14 | 0.06 | 0.09 | 412.47 | 713.55 | 19.20 |
| $SA_2P_{20}$ | 3.18 | 1.23 | 0.33 | 0.15 | 0.73 | 1.38 | 0.12 | 0.15 | 0.05 | 0.09 | 479.55 | 880.85 | 19.86 |
| $SA_2P_{40}$ | 3.28 | 1.26 | 0.36 | 0.16 | 0.72 | 1.41 | 0.12 | 0.16 | 0.06 | 0.10 | 629.96 | 1170.85 | 20.52 |
| $SA_2P_{60}$ | 3.50 | 1.28 | 0.38 | 0.17 | 0.70 | 1.39 | 0.12 | 0.16 | 0.06 | 0.10 | 630.61 | 1206.51 | 21.87 |
| $SA_3P_0$ | 3.26 | 1.25 | 0.34 | 0.16 | 0.90 | 1.48 | 0.14 | 0.18 | 0.11 | 0.15 | 483.75 | 869.64 | 20.38 |
| $SA_3P_{20}$ | 3.35 | 1.29 | 0.37 | 0.17 | 0.86 | 1.46 | 0.15 | 0.19 | 0.09 | 0.14 | 563.20 | 1049.02 | 20.94 |
| $SA_3P_{40}$ | 3.56 | 1.37 | 0.39 | 0.19 | 0.87 | 1.47 | 0.15 | 0.19 | 0.10 | 0.14 | 729.13 | 1380.73 | 22.27 |
| $SA_3P_{60}$ | 3.75 | 1.40 | 0.41 | 0.20 | 0.86 | 1.46 | 0.15 | 0.18 | 0.10 | 0.15 | 734.67 | 1406.16 | 23.41 |
| SEm± | 0.02 | 0.02 | 0.01 | 0.004 | 0.02 | 0.01 | 0.005 | 0.01 | 0.01 | 0.007 | 10.64 | 23.43 | 0.14 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | 30.10 | 66.29 | NS |

SA- Soil amendments; LR- Lime requirement; PSB- Phosphorus solubilising bacteria; NS- Non-significant.

stover yield (1176.39 kg $ha^{-1}$) were obtained with combined application of 5% LR + PSB and acquired an increase to an extent by 29.9% and 35.7%, respectively; also, sole application of lime and PSB increased seed yield by 19.6 and 11.4% and stover yield by 22.07 and 14.6% over control. Response of protein content to soil amendments also exhibited similar trend to that of nutrient content of black gram *i.e.*, $SA_3$>$SA_1$>$SA_2$>$SA_0$; 21.25, 21.06, 20.36 and 19.67%, respectively. Liming enhances availability of major nutrients to plant by improving soil reaction which increases nutrient assimilation by plants and thereby adds to nutrient composition of plant. The improvement in yield may also ascribed to the neutralization of exchangeable $Al^{3+}$ ions and increase in available $Ca^{2+}$ which favoured excellent seed filling; attributing to improvement in soil pH and other physico-chemical properties of soil that boosts plant accessibility to soil nutrients. PSB secretes organic acids, which either directly dissolve the mineral P as a result of anion exchange of phosphate by acid anion or can chelate $Al^{3+}$ and $Fe^{3+}$ associated with P (Seema *et al*., 2013) enhancing the supply of available P to plants which might have utilized in better root development and nodulation followed by higher nitrogen fixation in the soil and thereby better nutrient uptake by plants. Furthermore, production of phytohormones by PSB promoting roots systems thereby facilitating higher nutrient uptake. On contrary no application of amendments resulted in minimum seed yield and nutrient composition owing to low soil nutrient status in addition to poor activity of soil micro-organism as influenced by soil acidity. These results are in congruent with Varma *et al*. (2017) and Odyuo and Sharma (2020). Application of phosphorus markedly increased the N, P and K content in both seed and stover. Maximum N, P and K were recorded with the application of 60 kg $P_2O_5$ $ha^{-1}$. However, N, P content in stover and K content in seed and stover at 60 kg $P_2O_5$ $ha^{-1}$ were not statistically different to that of 40 kg $P_2O_5$ $ha^{-1}$. P application did have any significant influence on Ca and Mg content neither in seed nor in stover of black gram. Seed and stover yield were enhanced significantly with the application of phosphorus. Maximum seed and stover yield were recorded at $P_{60}$ but it was statistically at par with $P_{40}$; application of 40 kg $P_2O_5$ increased the seed yield by 44.9% and stover yield by 55.9% over control. Protein content of black gram was remarkably influenced with the application of P; an increasing trend was observed in protein content with the increase in P levels. Maximum protein content (22.18%) was recorded at $P_{60}$ and minimum (19.43%) at $P_0$. According to Uchoi and Sharma (2023), nutritional environment of rhizosphere and plant system are improved with P application which as a result increases plant metabolism and photosynthetic activity leading to growth and development in terms of plant height, branches and yield. The findings are in consistent with those reported by Zohmingliana *et al*. (2018) and Patel *et al*. (2019).

