

Impact of phosphorus and sulphur on the growth and productivity of green gram (*Vigna radiata*)

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ABSTRACT

Cultivation of pulses fit well to various cropping system and show climate-resilience. Pulses are low external input demanding, can fix atmospheric nitrogen biologically and improve soil health. Among different pulses, green gram (*Vigna radiata* L.) is considered as an important crop in India. The crop responds to exogenous application of phosphorus and sulphur. Considering the above, a field trial was conducted to find the influence of phosphorus and sulphur on growth and productivity of green gram during *rabi* season of 2019-20 at Bagusala farm of Centurion University of Technology and Management. A split-plot design was considered for the experiment with three replication. The treatments were consisted of four levels of phosphorus (no application, 20, 40 and 60 kg P₂O₅/ha) in the main plot and three sulphur levels (15, 30 and 45 kg S/ha) in sub plot. The findings revealed that application at 60 kg P₂O₅/ha being statistically at par with 40 kg/ha P₂O₅ registered more growth parameters and yield attributes than the lower levels. The seed yield (1079.6 kg/ha) and stover yield (2025.1 kg/ha) were also noted with the application of 60 kg P₂O₅/ha and it remained statistically at par with 40 kg P₂O₅/ha. However, 30 kg S/ha being statistically at par with 45 kg S/ha resulted in superior growth attributes, yield parameters and seed (979.2 kg/ha) and stover yield (1871.8 kg/ha) to lower levels. Further, the combination of 60 kg P₂O₅/ha and 30 kg S/ha produced significantly more grain yield (1211.3 kg/ha) than other treatment combinations. The study concludes that *rabi* green gram can be grown with 60 kg P₂O₅ and 30 kg S/ha for a better productivity.

Key words : Green gram, growth attributes, phosphorus, sulphur, yield, yield attributes

INTRODUCTION

The world human population will reach to 9.1 billion by 2050 and in the current consequences of climate change, food as well nutritional security will be a great challenge in the future (FAO, 2017). On the other hand, the The United Nations Development Programme (UNDP) suggested to fulfill 17 sustainable development goals (SDGs) by 2030 for a better world (FAO, 2021). Increase in agricultural production and ensuring food security with a shrinking land area and dwindling natural resources are further hard tasks for the populous countries like India (Maitra *et al.*, 2018). Unfortunately, about 24 percent of one-fourth of the human population

is undernourished In India (Ahlawat *et al.*, 2016). All over the world, human diet is predominated by cereal-based food-stuffs and in the developed countries, proteins in food come from animals. However, in India, pulses are regarded as a vital source of protein, especially for vegetarians. For non-vegetarians also, pulses provide cholesterol free, proteineous food rich in dietary fibre, minerals and vitamins. Cultivation of pulses has multiple benefits as these fit well to different cropping system and create diversification of crops, being hardy and ecologically sound crops they show climate-resilience, low external input demanding crops and thus, register less carbon footprint in agriculture, fix atmospheric nitrogen biologically with improvement of soil

health and provide nutritious foodgrains. Considering the above benefits, it can be stated that cultivation of pulses has enough potential to fulfill the SDG 2, SDG 13 and SDG 15 by facilitating food and nutritional security, eco-friendliness and diversification on farmland.

India ranks first in the world as producer, consumer and importer of pulses. The fourth advance estimate indicated that the area, production and yield of pulses was 29.03 million ha, 23.40 million t and 806 kg/ha in 2018-19 (GoI, 2019). But in the US and Canada pulses productivity is more than double of India's yield per unit area (Ahlawat *et al.*, 2016; DPD, 2020; MAFW, 2021). Among different pulses grown in India, moong (*Vigna radiata* L.) is considered as an important crop. India produced 1.78 million t of green gram from 3.83 million ha area in 2018-19 (DPD, 2021). Rajasthan, Maharashtra and Karnataka are the leading states in green gram production in India. Odisha also produces green gram in 8.26 lakh ha with a production and productivity of 4.08 lakh t and 495 kg/ha, respectively (GoO, 2020). As a short duration crop, it fits well to different cropping systems of Odisha.

