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Phosphorus Management in *Lathyrus* Varieties in Vertisolos

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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

A field experiment was conducted during the Rabi season of 2024 to evaluate the response of *Lathyrus* varieties to different phosphorus levels for fodder yield, crude protein yield, economics, and post-harvest soil properties under Vertisol conditions. The experiment was laid out in a split-plot design with three replications. Four phosphorus levels, 0, 40, 60, and 80 kg P_2O_5 ha^{-1}, were tested with five varieties: BAUL-106, BCK-19-21A, JCL-22-1, Mahateora, and Prateek. The crop was sown on 21 November 2024 using 50 kg seed ha^{-1} and harvested at 65 days after sowing at 50% flowering for fodder evaluation. The experimental soil was clay loam with pH 7.12, organic carbon 0.56%, available nitrogen 246.15 kg ha^{-1}, available phosphorus 17.36 kg ha^{-1}, and available potassium 301.78 kg ha^{-1}. Among varieties, Prateek recorded the highest mean green fodder yield of 262.68 q ha^{-1} and dry matter yield of 51.25 q ha^{-1}, while BAUL-106 recorded the lowest values. Among phosphorus levels, 80 kg P_2O_5 ha^{-1} produced the highest mean green fodder yield of 257.74 q ha^{-1} and dry matter yield of 55.06 q ha^{-1}. The treatment combination Prateek with 80 kg P_2O_5 ha^{-1} recorded the highest green fodder yield of 284.00 q ha^{-1} and dry matter yield of 59.90 q ha^{-1}. The results indicate that Prateek responded favourably to higher phosphorus application under the tested conditions.

Keywords: Lathyrus sativus; phosphorus management; Vertisol; green fodder yield; dry matter yield; crude protein yield; phosphorus-use efficiency; post-harvest soil properties; economic returns; forage production.

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1. Introduction

Lathyrus (*Lathyrus sativus* L.) is a crucial fodder-based bonus crop in the Central and Eastern Indian rice-growing areas. Over 0.89 million hectares of this crop are grown nationwide. Approximately 0.61 million hectares are grown in Madhya Pradesh and Chhattisgarh during the *Rabi* season, representing the nation's main *Lathyrus* belt under a rice-based relay farming system. This ancient crop has a long history and is well known for its resilience to moisture stress and other productivity-limiting factors.

Phosphorus application not only enhances the nutritional profile of dry matter but has also been shown to promote growth, initiate nodule formation, and affect the efficiency with which the rhizobium-legume symbiosis fixes nitrogen, an energy-dependent process. Optimising the amount of phosphorus is necessary because it is widely acknowledged as essential for maintaining soil fertility and increasing crop output. Phosphorus application increases grain yield, yield-contributing components, and grain quality in various legumes (Devi *et al.*, 2018; Shrivastva *et al.*, 2014; Kumhar *et al.*, 2021). However, phosphorus is one of the crucial nutrient elements that remains available in the soil for only a limited period after application. Phosphorus increases the yield of both annual and perennial legume species by increasing plant-available phosphorus in the soil. Optimum available phosphorus for maximum yield differs among species, as does phosphorus use efficiency (PUE). For this reason, species that perform well in low-phosphorus soils are valuable for this type of production system and environment. Furthermore, the price of phosphatic fertilisers is increasing because of the limited reserves of raw materials (e.g., rock phosphate) worldwide. Moreover, excessive use of fertiliser not only increases production costs but is also detrimental to the environment. Nevertheless, the application of optimal phosphorus rates and the use of genotypes with high phosphorus use efficiency (grain yield per unit phosphorus added) are strategies that farmers can adopt to improve legume crops in the region. Providing farmers with genotypes adapted to specific conditions of soil phosphorus availability and with good phosphorus use efficiency should improve yields without excessively increasing production costs or damaging the environment. Recent field evidence in cowpea indicates that varietal response and phosphorus level can jointly influence yield, nodulation, and phosphorus-use efficiency (Singh *et al.*, 2022). Studies of phosphate management also indicate that phosphorus source and application level can influence nutrient availability and soil fertility-related properties, reinforcing the importance of context-specific phosphorus management (Bhosale *et al.*, 2024). Recent studies in legumes further link phosphorus availability with nodulation, productivity, post-harvest soil fertility, and genotype-dependent phosphorus-use efficiency (Wu & Kumar, 2026; Pramanik *et al.*, 2026; Aliyu *et al.*, 2026). However, comparative information on the response of the five tested *Lathyrus* varieties to graded phosphorus levels for fodder yield, crude protein yield, economics, and post-harvest soil properties under Vertisol conditions is limited. Keeping the above points in view, the experiment was undertaken to study the effects of different phosphorus levels on the growth and yield of *Lathyrus.*