**Nutrient uptake**

It is apparent from the data presented in Table 2 that application of soil amendments brought about a significant increase in nutrient uptake of black gram. Maximum N, P, K, Ca and Mg uptake in seed, stover and total uptake were recorded with the application of $SA_3$ followed by $SA_1$, $SA_2$ and $SA_0$. Irrespective of treatments, Total N, P, K, Ca Mg uptake varied from 23.31 to 39.34 kg $ha^{-1}$, 2.57 to 4.79 kg $ha^{-1}$, 14.53 to 23.26 kg $ha^{-1}$, 1.26 to 2.15 kg $ha^{-1}$ and 1.09 to 2.43 kg $ha^{-1}$. Application of 5% LR in conjunction with PSB exhibited better uptake, taking in account the combined benefits of lime and PSB as projected in nutrient content and yield whilst in control plot due to low supply of nutrients suppressed the growth and development of crop thereby low nutrient content as well as low yield. The significant increase in nutrient uptake in seed, stover and total uptake can be ascribed to the improvement in yield and nutrient content due to liming and PSB application; since nutrient uptake is the product of nutrient content and yield, with the increase in these attributes, the nutrient uptake was also increased. The results are in conformity with Lynrah and Nongmaithem (2017) and Uchoi and Sharma (2023). Application of phosphorus @60 kg $P_2O_5$ $ha^{-1}$ had significantly enhanced the nutrient uptake of black gram. N, P, K, Ca and Mg uptake in seed, stover and total uptake were increased to an extent by 66.5%, 48.1%, 62.5%, 57.1% and 47.2% in seed; 71.9%, 71.8%, 59.5%,70.6% and 63.8% in stover; 68.7%, 86.3%, 59.8%, 66.4% and 56.1% in total uptake over control, respectively. However, N uptake in stover, K, Ca and Mg uptake in seed and stover at 60 kg $P_2O_5$ $ha^{-1}$ does not exhibit any significant difference with that of 40 kg $P_2O_5$ $ha^{-1}$. These finding are found relevant to Eutropia and Ndakidemi (2014); Bhavya *et al*. (2018) and Hansing *et al*. (2020).

**Interaction effect**

Interaction effect on seed yield, stover yield and nutrient uptake was found significant. Maximum seed and stover yield (734.67 and 1406.16 kg $ha^{-1}$, respectively) were recorded with treatment combination $SA_3P_{60}$ which was at par with $SA_3P_{40}$. Significantly higher N, P and K uptake in seed, stover and total uptake, including total Magnesium uptake was registered with 5% LR+PSB+60 kg $P_2O_5$ $ha^{-1}$ ($SA_3P_{60}$) and was found statistically at par with $SA_3P_{40}$. However, Maximum total calcium uptake was registered with $SA_3P_{40}$ and was not statistically different to that of $SA_3P_{60}$. The results confirm with the findings of Ameyu and Asfaw (2020) and Sharma *et al*. (2021). Better uptake was observed with the combined application of lime and PSB ($SA_3$), which might have supplemented nutrient availability in rhizosphere by means of improving better root development, facilitating higher nodulation thereby boosting biological N fixation and a favourable soil condition encouraging better availability of nutrients. These results are in agreement with that of Nadeem *et al*. (2018) and Bhabai *et al*. (2019).