Green gram is an easily digestible and nutritionally rich pulse crop as the seeds contain a fairly good amount of protein (21-25%), carbohydrate, a small quantity of riboflavin and thiamine with high content of lysine (4600 mg N/g), tryptophan (60 mg N/g), phosphorus (326 mg) and iron (4 mg) (Shahi *et al.* 2002; Patel *et al.* 2013). Further, sprouted seeds contain thiamine (Vitamin B₁), riboflavin (vitamin B₂) and ascorbic acid (Dhewa and Daniel, 2017).

In general, green gram is cultivated as relay or crop catch in Odisha mainly in rice based cropping system and proper agronomic management is not adopted. Green gram is very less nitrogen (N) demanding because of its ability to fix N biologically, but phosphorus (P) and sulphur (S) are two essential nutrients that enhance yield and quality of seeds produced.

Phosphorus is a major plant nutrient that influences cell division, germination of seeds, flowering, fruiting, synthesis of fat and starch. Besides, the nutrient take part in various biochemical activities is involved in the regulation of metabolic pathways inclusive of enzyme reactions (Malhotra *et al.*, 2018).

Phosphatic fertilizer is used wisely for better nodulation and efficient biological nitrogen fixation leading to growth and yield enhancement of legumes (Dharwe *et al.*, 2019). Further, phosphorus enhances growth and productivity of legumes (Sudharani *et al.*, 2018; Sahu *et al.*, 2020). Similarly, sulphur (S) has a significant impact on the synthesis of protein in pulses which is mainly stored in globulins and found in some amino acids such as cysteine, cystine and methionine and it promotes nodulation in legume crops (Becana *et al.*, 2018). Sulphur is an enzyme activator, a crucial nutrient for increasing legume crop productivity and a component of some vitamins such as vitamin A, biotin and thiamine. Moreover, S has significant role in the development of chlorophyll and enzyme activation process (Tiwari and Singh, 2012; Singh, 2017). These are the reasons behind sufficient sulphur application for successful growing of pulses (Sahu *et al.*, 2020; Sumasree, 2020). Considering the above, a field trial was conducted to find the effect of P and S on growth as well as productivity of green gram during *rabi* season in south Odisha conditions.

MATERIALS AND METHODS

The field experiment was carried out at Bagusala Farm, M. S. Swaminathan School of Agriculture, Centurion University of Technology and Management, Paralakhemundi, Odisha during *rabi*, 2020. The farm is located at the 23° 39' N latitude and 87° 42' E longitude with a mean sea level of 183m. During the period of experimentation, the average temperature ranged (maximum and minimum) from 26.1 to 34.6°C and 17 to 23°C, respectively. The crop received a rainfall of 73.6 mm. The relative humidity of morning and afternoon varied from 78.20 to 90.71% and 45.29 to 69.71%, respectively. The bright sunshine hours per day fluctuated from 4.86 to 9.00 hours. The experimental soil was sandy clay loam in texture having pH 6.4, organic carbon 0.45% and initial soil status of nitrogen, phosphorus, potassium and sulphur values were 170.5, 12.9, 179.6 and 10 kg/ha, respectively.

The treatments were examined in split-plot design, replicated thrice. In this experiment, twelve treatment combinations were allocated randomly consisted of four

phosphorus levels (no application, 20, 40 and 60 kg P₂O₅/ha) in the main plot and three sulphur doses (15, 30 and 45 kg S/ha) in sub plot. The net plot size was 5 m × 4 m. The field was levelled properly and the seeds are sown at the spacing of 30 cm × 10 cm in the line sowing. The green gram variety taken to carry out the experiment was Samrat with the seed rate of 20 kg/ha. The recommended fertilizer dose of 20:40:40:20 kg/ha N:P₂O₅:K₂O:S was applied as basal through urea, di-ammonium phosphate (DAP), single super phosphate (SSP) and muriate of potash (MOP) as sources of primary nutrient like N, P and K, respectively and rest the sulphur was added to the soil as elemental sulphur just before sowing. Thinning operation and filling of gaps were done at 7 DAS keeping two plants 10 cm away from each other to maintain equal plant population in all the plots. The experimental plots were kept weed free throughout the crop growing period. To manage the weed population, pre-emergence application of pendimethalin at the rate of 3.3 lit per hectare followed by one hand weeding on 40 days after sowing were done during investigation. The growth parameters were measured periodically, however, yield attributes and yields were recorded at maturity stage.