2. Methodology

The field study was conducted at the Research Farm, Department of Agronomy, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.), during the *Rabi* season of 2024–2025 as part of the All India Coordinated Research Project on Forage Crop, located at 23^0 10' North latitude and 79^0 59' East longitude in the central region of Madhya Pradesh. The experimental field had clay-loam soil with a neutral p^H of 7.12, low organic carbon (0.56%), low available N (246.15 kg/ha), medium available P (17.36 kg/ha), and available K of 301.78 kg/ha. Twenty treatments were arranged in a split-plot design with three replications. These treatments included four phosphorus levels (0, 40, 60 and 80 kg/ P_2O_5ha) and five varieties (BAUL-106, BCK-19-21A, JCL-22-1, Mahateora and Prateek). Each variety was sown on 21 November 2024 at 50 kilograms of seed/ha in rows 30 cm apart, with a uniform basal dose of 20 kg N + 20 kg K_2O/ha. Phosphorus was applied as prescribed.

All recommended agronomic practices were followed during the growing period, and soil analysis was conducted. Phosphorus was applied at sowing according to the treatments in all plots through SSP (single superphosphate); nitrogen and potassium were also applied at sowing in the form of urea and muriate of potash, respectively. At 65 days after sowing (DAS), when 50% flowering was observed in the field, the crop was harvested for fodder evaluation. Green fodder yield was measured, and samples were collected. OPSTAT software was used for statistical analysis using standard analysis-of-variance procedures for a split-plot design. Fisher's protected least significant difference test was used to determine statistically significant mean differences at $P<0.05$.

3. Results and Discussion

3.1 Effect of Phosphorus Levels on Yield

Variety V_5 (Prateek) recorded the highest post-harvest values for green fodder yield and dry matter yield (q/ha) and was identified as the best variety for increasing *Lathyrus* yield. However, variety V_1 (BAUL-106) recorded the lowest post-harvest values for green fodder yield and dry matter yield (q/ha) (Table 1). The superiority of Prateek in multiple growth parameters, such as greater plant height and a higher number of branches, was associated with its higher green fodder and dry matter yields. Similar results for this character were also reported by Hossain *et al.* (2005), Yadav *et al.* (2023), Mundada *et al.* (2004), and Tiwari *et al.* (2013). Phosphorus level P_3 (80 kg P_2O_5/ha) recorded the highest post-harvest values for green fodder yield and dry matter yield (q/ha) and was superior to the other phosphorus treatments. However, the lowest post-harvest values for green fodder yield and dry matter yield (q/ha) were obtained at phosphorus level P_0 (0 kg P_2O_5/ha) (Table 2). Phosphorus application had beneficial effects on root development, vegetative growth, and photosynthetic efficiency, resulting in increased nutrient uptake, enhanced growth processes through energy metabolism, and greater vegetative biomass through cell division and cell elongation, which were reflected in higher *Lathyrus* yield. These results are supported by the findings of Shekara *et al.* (2012), Pahade *et al.* (2023), Jat *et al.* (2013), Roy and Tudu (2015), and Mawo *et al.* (2016).

Table 1. Green fodder yield (q/ha) as influenced by different varieties and phosphorus levels

Varieties	Phosphorus levels (kg/ha)				
	P_0(0)	**P_1(40)**	**P_2 (60)**	**P_3 (80)**	**Mean V**
V_1(BAUL-106)	210.10	222.70	231.90	236.70	225.35
V_2(BCK-19-21A)	217.50	223.10	234.30	237.80	228.18
V_3(JCL-22-1)	211.90	240.70	254.00	265.50	243.03
V_4(Mahateora)	222.50	248.40	261.60	269.50	250.50
V_5(Prateek)	226.70	263.70	276.30	284.00	262.68
Mean P	**217.74**	**239.72**	**252.58**	**257.74**	
	V	**P**	**VxP**	**PxV**	
SEm±	**4.63**	**3.21**	**2.36**	**2.85**	
CD(P=0.05)	**13.89**	**9.63**	**7.08**	**8.55**	