**Table 2:** Effect of soil amendments and phosphorus on nutrient uptake of black gram (Pooled).

| Treatments | N Uptake (kg ha$^{-1}$) | | P uptake (kg ha$^{-1}$) | | K uptake (kg ha$^{-1}$) | | Ca uptake (kg ha$^{-1}$) | | Mg uptake (kg ha$^{-1}$) | | Total uptake (kg ha$^{-1}$) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Seed | Stover | Seed | Stover | Seed | Stover | Seed | Stover | Seed | Stover | N | P | K | Ca | Mg |
| $SA_0$ (Control) | 15.40 | 10.62 | 1.64 | 1.28 | 3.52 | 12.28 | 0.55 | 1.36 | 0.29 | 0.80 | 26.02 | 2.92 | 15.80 | 1.91 | 1.09 |
| $SA_1$ (5% LR) | 19.60 | 14.34 | 2.13 | 1.87 | 4.76 | 15.71 | 0.82 | 1.90 | 0.51 | 1.43 | 33.95 | 4.00 | 20.47 | 2.72 | 1.93 |
| $SA_2$ (PSB) | 17.75 | 12.50 | 1.93 | 1.60 | 3.98 | 14.16 | 0.66 | 1.59 | 0.33 | 0.99 | 30.25 | 3.53 | 18.13 | 2.25 | 1.32 |
| $SA_3$ (5% LR + PSB) | 22.06 | 15.97 | 2.43 | 2.20 | 5.58 | 17.67 | 0.95 | 2.22 | 0.66 | 1.78 | 38.03 | 4.63 | 23.25 | 3.18 | 2.43 |
| SEm± | 0.19 | 0.23 | 0.02 | 0.03 | 0.07 | 0.17 | 0.02 | 0.05 | 0.02 | 0.04 | 0.39 | 0.04 | 0.20 | 0.05 | 0.05 |
| CD (P=0.05) | 0.54 | 0.64 | 0.06 | 0.07 | 0.20 | 0.49 | 0.04 | 0.13 | 0.04 | 0.11 | 1.10 | 0.11 | 0.57 | 0.14 | 0.13 |
| **Phosphorus levels** | | | | | | | | | | | | | | | |
| $P_0$ | 13.78 | 9.53 | 1.44 | 1.13 | 3.31 | 11.21 | 0.56 | 1.26 | 0.36 | 0.94 | 23.31 | 2.57 | 14.53 | 1.82 | 1.30 |
| $P_{20}$ | 16.33 | 11.73 | 1.76 | 1.47 | 3.91 | 13.31 | 0.67 | 1.54 | 0.39 | 1.11 | 28.06 | 3.23 | 17.22 | 2.21 | 1.50 |
| $P_{40}$ | 21.75 | 15.80 | 2.41 | 2.08 | 5.24 | 17.42 | 0.87 | 2.12 | 0.51 | 1.44 | 37.54 | 4.49 | 22.65 | 2.99 | 1.95 |
| $P_{60}$ | 22.95 | 16.39 | 2.52 | 2.27 | 5.38 | 17.88 | 0.88 | 2.15 | 0.53 | 1.50 | 39.34 | 4.79 | 23.26 | 3.03 | 2.03 |
| SEm± | 0.19 | 0.23 | 0.02 | 0.03 | 0.07 | 0.17 | 0.02 | 0.05 | 0.02 | 0.04 | 0.39 | 0.04 | 0.20 | 0.05 | 0.05 |
| CD (P=0.05) | 0.54 | 0.64 | 0.06 | 0.07 | 0.20 | 0.49 | 0.04 | 0.13 | 0.04 | 0.11 | 1.10 | 0.11 | 0.57 | 0.14 | 0.13 |
| **Interaction** | | | | | | | | | | | | | | | |
| $SA_0P_0$ | 11.86 | 8.08 | 1.21 | 0.86 | 2.77 | 9.63 | 0.44 | 0.95 | 0.24 | 0.69 | 19.94 | 2.06 | 12.41 | 1.39 | 0.93 |