The data obtained were analyzed statistically by following the ANOVA as mentioned by Gomez and Gomez (1984) and F value was computed at 5% level of probability and critical difference was measured for the comparison of treatment means. For the statistical analysis purpose, the software used was Excel from Microsoft Office Home and

Student version 2019-en-us, Microsoft Inc., Redmond, Washington (DC, USA).

RESULTS AND DISCUSSION

Effect of Phosphorus Levels on Growth Attributes

Data revealed that application of 60 kg P₂O₅/ha recorded significantly more plant height at harvest (40.8 cm), number of branches/plant at 60 DAS (5.8), dry matter accumulation at harvest (322.3 g/m²), leaf area index at 60 DAS (2.3) and number of nodules/plant at 45 DAS (17.0) over without P application and the application of 20 kg P₂O₅/ha, while it was par with 40 kg P₂O₅/ha (Table 1). Phosphorus promotes root development, root proliferation, nodulation and nitrogen fixation. P is the integral part of co-enzymes, Adenosine di phosphate (ADP) and Adenosine tri phosphate (ATP), which serves as the plant's 'energy currency'. Phosphate derivatives are involved in almost every significant metabolic reaction. Hence, photosynthesis, protein and phospholipid biosynthesis, nucleic acid synthesis, membrane transport, and cytoplasmic streaming are affected by phosphorus. Increased phosphorus abundance due to its application in soil with low phosphorus content enhanced the availability of N in the green gram field, resulting in enhanced N, P and K absorption by the crop. Increased nutrient uptake may have increased photosynthesis and then metabolite translocation to various parts of the plant, encouraging meristematic tissue production

Table 1. Effect of phosphorus and sulphur levels on growth attributing characters of green gram.

Treatments	Plant height at harvest (cm)	Number of branches/plant at 60 DAS	Dry matter accumulation at harvest (g/m ²)	Leaf area index at 60 DAS (LAI)	Number of nodules/plant at 45 DAS
Phosphorus level					
No application of P ₂ O ₅	36.9	4.1	237.3	1.7	14.5
20 kg P ₂ O ₅ /ha	38.2	4.4	250.4	1.9	14.9
40 kg P ₂ O ₅ /ha	40.0	5.4	297.8	2.2	16.5
60 kg P ₂ O ₅ /ha	40.8	5.8	322.3	2.3	17.0
SEm±	0.29	0.18	10.2	0.06	0.30
CD (P=0.05)	1.0	0.61	35.3	0.21	1.0
Sulphur level					
15 kg S/ha	37.5	4.5	255.4	1.9	15.0
30 kg S/ha	39.8	5.3	290.5	2.2	16.3
45 kg S/ha	39.7	5.0	284.9	2.1	15.9
SEm±	0.45	0.12	6.6	0.04	0.27
CD (P=0.05)	1.3	0.34	19.3	0.12	0.78

in apical buds and intercalary meristem and thus root and shoot formation occurred. This finding corroborated the results of Kumawat *et al.* (2014), Vidhyashree *et al.* (2017), Kumar and Yadav (2018) and Sudharani *et al.* (2018) who earlier noted enhanced growth of legumes with exogenous P application.

Effect of Sulphur Levels on Growth Attributes

A dose of 30 kg S/ha produced significantly more plant height at harvest (39.8 cm), number of branches/plant at 60 DAS was (5.3), dry matter accumulation at harvest (290.5 g/m²), leaf area index at 60 DAS (2.2) and number of nodules/plant at 45 DAS (16.3) than the application of 15 kg S/ha; but, it remained statistically similar with the application of 45 kg/ha S. Sulphur application enhances the photosynthesis rate due to enhanced protein synthesis and regeneration of higher number of chlorophyll molecules. Hence, application of sulphur probably increased the plant growth attribute as the element is known to play a major role in cell division and differentiation and root elongation which imitated into higher absorption of nutrients and photosynthesis rate inclusive of more dry matter production. Reduction in plant growth of green gram at higher dose of sulphur was noted and it might be due to the antagonistic effect of excess S. Previous studies indicated that S in excess amount was responsible for reduced dry weight accumulation and delay in flowering inclusive of negative changes in the metabolism of plant cells (Zenda *et al.*, 2021). These results corroborate with the results of

Singh and Yadav (2013), Kumawat *et al.* (2014) and Parashar *et al.* (2020).