Table 2. Dry matter yield (q/ha) as influenced by different varieties and phosphorus levels

Varieties	Phosphorus levels (kg/ha)				
	P_0 (0)	**P_1 (40)**	**P_2 (60)**	**P_3 (80)**	**Mean V**
V_1(BAUL-106)	28.27	41.50	46.97	52.73	42.37
V_2(BCK-19-21A)	31.80	44.67	48.10	51.93	44.13
V_3(JCL-22-1)	35.30	46.93	50.43	53.97	46.66
V_4 (Mahateora)	36.77	48.20	52.77	56.77	48.63
V_5(Prateek)	38.83	52.90	53.37	59.90	51.25
Mean P	34.19	46.84	50.33	55.06	
	V	**P**	**VxP**	**PxV**	
SEm±	1.83	3.21	2.36	2.85	
CD (0.05)	5.89	9.63	7.08	8.55	

Interaction effect of phosphorus levels and varieties on growth, yield and quality of Lathyrus

The best treatment combination was determined to be V_5P_3 (Prateek x 80 kg P_2O_5/ha), which provided the maximum green fodder yield, dry matter yield, and quality parameters (crude protein and protein yield) compared with the other treatment combinations. The interaction between varieties and phosphorus levels also significantly influenced the various growth and yield parameters (Jha *et al.*, 2024).

3.2 Effect of Phosphorus Levels on Crude Protein of *Lathyrus* Varieties

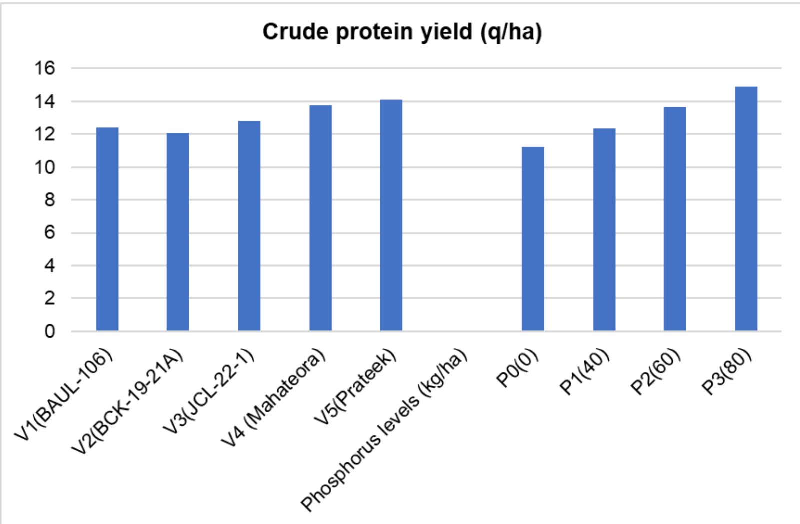

Fig. 1. Crude protein yield (q/ha)

Variety V_2 (BCK-19-21A) recorded the lowest crude protein (%) and crude protein yield (q/ha), whereas variety V_5 (Prateek) recorded the highest crude protein (%) and crude protein yield (q/ha), making it the best-performing variety for these parameters. Genetic variation among varieties may account for the differences in yield and crude protein percentage. Similar results for this character were also reported by Mundada *et al.* (2004), Kumhar *et al.* (2025), and Gangwar *et al.* (2016). The best phosphorus dose for crude protein (%) in *Lathyrus* was phosphorus level P_3 (80 kg P_2O_5/ha), which produced the highest crude protein (%) and crude protein yield (q/ha) (Sharma *et al.*, 2025). Phosphorus level P_0 (0 kg P_2O_5/ha) produced the lowest crude protein (%) and crude protein yield (q/ha). Phosphorus application had beneficial effects on nitrogen fixation by supporting nodule formation, improving nitrogen uptake and metabolism (directly linked to protein synthesis), and enhancing enzyme activity and RNA/DNA synthesis, resulting in increased nitrogen assimilation and higher crude protein concentrations in plant tissues. These results are consistent with those reported by Jha *et al.* (2014), Jha *et al.* (2016), Kumar *et al.* (2012), Kumhar *et al.* (2022), Malviya *et al.* (2012), and Shri *et al.* (2014).