| $SA_0P_{20}$ | 13.71 | 9.39 | 1.44 | 1.08 | 3.12 | 10.97 | 0.52 | 1.24 | 0.25 | 0.72 | 23.10 | 2.52 | 14.09 | 1.76 | 0.97 |
| $SA_0P_{40}$ | 17.46 | 12.32 | 1.92 | 1.52 | 4.03 | 14.09 | 0.63 | 1.58 | 0.34 | 0.85 | 29.78 | 3.44 | 18.13 | 2.20 | 1.19 |
| $SA_0P_{60}$ | 18.56 | 12.71 | 2.00 | 1.68 | 4.16 | 14.43 | 0.63 | 1.66 | 0.33 | 0.94 | 31.27 | 3.68 | 18.59 | 2.28 | 1.27 |
| $SA_1P_0$ | 14.80 | 10.45 | 1.56 | 1.29 | 3.64 | 12.27 | 0.63 | 1.45 | 0.39 | 1.06 | 25.25 | 2.85 | 15.90 | 2.08 | 1.45 |
| $SA_1P_{20}$ | 17.45 | 12.92 | 1.87 | 1.61 | 4.24 | 14.24 | 0.71 | 1.56 | 0.50 | 1.39 | 30.38 | 3.47 | 18.48 | 2.27 | 1.89 |
| $SA_1P_{40}$ | 22.66 | 16.79 | 2.49 | 2.19 | 5.57 | 18.02 | 0.95 | 2.23 | 0.57 | 1.66 | 39.45 | 4.68 | 23.59 | 3.18 | 2.23 |
| $SA_1P_{60}$ | 23.50 | 17.21 | 2.61 | 2.40 | 5.61 | 18.30 | 0.98 | 2.37 | 0.57 | 1.60 | 40.72 | 5.00 | 23.91 | 3.35 | 2.17 |
| $SA_2P_0$ | 12.70 | 8.47 | 1.30 | 0.98 | 2.89 | 9.99 | 0.46 | 1.04 | 0.26 | 0.68 | 21.18 | 2.28 | 12.89 | 1.50 | 0.94 |
| $SA_2P_{20}$ | 15.28 | 10.90 | 1.64 | 1.35 | 3.48 | 12.43 | 0.60 | 1.38 | 0.28 | 0.80 | 26.18 | 2.99 | 15.91 | 1.98 | 1.08 |
| $SA_2P_{40}$ | 20.82 | 14.97 | 2.34 | 1.94 | 4.72 | 16.75 | 0.79 | 1.90 | 0.37 | 1.21 | 35.79 | 4.27 | 21.47 | 2.69 | 1.59 |
| $SA_2P_{60}$ | 22.20 | 15.67 | 2.44 | 2.13 | 4.83 | 17.44 | 0.79 | 2.03 | 0.40 | 1.27 | 37.87 | 4.57 | 22.27 | 2.83 | 1.67 |
| $SA_3P_0$ | 15.78 | 11.11 | 1.68 | 1.41 | 3.96 | 12.96 | 0.71 | 1.61 | 0.54 | 1.35 | 26.89 | 3.09 | 16.92 | 2.32 | 1.89 |
| $SA_3P_{20}$ | 18.88 | 13.70 | 2.09 | 1.84 | 4.80 | 15.60 | 0.86 | 1.97 | 0.54 | 1.51 | 32.59 | 3.93 | 20.40 | 2.84 | 2.05 |
| $SA_3P_{40}$ | 26.03 | 19.12 | 2.89 | 2.68 | 6.63 | 20.79 | 1.11 | 2.76 | 0.75 | 2.05 | 45.15 | 5.57 | 27.43 | 3.87 | 2.79 |
| $SA_3P_{60}$ | 27.55 | 19.95 | 3.05 | 2.87 | 6.93 | 21.33 | 1.12 | 2.56 | 0.80 | 2.19 | 47.50 | 5.92 | 28.26 | 3.68 | 3.00 |
| SEm± | 0.38 | 0.45 | 0.05 | 0.05 | 0.14 | 0.34 | 0.03 | 0.09 | 0.03 | 0.08 | 0.78 | 0.08 | 0.40 | 0.10 | 0.09 |
| CD (P=0.05) | 1.09 | 1.27 | 0.13 | 0.15 | 0.39 | 0.97 | NS | NS | NS | NS | 2.20 | 0.23 | 1.14 | 0.28 | 0.26 |