Effect of Phosphorus Levels on Yield Attributes

The values of number of pods/plant (16.0), number of seeds/pod (7.2), pod length (6.9 cm) and test weight (29.4) was significantly more with 60 kg P₂O₅/ha than no phosphorus application and 20 kg P₂O₅/ha and the treatment remained on par 40 kg P₂O₅/ha (Table 2). An appropriate supply of phosphorus to crop probably played the vital role in plant growth, photosynthesis, flowering, seed setting and nitrogen fixation which ultimately resulted in enhancement of yield attributes. These finding were in accordance to the researches of Kumar *et al.* (2012), Singh and Singh (2012), Singh *et al.* (2017), Singh *et al.* (2018) and Taliman *et al.* (2019).

Effect of Sulphur Levels on Yield Attributes

Progressive increase in level of sulphur upto 30 kg S/ha led to significant improvement in all the yield attributes, namely, number of pods/plant (15.0), number of seeds/pod (6.9), pod length (6.8 cm), and test weight (28.5 g) over 15 kg S/ha, but the treatment remained statistically at par with 45 kg S/ha (Table 2). The balanced nutrient application with S was noted to improve yield attributes as the element is known to facilitate the formation of reproductive organs, which led to the production of pods and seeds in plants (Zenda *et al.*, 2021). As a result, sulphur application had increased the yield attributing

Table 2. Effect of phosphorus and sulphur levels on yield attributing characters of green gram.

Treatments	Number of pods/ plant	Number of seeds/ pod	Pod length (cm)	Test weight (g)
Phosphorus level				
No application of P ₂ O ₅	12.8	6.2	6.1	26.8
20 kg P ₂ O ₅ /ha	13.7	6.4	6.4	27.4
40 kg P ₂ O ₅ /ha	15.2	6.8	6.8	28.7
60 kg P ₂ O ₅ /ha	16.0	7.2	6.9	29.4
SEm±	0.36	0.19	0.08	0.49
CD (P=0.05)	1.3	0.64	0.28	1.70
Sulphur level				
15 kg S/ha	13.4	6.3	6.2	27.2
30 kg S/ha	15.0	6.9	6.8	28.5
45 kg S/ha	14.8	6.7	6.6	28.4
SEm±	0.20	0.14	0.09	0.48
CD (P=0.05)	0.59	0.39	0.26	1.4

parameters in mungbean. Similar findings were recorded earlier by Kaisher *et al.* (2010), Kumar *et al.* (2012) and Thesiya *et al.* (2013).

Effect of Phosphorus Levels on Yield

An increase in rate of phosphorus showed significant impact on seed and stover yield of green gram (Table 3). A dose of 60 kg P₂O₅/ha resulted in significantly more seed productivity (1079.6 kg/ha), stover yield (2025.1 kg/ha) and harvest index (34.7%) over no phosphorus application and the application of 20 kg P₂O₅/ha, while the treatment remained statistically similar with its lower dose, i.e., 40 kg P₂O₅/ha. Enhancement in seed yield with the treatment (60 kg P₂O₅/ha) was because of more pods/plant and 1000-grain weight and this could be probably because of sufficient assimilated assimilates production by the treatment and proper partitioning of it to the reproductive parts. Enhancement in stover yield might be due to increased plant height, branching, and dry matter accumulation at harvest as a consequence of a better assimilates production by the plants. Such results are in accordance with the researches of Bairwa *et al.* (2012), Kumawat *et al.* (2014) and Das (2017).