3.3 Effect of Phosphorus Levels on Economics of the Treatment of *Lathyrus* Varieties

The treatment combinations V_1P_3 (BAUL-106 x 80 kg P_2O_5/ha), V_2P_3 (BCK-19-21A x 80 kg P_2O_5/ha), V_3P_3 (JCL-22-1 x 80 kg P_2O_5/ha), V_4P_3 (Mahateora x 80 kg P_2O_5/ha) and V_5P_3 (Prateek x 80 kg P_2O_5/ha) were found to have the greatest cost of cultivation (Rs/ha) (Fig. 2).

The treatment combination V_5P_3 (Prateek x 80 kg P_2O_5/ha) showed the highest gross monetary returns (Rs/ha) and net monetary returns (Rs/ha). By contrast, treatment combinations V_1P_0 (BAUL-106 x 0 kg P_2O_5/ha), V_2P_0 (BCK-19-21A x 0 kg P_2O_5/ha), V_3P_0 (JCL-22-1 x 0 kg P_2O_5/ha), and V_4P_0 (Mahateora x 0 kg P_2O_5/ha) had the lowest cost of cultivation (Rs/ha). Treatment combination V_1P_0 (BAUL-106 x 0 kg P_2O_5/ha) had the lowest gross monetary returns (Rs/ha) and net monetary returns (Rs/ha). The highest benefit-cost ratio (1.82) was recorded for treatment combinations V_5P_1 (Prateek x 40 kg P_2O_5/ha) and V_5P_2 (Prateek x 60 kg P_2O_5/ha). V_1P_3 (BAUL-106 x 80 kg P_2O_5/ha) recorded the lowest benefit-cost ratio (1.46). Similar results for this character were also reported by Chand *et al.* (2025), Bhalse *et al.* (2024), Bhayal *et al.* (2022), Malviya *et al.* (2012), and Kumhar *et al.* (2022).

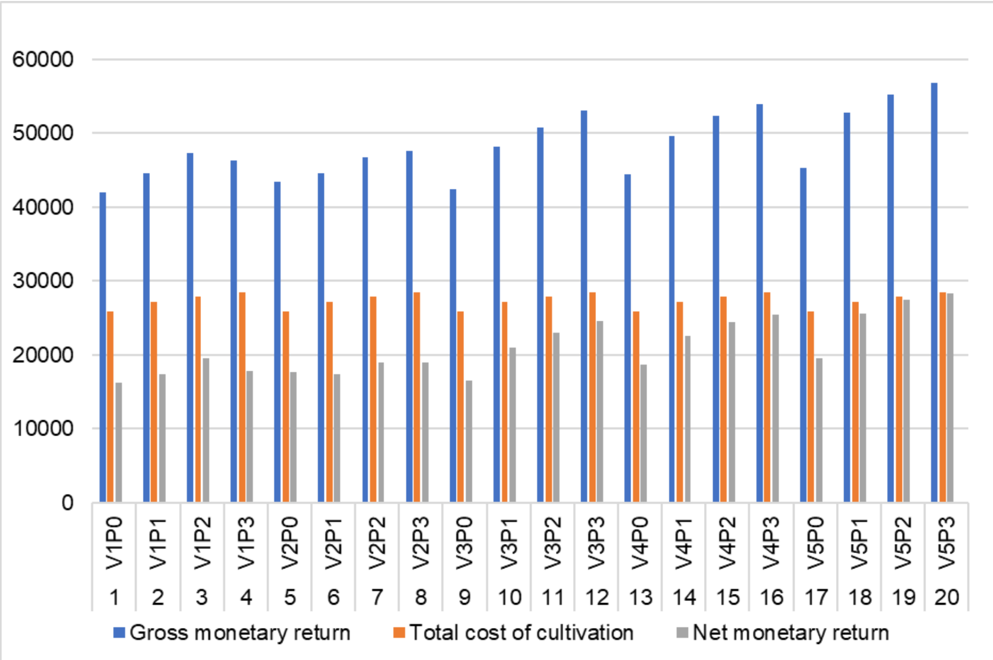

Fig. 2. Effect of different lathyrus varieties and phosphorus levels on economic returns, including cost of cultivation, gross monetary returns, net monetary returns, and benefit–cost ratio under Vertisol conditions