SA- Soil amendments; LR- Lime requirement; PSB- Phosphorus solubilising bacteria; NS- Non-significant.

**Table 3:** Phosphorus use efficiency of black gram as influenced by phosphorus application (Pooled).

| Phosphorus levels | PUPE | PUTE | PUE | FPUPE | FPUTE | FPUE |
|---|---|---|---|---|---|---|
| $P_0$ | 0.25 | 171.81 | 43.55 | 0 | 0 | 0 |
| $P_{20}$ | 0.28 | 155.87 | 43.67 | 0.033 | 93.81 | 3.10 |
| $P_{40}$ | 0.30 | 142.54 | 43.13 | 0.048 | 103.36 | 4.96 |
| $P_{60}$ | 0.29 | 133.97 | 38.70 | 0.037 | 90.17 | 3.34 |
| Mean | 0.28 | 151.05 | 42.26 | 0.04 | 95.78 | 3.80 |
| CV% | 7.7 | 10.9 | 5.6 | 19.7 | 7.1 | 26.6 |

PUTE- Phosphorus uptake efficiency; PUTE- Phosphorus utilization efficiency; PUE- Phosphorus use efficiency; FPUPE- Fertilizer P uptake efficiency; FPUTE- Fertilizer P utilization efficiency; FPUE- Fertilizer P use efficiency; CV: Coefficient of variance.

### Phosphorus use efficiency

P uptake efficiency (PUPE), ratio of kg P in plants and kg P in soil, increased with increase in P levels and then decreased at $P_{60}$ (Table 3). Highest PUPE was recorded at $P_{40}$ and lowest at $P_0$. P utilization efficiency (PUTE), kg of seed yield divided by kg of P in plant, highest value on PUTE was recorded at control and lowest at 60 kg $P_2O_5$ $ha^{-1}$. P use efficiency (PUE), measure of economic yield produced per unit P in the soil, although highest PUE was recorded at $P_{20}$ a decreasing trend in P use efficiency was observed with increase in phosphorus levels. However, highest value on fertilizer P uptake efficiency (FPUPE), fertilizer P utilization efficiency (FPUTE) and fertilizer P use efficiency (FPUE) was observed on 40 kg $P_2O_5$ $ha^{-1}$.

## CONCLUSION

The study inferred that application of soil amendments and phosphorus increased the nutrient composition, uptake and yield of black gram. From the results it can be suggested that application of 5% LR + PSB along with 40 kg $ha^{-1}$ $P_2O_5$ proved to be suitable for black gram cultivation in acidic soil of Nagaland.

### Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

### Informed consent

All animal procedures for experiments were approved by the Committee of Experimental Animal care and handling techniques were approved by the University of Animal Care Committee

### Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

## REFERENCES


Adnan, A., Mavinic, D.S. and Koch, F.A. (2003). Pilot-scale study of phosphorus recovery through struvite crystallization-examining of process feasibility. *Journal of Environmental Engineering and Science*. **2(5):** 315-324.

Ameyu, T. and Asfaw, E. (2020). Effect of lime and phosphorus fertilizer on soybean [*Glycine max* (L.) Merrill] grain yield and yield components at Mettu in South Western Ethiopia. *International Journal of Environmental Monitoring and Analysis*. **8(5):** 144-154.

Anonymous, (2023-24). First Advance Estimates of Production of Major *kharif* Crops, Ministry of Agriculture and Farmers Welfare, Press Information Bureau, Government of India. Available at https://pib.gov.in/PressReleasePage.aspx?PRID=1972233.

Bandypadhyay, S., Ray, P. and Ray, S.K. (2016). Present status and future strategies to maintain the soil health in the North East India. Souvenir Article for the National Seminar on Bringing Second Green Revolution in North East India, 2016, February, 11-12th, 2016. National Bureau of Soil Survey and Land Use Planning (ICAR), Jorhat, India.

Bargaz, A., Elhaissoufi , W., Khourchi, S., Benmrid, B., Borden, K. A. and Rchiad, Z. (2021). Benefits of phosphate solubilizing bacteria on belowground crop performance for improved crop acquisition of phosphorus. *Microbiological Research*. **252:** 126842.

Bhabai, B., Mukhopadhyay, D. and Mitra, B. (2019). Effect of biofertilizer and phosphorus on green gram (*Vigna radiata*). *Journal of Pharmacognosy and Phytochemistry*. **8(4):** 505-509.

Bhavya, G., Shaker, K.S., Jayasree, G. and Reddy, M.M. (2018). Nutrient uptake and yield of green gram (*Vigna radiata* L.) as influenced by phosphorus fertilization, organic manures and biofertilizers. *International Journal of Chemical Studies*. **6(3):** 32-35.