Effect of Sulphur Levels on Yield

All the increased rates of S were significantly superior to 15 kg S/ha of in increasing the seed yield, stover yield and harvest index of green gram (Table 3). A dose of 30 kg S /ha produced significantly higher seed yield (979.2 kg/ha), stover yield (1871.8 kg/ha) and harvest index (34.0%) over 15 kg S/ha and remained on par with 45 kg S/ha. Seed yield was increased with increase in sulphur level due to the reason that sulphur plays a key role in accelerating yield

Table 3. Effect of phosphorus and sulphur levels on seed yield, stover yield and harvest index of green gram

Treatments	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)
Phosphorus level			
No application of P ₂ O ₅	696.4	1594.1	30.5
20 kg P ₂ O ₅ /ha	813.9	1685.7	32.5
40 kg P ₂ O ₅ /ha	1004.0	1886.7	34.5
60 kg P ₂ O ₅ /ha	1079.6	2025.1	34.7
SEm±	31.9	46.7	0.86
CD (P=0.05)	110.5	161.7	3.0
Sulphur level			
15 kg S/ha	754.3	1663.2	31.1
30 kg S/ha	979.2	1871.8	34.0
45 kg S/ha	962.0	1858.7	34.0
SEm±	18.1	40.7	0.68
CD (P=0.05)	52.9	118.7	2.0

components of green gram. The beneficial effect of sulphur on stover yield could be attributed to the important role of sulphur in the division of plant cells, photosynthetic processes, and chlorophyll formation. Sulphur also promotes the formation of root nodules in legumes which was increased with increasing the sulphur availability during the vegetative growth period that probably triggered plant height, number of branches/plant at harvest and increased stover yield. These outcomes corroborated the reports of Kumawat *et al.* (2014), Das (2017) and Dharwe *et al.* (2018).

Interaction Effect Between Phosphorus and Sulphur

Interaction effect between phosphorus and sulphur levels was found to be insignificant in case of all the growth attributes, stover yield and harvest index of green gram. In the case of seed yield, the interaction effect of P × S was found to be significant (Table 4). Highest seed yield (1211.3 kg/ha) was achieved by the combined application of 60 kg P₂O₅/ha and 30

Table 4. Seed yield (kg/ha) as influenced by the interaction effect of phosphorus and sulphur levels

Treatment	Seed Yield (kg/ha)			
	15 kg S/ha	30 kg S/ha	45 kg S/ha	Mean
No application of P ₂ O ₅	643.0	714.0	732.3	696.4
20 kg P ₂ O ₅ /ha	677.7	838.7	925.3	813.9
40 kg P ₂ O ₅ /ha	782.3	1152.7	1077.0	1004.0
60 kg P ₂ O ₅ /ha	914.0	1211.3	1113.3	1079.6
Mean	754.3	979.2	962.0	898.5
SEm±			36.2	
CD (P=0.05)			105.8	

kg S/ha which was statistically at par with the seed yield obtained under the combined application of 40 kg P₂O₅/ha and 30 kg S/ha (1152.7 kg/ha) and 60 kg P₂O₅/ha and 45 kg S/ha (1113.3 kg/ha). This interaction revealed that the application of phosphorus and sulphur together has a synergistic effect that helped in improving the seed yield of green gram. Similar increase in seed yield of green gram due to the combined application of P and S was also reported by Das (2017), Dharwe *et al.* (2018) and Parashar *et al.* (2020).

CONCLUSION

The present study revealed that exogenous application of both the phosphorus and sulphur showed significant impact on growth and productivity of *rabi* green gram. A dose of 60 kg phosphorus and 30 kg sulphur resulted in superior performances in enhancement of growth and yield parameters and seed as well as stover yield of green gram. Further, combined application of phosphorus and sulphur was synergistic on influencing growth and yield of green gram. From the research, it may be concluded that *rabi* green gram can be grown in south Odisha conditions with the application of 60 kg P₂O₅/ha and 30 kg S/ha to maximize productivity of green gram.