3.4 Effect of Phosphorus Levels and Varieties on Chemical Properties of Soil

Table 3. Changes in soil properties over their initial status as influenced by different varieties and phosphorus levels after completion of crop cycle

Treatment combination	p^H	OC%	Available Nitrogen (kg/ha)	Available Phosphorus (kg/ha)	Available Potassium (kg/ha)
V_1P_0	7.15	0.52	237.94	17.02	301.65
V_1P_1	7.17	0.54	240.10	17.15	304.40
V_1P_2	7.15	0.57	243.62	18.15	306.22
V_1P_3	7.18	0.59	239.45	18.17	308.53
V_2P_0	7.15	0.52	241.88	17.62	303.00
V_2P_1	7.18	0.55	241.40	17.10	305.16
V_2P_2	7.19	0.57	243.55	17.18	307.33
V_2P_3	7.21	0.50	240.22	18.07	310.18
V_3P_0	7.12	0.50	242.13	18.30	300.05
V_3P_1	7.14	0.52	239.22	18.60	303.25
V_3P_2	7.18	0.53	242.13	18.60	305.25

Treatment combination	p^H	OC%	Available Nitrogen (kg/ha)	Available Phosphorus (kg/ha)	Available Potassium (kg/ha)
V_3P_3	7.13	0.58	233.77	18.60	307.43
V_4P_0	7.15	0.50	236.94	18.12	301.16
V_4P_1	7.17	0.53	239.77	18.44	303.22
V_4P_2	7.19	0.56	242.78	18.66	305.65
V_4P_3	7.19	0.58	234.44	18.70	308.42
V_5P_0	7.14	0.51	238.12	18.48	302.20
V_5P_1	7.16	0.54	240.99	18.32	304.75
V_5P_2	7.19	0.57	244.44	18.78	306.65
V_5P_3	7.20	0.56	246.15	18.88	309.04
Initial value	**7.12**	**0.56**	**246.15**	**17.36**	**301.78**

According to the results, after harvesting *Lathyrus*, the highest levels of nitrogen, phosphorus, potassium, and p^H were recorded under treatment combination V_5P_3 (Prateek x 80 kg P_2O_5/ha). The initial values of nitrogen (246.15 kg/ha), phosphorus (17.36 kg/ha), potassium (301.78 kg/ha), and p^H (7.12) were recorded in the current study (Table 3).

Higher dry matter yield and nitrogen sufficiency in the soil solution may account for the greater absorption of nitrogen, phosphorus, and potassium, which, in turn, may result in improved uptake to sufficient levels. The changes in soil chemical properties following phosphorus treatment may be explained by enhanced rhizosphere uptake due to increased root growth, anchorage, and deep penetration, which increase phosphorus absorption (Sahu *et al.*, 2023; Tiwari *et al.*, 2011). These results are consistent with those reported by Singh *et al.* (2013), Verma *et al.* (2016), Yadav *et al.* (2024), and Jha *et al.* (2007).

4. Conclusion

Variety Prateek was significantly superior to the other varieties in green fodder, dry matter, and crude protein yield of *Lathyrus*. Application of 80 kg P_2O_5 /ha produced significantly higher green fodder, dry matter, and crude protein yields, followed by 60 kg P_2O_5 /ha in V_5 and V_4. The treatment combination V_5P_3 (Prateek x 80 kg P_2O_5 /ha) was significantly superior and produced the maximum growth and yield parameters; it was at par with V_4P_3 (Mahateora x 80 kg P_2O_5 /ha) and superior to the other treatments. The treatment combination Prateek x 80 kg P_2O_5 /ha was more remunerative and recorded the highest net monetary returns and benefit-cost ratio, followed by Mahateora x 80 kg P_2O_5 /ha.

5. Limitations

The study was conducted during a single Rabi season at one experimental location under specific Vertisol conditions, using five *Lathyrus* varieties and four phosphorus levels in a split-plot design with three replications. The crop was evaluated for fodder production at 65 days after sowing, limiting assessment to this growth stage and season. Consequently, the observed yield, quality, economic, and post-harvest soil responses may not be directly generalisable to other environments or seasons. Future multi-season and multi-location trials could confirm the consistency of these treatment responses.