Directorate of Economics and Statistics. (2023). In: Statistical Handbook of Nagaland. pp. 30.

Eutropia, V.T. and Ndakidemi, P.A. (2014). Macronutrients uptake in soybean as affected by *Bradyrhizobium japonicum* and phosphorus supplements. *American Journal of Plant Sciences*. **5:** 488-496.

Hangsing, N., Tzudir, L. and Singh, A.P. (2020). Effect of spacing and levels of phosphorus on the growth and yield of green gram (*Vigna radiata*) under rainfed condition of Nagaland. *Agricultural Science Digest*. **40(2):** 139-143. doi: 10.18805/ag.D-5022.

Lynrah, A. and Nongmaithem, D. (2017). Effect of lime and integrated nutrient management on soybean under rainfed condition of Nagaland. *International Journal of Bio-resource and Stress Management.* **8(5):** 679-683.

Nadeem, M.A., Singh, V., Dubey, R.K., Pandey, A.K., Singh, B., Kumar, N. and Pandey, S. (2018). Influence of phosphorus and bio-fertilizers on growth and yield of cowpea [*Vigna unguiculata* (L.) Walp.] in acidic soil of NEH region of India. *Legume Research*. **41(5):** 763-766. doi: 10.18805/LR-3790.

Odyuo, Z.R. and Sharma, Y.K. (2020). Response of green gram (*Vigna radiata*) to fertility levels in acid soil of Nagaland. *Annals of Plant and Soil Research*. **22(3):** 296-300.

Panse, V.G. and Sukhatme, P.V. (1961). Statistical Methods for Agricultural Workers. Indian Council of Agricultural Research, New Delhi.

Patel, H.B., Shah, K.A. and Patel, K.H. (2019). Response of green gram to different level of phosphorus and organic liquid fertilizer on yield, quality, nutrient content and uptake. *International Journal of Current Microbiology and Applied Sciences.* **8(4):** 1234-1242.

Prochnow, B.L. (2014). Soil acidity evaluation and management. *Better Crops*. **98:** 22-25.

Seema, B., Sharma, Riyaz, Z., Sayyed, Mrugesh, H., Trivedi and Thivakaran, A. Gobi. (2013). Phosphate solubilizing microbes: Sustainable approach for managing phosphorus deficiency in agricultural soils. *Springer Plus.* **2:** 587.

Sharma, A., Pathania, P. and Sharma, M. (2021). Effect of PSB, FYM with variable levels of P on the yield attributes and productivity of black gram in Shiwalik hills of Himachal Pradesh. *Journal of Food Legumes.* **34(1):** 31-37.

Sharma, S.B., Sayyed, R.Z., Trivedi, M.H., Gobi, T.A. (2013). Phosphate solubilizing microbes: Sustainable approach for managing phosphorus deficiency in agricultural soils. *Springer Plus*. **2:** 1-14. https://doi.org/10.1186/2193-1801-2-587.

Sharma, U.C., Dutta, M. and Sharma, J.S. (2006). Soils and their management in North East India. ICAR Research Complex for NEH Region, Meghalaya.

Singh, S.K., Biswas, D.R., Srinivasamurthy, C.A., Dutta, S.P., Jayasree, G., Jha, P., Sharma, S.K., Katkar, R.N., Raverkar, K.P. and Ghosh, A.K. (2019). Soil Analysis. Indian Society of Soil Science, New Delhi.

Uchoi, A. and Sharma, Y.K. (2023). Influence of lime and phosphorus on performance of black gram (*Vigna mungo*) and soil properties in Dystrudept of Nagaland. *Journal of the Indian Society of Soil Science*. **71(1):** 113-118.

Varma, D., Meena, R.S., Kumar, S. and Kumari, E. (2017). Response of mung bean to NPK and lime under the conditions of Vindhyan region of Uttar Pradesh. *Legumes Research*. **40(3):** 542-545. doi: 10.18805/lr.v0i0.7854.

Zohmingliana, M., Sharma, Y.K. and Gupta, R.C. (2018). Influence of phosphorus and bio-inoculants on performance of French bean (*Phaseolus vulgaris* L.). *Legumes Research*. **41(4):** 594-597. doi: 10.18805/LR-3869.