REFERENCES

- Ahlawat, I. P. S., Sharma, P. and Singh, U. (2016). Production, demand and import of pulses in India. *Ind. J. Agron.* **61** : S33-S41.
- Bairwa, R. K., Nepalia, V., Balai, C. M., Chauhan, G. S. and Ram, B. (2012). Effect of Phosphorus and Sulphur on Growth and Yield of Summer Mungbean. *J. Food Leg.* **25** : 211-14.
- Becana, M., Wienkoop, S. and Matamoros, M. A. (2018). Sulfur transport and metabolism in legume root nodules. *Front. Plant. Sci.* **10** : doi: 10.3389/fpls.2018.01434.
- Das, S. K. (2017). Effect of Phosphorus and sulphur on yield attributes, yield, nodulation and nutrient uptake of green gram [*Vigna radiata* (L.) wilczek]. *Legume Res.* **40** :138-43.
- Dharwe, D. S., Dixit, H. C., Dotaniya, C. K., Doutaniya, S. M. R. and Jamara, P. (2018). Influences of phosphorus and sulphur on yield attributes of summer green gram (*Vigna radiata* L.). *J. Pharm. Phytochem.* **7** : 147-49.
- Dharwe, D. S., Dixit, H. C., Dotaniya, C. K., Khandagle, A., Mohbe, S. and Doutaniya, R. K. (2019). Effect of phosphorus and sulphur on the yield & nutrient content of green gram. *Int. J. Chem. Stud.* **7** : 01-05.
- Dhewa, J. S. and Daniel, S. (2017). Effect of different levels of phosphorus and sulphur on growth and nutrient uptake of green gram (*Vigna radiata* L.) under teak (*Tectona grandis* L.) based agroforestry system. *Int. J. Curr. Microbiol. Appl. Sci.* **6** : 520-34.
- DPD (2020). Directorate of Pulses Development State-Wise Area, Production and Seed Requirement: Green Gram (Mungbean), *Khariif Pulses Prospects-2020-21*, http://Dpd.Gov.In/Pulses_Khariif%20prospects%202020%20.Pdf.
- DPD (2021). Directorate of Pulses Development, Statistics. http://dpd.gov.in/Stats_new.htm; (Accessed 15 August, 2021).
- FAO (2017). The future of Food and Agriculture – Trends and challenges. Rome. <http://www.fao.org/3/i6583e/i6583e.pdf> (Accessed 15 August, 2021).
- FAO (2021). Sustainable Development Goals, 17 Goals to Transform Our World. <http://www.fao.org/3/i6583e/i6583e.pdf> (Accessed 25 August, 2021).
- GoI (2019). Agricultural Statistics at a Glance, Government of India, Ministry of Agriculture and Farmers Welfare, Department of Agriculture, Cooperation and Farmers Welfare Directorate of Economics and Statistics, New Delhi. pp. 60-31.
- Gomez, K. A. and Gomez, A. A. (1984). Statistical Procedures for Agricultural Research. 2nd Ed. IRRI, Philippines. John Wiley and Sons Publication, New York.
- GoO (2020). Five decades of Odisha Agriculture Statistics, Directorate of Agriculture and Food Production, Government of Odisha. pp. 51.
- Kaisher, M. S., Rahman, M. A., Amin, M. H. A., Amanullah, A. S. M. and Ahsanullah, A. S. M. (2010). Effects of sulphur and boron on the seed yield and protein content of mungbean. *Bang. Res. Pub. J.* **3** :1181-186.
- Kumar, R., Singh Y. V., Singh S, Latare A. M. and Mishra P. K. (2012). Effect of phosphorus and sulphur nutrition on yield attributes, yield of mungbean (*Vigna radiata* L. Wilczek). *J. Chem. Pharma. Res.* **4** : 2571-573.
- Kumar, S. and Yadav, S. S. (2018). Effect of phosphorus fertilization and bio-organics on growth, yield and nutrient content of mungbean (*Vigna radiata* L. Wilczek). *Res. J. Agric. Sci.* **9** :1252-257.
- Kumawat, S. R., Khistriya, M. K., Yadav, S. L. and Manoj, K. (2014). Effect of sulphur and