Declaration of AI Use

This manuscript was prepared through the intellectual contributions of the author(s) to the study design, data analysis, interpretation of results, and scholarly content. Grammarly and ChatGPT were used solely to assist with grammatical refinement and reference formatting during manuscript revision. The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that no competing interests exist.

References

Aliyu, O. M., Oladimeji, K. T., Abdulkareem, Y. F., Alabi, T., Olajide, T. A., & Muhammed, W. M. (2026). Genotypic variation in phosphorus-use efficiency underpins yield stability and drives soil regeneration in cowpea (*Vigna unguiculata* L. Walp.). *Journal of Soil Science and Plant Nutrition*. https://doi.org/10.1007/s42729-026-03425-z

Bhalse, L., Jha, A. K., Verma, B., Raghuvanshi, S., Porwal, M., & Sahu, M. P. (2024). Efficacy of pyroxasulfone and its combinations against weeds in wheat (*Triticum aestivum*). *Indian Journal of Agronomy, 68*(4), 443–446. https://doi.org/10.59797/ija.v68i4.5470

Bhayal, L., Kewat, M. L., Bhayal, D., Aakash, Jha, A. K., & Jain Badkul, A. (2022). Influence of different sowing dates and nutrient management on yield attributes and yield of wheat (*Triticum aestivum* L.). *International Journal of Plant & Soil Science, 34*(22), 362–367. https://doi.org/10.9734/ijpss/2022/v34i2231385

Bhosale, S. V., Gosavi, A. B., Ghorpade, V. N., Waghdhare, D. S., & Bhosale, P. C. (2024). Nutrient release pattern and soil enzyme activities of calcareous soil as influenced by phosphate rich organic manure. *Journal of Global Agriculture and Ecology, 16*(4), 87–95. https://doi.org/10.56557/jogae/2024/v16i48991

Chand, S., Kumar, S., Roy, A. K., Vijay, D., Choudhary, B. B., Indu, Kumar, P., Agrawal, R. K., Yadav, V. K., Kaushal, P., Yadava, D. K., Kumar, R. V., Singh, A. K., Ahmed, S., Malaviya, D. R., Singhal, R. K., Prasad, B., Kapoor, R., Jha, A. K., & Panchta, R. (2025). Analyzing trends and future projections in fodder oats (*Avena sativa* L.) for quality seed production in India. *Frontiers in Plant Science, 16*, 1525422. https://doi.org/10.3389/fpls.2025.1525422

Devi, M. B., Devi, M. T., Jha, A. K., Yumnam, A., Balusamy, A., Verma, V. K., Talang, H. D., Deshmukh, N. A., Rymbai, H., & Assumi, S. R. (2018). Yield and yield attributes of garden pea (*Pisum sativum* var. *hortense* L.) as influenced by nutrient management practices under agroclimatic conditions of Meghalaya. *International Journal of Current Microbiology and Applied Sciences, 7*(9), 3447–3454. https://doi.org/10.20546/ijcmas.2018.709.427

Gangwar, S., Naik, K. R., Jha, A., & Bajpai, A. (2016). Soil properties as influenced by organic nutrient management practices under rice based cropping systems. *Research on Crops, 17*(1), 8–12. https://doi.org/10.5958/2348-7542.2016.00002.4

Hossain, M. T., Hossain, M. A., & Sattar, M. A. (2005). Influence of phosphorus, zinc and molybdenum on nutrient and P-ODAP contents of grasspea (*Lathyrus sativus* L.) seed. *Journal of the Bangladesh Agricultural University, 3*(1), 65–69. https://doi.org/10.22004/ag.econ.276408

Jat, S. R., Patel, B. J., Shivran, A. C., Kuri, B. R., & Jat, G. (2013). Effect of P and S levels on growth and yield of cowpea under rainfed conditions. *Annals of Plant and Soil Research, 15*(2), 114–117.

Jha, A. K., Sharma, R. S., & Vishwakarma, S. K. (2007). Development of resource conservation techniques for tillage and sowing management in rice-wheat cropping system under irrigated production system of Kymore Plateau and Satpura hill zone of Madhya Pradesh. *JNKVV Research Journal, 41*(1), 26–31.

Jha, A. K., Shrivastava, A., & Raghuvanshi, N. S. (2014). Effect of different phosphorus levels on growth, fodder yield and economics of various cowpea genotypes under Kymore plateau and Satpura hills zone of Madhya Pradesh. *International Journal of Agricultural Sciences, 10*(1), 409–411. https://researchjournal.co.in/upload/assignments/10_409-411.pdf

Jha, A. K., Shrivastava, A., Mehta, A. K., Billaiya, S. K., & Raghuvanshi, N. S. (2016). Effect of different concentration of seaweed saps on quality, green fodder and seed yields of berseem (*Trifolium alexandrium*). *International Journal of Bio-resource and Stress Management, 7*(5), 1008–1011. https://doi.org/10.23910/IJBSM/2016.7.5.1649

Jha, A. K., Yadav, P. S., Shrivastva, A., Dubey, A., & Jaiswal, A. (2024). Influence of tillage and nutrient management on fodder productivity and economics of oat in rice-oat cropping system. *International Journal of Research in Agronomy, 7*(4), 607–614. https://doi.org/10.33545/2618060X.2024.v7.i4h.626

Kumar, A., Yadav, P. K., Yadav, R. K., Singh, R., & Yadav, H. K. (2012). Growth, biomass production and quality characters of cowpea as influenced by phosphorus and sulphur fertilization on loamy sands of semi-arid sub-tropics. *Asian Journal of Soil Science, 7*(1), 80–83.

Kumhar, B. L., Agrawal, K. K., Jha, A. K., & Rai, H. K. (2021). Variability of soil infiltration rate in different grass based cropping system in Kymore Plateau Satpura Hills region. *Forage Research, 47*(3), 325–328. https://forageresearch.in/wp-content/uploads/2022/03/325-328.pdf

Kumhar, B. L., Agrawal, K. K., Jha, A. K., Patidar, J., Kumar, V., Kumar, S., & Satpal. (2025). Long term effect of grass based cropping system to improves soil health and sustainability. *Forage Research, 51*(3), 341–349. https://forageresearch.in/category/vol-51-3/

Kumhar, B. L., Agrawal, K. K., Jha, A. K., Rai, H. K., Kumar, V., Choudhary, M., & Kantwa, S. R. (2022). Productivity and economical viability of grass-based cropping systems. *Range Management and Agroforestry, 43*(1), 167–171. https://publications.rmsi.in/index.php/rma/article/view/648

Malviya, P., Jha, A. K., & Upadhyay, V. B. (2012). Effect of different proportions of vermicompost and fertilizers on growth and yield of scented rice and soil properties. *Annals of Agricultural Research New Series, 33*(4), 228–234. https://epubs.icar.org.in/index.php/AAR/article/view/42707

Mawo, Y. M., Mohammed, I. B., & Garko, M. S. (2016). Effect of phosphorus levels on growth, yield and development of cowpea (*Vigna unguiculata* (L.) Walp.) varieties. *International Journal of Scientific Engineering and Applied Science, 2*(5). https://ijseas.com/volume2/v2i5/ijseas20160540.pdf

Mundada, A. D., Chore, C. N., Deotale, R. D., Paliwal, M. C., & Ingole, A. S. (2004). Performance of *Lathyrus* genotypes under different environments on chemical and biochemical parameters. *Journal of Soils and Crops, 14*(2), 433–436.

Pahade, S., Jha, A. K., Verma, B., Meshram, R. K., Toppo, O., & Shrivastava, A. (2023). Efficacy of sulfentrazone 39.6% and pendimethalin as a pre-emergence application against weed spectrum of soybean (*Glycine max* L. Merrill). *International Journal of Plant & Soil Science, 35*(12), 51–58. https://doi.org/10.9734/ijpss/2023/v35i122966

Pramanik, M., Nath, R., Roy, S., Bachaspati, S., & Asif, S. M. (2026). Root functional traits mediate agronomic and phosphorus effects on productivity and soil fertility of field pea in post-rice systems. *Plant and Soil, 522*, 1047–1063. https://doi.org/10.1007/s11104-026-08561-0

Roy, D. C., & Tudu, N. K. (2015). On farm evaluation of yield and quality of multicut sorghum (*Sorghum bicolor*) fodder through application of phosphorus. *International Journal of Science and Research, 4*(1), 2825–2828. https://www.ijsr.net/archive/v4i1/SUB151072.pdf