- phosphorus on growth and yield attributes on summer green gram [*Vigna radiata* (L.) Wilczek]. *Int. J. Agric. Sci.* **10** : 770-73.
- MAFW- Ministry of Agriculture and Farmers Welfare (2021). Third Advance Estimates of Production of Foodgrains for 2020-21. Department of Agriculture, Cooperation and Farmers Welfare (DAC&FW), Directorate of Economics and Statistics (DES). <https://eands.dacnet.nic.in>.
- Maitra S., Zaman, A., Mandal, T.K. and Palai J. B. (2018). Green Manures in Agriculture: A Review. *J. Pharm. Phytochem.* **7** : 1319-327.
- Malhotra, H., Sharma, S. and Pandey, R. (2018). Phosphorus nutrition: plant growth in response to deficiency and excess. In: *Plant Nutrients and Abiotic Stress Tolerance* Springer, Singapore. pp. 171-90.
- Parashar, A., Jain, M. and Tripathi, L. (2020). Effect of phosphorus and sulphur on the growth and yield of black gram (*Vigna mungo* L.). *J. Pharm. Phytochem.* **9** : 2585-588.
- Patel, H. R., Patel, H. F., Maheriya, V. D. and Dodia, I. N. (2013). Response of *kharif* green gram (*Vigna radita* L. Wilczek) to sulphur and phosphorus fertilization with and without biofertilizer application. *Bioscan.* **8** : 149-52.
- Sahu, S., Shankar, T., Maitra, S., Mohapatro, S. and Swamy, G. V. V. S. N. (2020). A review on effect of phosphorus and sulphur on growth, productivity and nutrient uptake of green gram (*Vigna radiata* L.). *Agro. Econ. Int. J.* **7** : 91-93.
- Shahi, D. K., Sharma, A., Singh, L. (2002). Improvement in nutrition quality of green gram as influenced by fertilization and inoculation. *Ind. J. Agri. Sci.* **72** : 210-12.
- Singh, A. K. and Singh, R. S. (2012). Effect of phosphorus and bioinoculants on yield, nutrient uptake and economics of long duration pigeon pea (*Cajanus cajan*). *Ind. J. Agron.* **57** : 265-69.
- Singh, N. (2017). Pulses: an Overview. *J. Food Sci. Technol.* **54** : 853-57. doi : 10.1007/s13197-017-2537-4.
- Singh, P., Yadav, K. K., Meena, F., Singh, B. and Singh, R. (2017). Effect of phosphorus and sulphur on yield attributes, yield and nutrient uptake of mung bean (*Vigna radiata* L.) in central plain zone of Punjab, India. *Plant Arch.* **17** : 1756-760.
- Singh, R. S. and Yadav, V. (2013). Response of green gram [*Vigna radita* (L.) Wilczek] varieties to varying phosphorus levels. *Ann. Agric. Res.* **34** : 71-78.
- Singh, R., Singh, V., Singh, P. and Yadav, R. A. (2018). Effect of phosphorus and PSB on yield attributes, quality and economics of summer greengram (*Vigna radiata* L.). *J. Pharm. Phytochem.* **7** : 404-08.
- Sudharani, Y., Mohapatra, P.P., Pramanik K. and Maitra S. (2018). Effect of different phosphorus levels on growth and yield of cowpea (*Vigna unguiculata* L.) Genotypes. *Int. J. Manage. Technol. Eng.* **8** : 2876-881.
- Sumasree, D. R. (2020). Role of sulphur in pulse crops: A review. *Int. J. Chem. Stud.* **8** : 2302-307. doi : <https://doi.org/10.22271/chemi.2020.v8.i6ag.11119>.
- Taliman, N. A., Dong, Q., Echigo, K., Raboy, V. and Saneoka, H. (2019) Effect of phosphorus fertilization on the growth, photosynthesis, nitrogen fixation, mineral accumulation, seed yield, and seed quality of a soybean low-phytate line. *Plant.* **8** : doi : 10.3390/plants8050119.
- Thesiya, N. M., Chovatia, P. K. and Kikani, V. L. (2013). Effect of potassium and sulphur on growth and yield of black gram (*Vigna mungo* (L.) under rainfed condition. *Legume Res.* **36** : 255-58.
- Tiwari B. K. and Singh N. (2012). Pulse chemistry and technology. Cambridge: Royal Society of Chemistry. pp. 1-10.
- Vidhyashree, V., Naga, S. R., Yadav, B. L., Koli, D. K. and Rao, I. J. (2017). Effect of phosphorus and biofertilizers on growth and yield of mung bean [*Vigna radiata* (L.) Wilczek]. *Int. J. Curr. Microbiol. Appl. Sci.* **6** : 3992- 997.
- Zenda, T., Liu, S., Dong, A. and Duan, H. (2021). Revisiting sulphur—The once neglected nutrient: It's roles in plant growth, metabolism, stress tolerance and crop production. *Agric.* **11** : <https://doi.org/10.3390/agriculture11070626>.