Sahu, V., Kewat, M. L., Verma, B., Singh, R., Jha, A. K., Sahu, M. P., & Porwal, M. (2023). Effect of carfentrazone-ethyl on weed flora, growth and productivity in wheat. *The Pharma Innovation Journal, 12*(3), 3621–3624. https://doi.org/10.5281/zenodo.7753409

Sharma, A., Agarwal, S. B., Jha, A. K., Sahu, R. K., Jatav, S. S., Singh, P. P., & Parte, V. (2025). Changes in root growth nodulation behavior, plant survivability of chickpea under organic source of nutrients and bio agent. *Plant Archives, 25*(2), 1525–1529. https://doi.org/10.51470/PLANTARCHIVES.2025.v25.no.2.221

Shekara, B. G., Sowmyalatha, B. S., & Baratkumar, C. (2012). Effect of phosphorus levels on forage yield of fodder cowpea. *Journal of Horticulture Letters, 2*(1), 12–13. https://bioinfopublication.org/files/articles/2_1_2_JHL.pdf

Shri, S., Jha, A. K., & Shrivastava, A. (2014). Evaluation of different intercropping systems for productivity and economics in maize (*Zea mays* L.). *Annals of Agricultural Research New Series, 35*(2), 200–204. https://epubs.icar.org.in/index.php/AAR/article/view/42204

Shrivastva, A., Jha, A. K., & Jha, G. (2014). Productivity and nutrient uptake influenced by different food-forage based cropping system in Kamore Plateau and Satpura hill zone of Madhya Pradesh. *Annals of Agricultural Research New Series, 35*(3), 286–291. https://epubs.icar.org.in/index.php/AAR/article/view/44129

Singh, H. V., Jha, G., Babu, S., & Jha, A. K. (2013). Effect of seed rate and sowing depth on growth, yield attributes and yield of irrigated wheat (*Triticum aestivum*) in Madhya Pradesh. *Indian Journal of Agronomy, 58*(2), 259–261. https://doi.org/10.59797/ija.v58i2.4184

Singh, R., Shridhar, & Dass, A. (2022). Growth, yield and phosphorus use efficiency of vegetable cowpea (*Vigna unguiculata*) varieties as influenced by phosphorus levels under rainfed conditions of semi-arid environment. *Journal of Experimental Agriculture International, 44*(7), 28–37. https://doi.org/10.9734/jeai/2022/v44i730834

Tiwari, R. K., Dwivedi, B. S., Deshmukh, G., Pandey, A. K., & Jha, A. (2011). Effect of weed control treatments on growth of little seed canary grass and productivity of wheat. *Indian Journal of Weed Science, 43*(3–4), 239–240. https://www.isws.org.in/IJWSn/File/2011_43_Issue-3%264_239-240.pdf

Tiwari, R. K., Jha, A., Tripathi, S. K., Khan, I. M., & Rao, S. K. (2013). Rice based cropping system and climate change. *JNKVV Research Journal, 47*(3), 239–247.

Verma, D., Gontia, A. S., Jha, A., & Deshmukh, A. (2016). Study of cutting management on proximate analysis in wheat, oat and barley crops. *International Journal of Agriculture, Environment and Biotechnology, 9*(4), 593–597. https://doi.org/10.5958/2230-732X.2016.00077.2

Wu, W., & Kumar, A. (2026). Phosphate starvation and the nodulation dilemma: Regulatory mechanisms linking phosphorus availability to legume-rhizobia symbiosis. *Journal of Plant Growth Regulation, 45*, 4045–4050. https://doi.org/10.1007/s00344-026-12131-0

Yadav, P. S., Jha, A. K., Kewat, M. L., Verma, B., & Sahu, M. P. (2024). Effect of sowing management and herbicides application on weeds and yield of berseem (*Trifolium alexandrinum*). *Indian Journal of Agronomy, 69*(1), 71–77. https://doi.org/10.59797/ija.v69i1.5485

Yadav, P. S., Kewat, M. L., Jha, A. K., Hemalatha, K., & Verma, B. (2023). Effect of sowing management and herbicides on the weed dynamics of berseem (*Trifolium alexandrinum*). *The Pharma Innovation Journal, 12*(2), 2845–2848. https://doi.org/10.5281/zenodo.7742060

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