Int.J.Curr.Microbiol.App.Sci (2026) *15*(1): 246-254

EXCELLENT PUBLISHERS

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 15 Number 1 (2026)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2026.1501.030

Correlation between Rice Yield and Soil Phosphorus Fractions under STCR-Based Nutrient Management

Swati Sahu[1], Lalit Kumar Srivastava[1], Anusuiya Panda[2]* and Vinay Bachkaiya[1]

[1]*College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur-492012, Chhattisgarh, India*
[2]*College of Agriculture, Rani Lakshmi Bai Central Agricultural University, Jhansi, Uttar Pradesh-284003, India*

**Corresponding author*

A B S T R A C T

Keywords

Soil phosphorus fractions, farmyard manure, Vertisol, phosphorus uptake, soil testing

Article Info

Received:
25 November 2025
Accepted:
31 December 2025
Available Online:
10 January 2026

This study investigates how nutrient management influences soil phosphorus (P) fractions and rice yield in a rice–wheat system on Vertisols under Indian conditions. We evaluated STCR-based fertilizer prescriptions, with and without farmyard manure (FYM), across yield-target scenarios in a randomized block design with four replications and five treatments. Soil was fractionated to quantify major inorganic P pools (Ca–P, Red–P, Fe–P, Al–P, Saloid–P/RS–P) and total P, while crop tissues and grain yields provided P uptake data; P balance was estimated to assess soil fertility status under different P regimes. Results show that STCR-based doses targeting 22 q ha^{-1} consistently yielded the highest grain yields and total P uptake, with concomitant increases in Ca–P and Red–P pools. FYM enhanced nutrient-use efficiency and boosted specific P fractions, though FYM–fertilizer interactions varied by treatment. Across fractions, total P and its components rose with cumulative P input, aligning with improved P availability and uptake in rice and subsequent wheat. The Ca–P pool dominated inorganic P across Vertisols, with Red–P, Fe–P, Al–P, and RS–P contributing variably; their distribution was modulated by soil chemistry and fertilizer history. Regression analyses identified Red–P as the strongest predictor of grain yield, followed by Saloid–P and available P, while Total–P explained less variation. Positive P balances indicated sustained P supply under STCR strategies, though regional and long-term validations are recommended to refine recommendations for resource-limited farmers, including economic analyses and integration with soil testing and organic amendments to optimize P partitioning, yield targets, and soil fertility in Indian Vertisols.

Introduction

Rice (*Oryza sativa L.*) is a fundamental staple crop worldwide, underpinning food security and rural livelihoods for billions of people. Cultivation spans approximately 165.04 million hectares across about 100 countries, reflecting its central role in global agriculture and nutrition. This prominence, along with the crop's diverse production systems—from flooded paddies to rainfed uplands—highlights the importance of optimizing nutrient management to sustain yields while protecting soil health and environmental quality (Sawargaonkar *et al* 2026). Phosphorus (P) deficiency remains one of the major constraints on plant growth and crop production worldwide. As a key macronutrient, phosphorus underpins critical biochemical and physiological processes, including energy transfer, nucleic acid synthesis (DNA and RNA), and the promotion of vegetative growth in rice as well as other cereals. Understanding P dynamics in soils and optimizing its management through soil testing and balanced fertilization is essential for sustaining yields, improving nutrient use efficiency, and safeguarding environmental health in diverse agroecosystems (Bird *et al* 2001). Phosphorus (P) is a fundamental macronutrient essential for plant growth and development. It is a key component of phospholipids and nucleotides, which form cellular membranes and genetic material, and it participates in critical physiological processes including membrane function, photosynthesis, respiration, glycolysis, redox reactions, and signal transduction. Phosphorus availability also influences plant–microbe interactions, particularly under P-deficient conditions, where signaling molecules and growth regulators coordinate adaptive responses. Understanding P dynamics and optimizing P nutrition through soil testing and balanced fertilization are therefore pivotal for sustaining crop productivity (Akiyama *et al* 2005). Fertilizer strategies that combine chemical nutrients with organic amendments (e.g., farmyard manure, FYM) and those based on soil-test–crop response (STCR) prescriptions aim to optimize P use efficiency and align nutrient supply with crop demand. Despite advances, the relationship between rice yield and soil P fractions under STCR-guided management remains underexplored in Vertisols, where high pH, calcareous substrates, and specific mineralogy modulate P fixation and release. This study investigates (i) how STCR-based nutrient regimens influence the distribution of soil P fractions in a rice–wheat rotation, (ii) how changes in Ca–P, Red–P, Fe–P, Al–P, Saloid–P, and RS–P correlate with grain yield, and (iii) the role of FYM in modulating these relationships. By integrating fractionation data with yield outcomes in a field experiment, the work aims to inform precise, sustainable nutrient management strategies that optimize yield while conserving soil P resources in Indian Vertisols.

Materials and Methods

Description and location of the study area

Raipur is the capital of Chhattisgarh state and it is situated in the center of Chhattisgarh at lies between 21^0 16'N latitude and 81^0 60'E longitude with altitude of 289.56 meters the mean sea level. The Instructional Farm, Indira Gandhi Agricultural University Raipur (C.G.) is situated on near to NH 6 in the eastern part of Raipur city and located between 20^0 4' North latitude and 81^0 39' East longitude with altitude of 293 m above mean sea level.

Physico-chemical properties of experimental soil

The study site features a clayey Vertisol with a texture comprising 26% sand, 28% silt, and 44% clay, which classifies it as a clayey Vertisol. The bulk density is 1.35 Mg m^{-3}. The soil exhibits an alkaline pH of 7.88 and electrical conductivity of 0.20 dS m^{-1} at 25°C. The organic carbon content is 0.47%,. Available nutrient pools are: nitrate–nitrogen 217.34 kg ha^{-1}, available phosphorus as P_2O_5 19.32 kg ha^{-1}, and available potassium as K_2O 498.05 kg ha^{-1}. Micronutrients show adequate to sufficient levels, with iron (Fe) 27.54 mg kg^{-1}, zinc (Zn) 11.57 mg kg^{-1}, copper (Cu) 2.57 mg kg^{-1}, and manganese (Mn) 3.25 mg kg^{-1}.

Experimental design and treatments

The field experiment was conducted on a Vertisol using a randomized block design with four replications and five rice treatments. The treatments were arranged to compare a non-fertilized control (T1) with a gradation of nutrient management and yield-target strategies: T2 (GRD) used a balanced NPK ratio of 100:60:40; T3 applied the STCR dose corresponding to a yield target of 5 t/ha; T4 employed the STCR dose corresponding to a yield target of 6 t/ha; and T5 used the STCR dose for 6 t/ha yield target combined with farmyard manure (FYM).

Collection, preparation and analysis of plant samples

Plant samples collection and preparation

Plant samples of rice collected at maturity just before the harvesting and were air dried. Plot wise grain and straw samples were grinded separately and used for the chemical analysis.

Plant sample analysis for N, P and K content

Total nitrogen content

Grinded samples of straw and grain were digested separately with 10 ml conc. H_2SO_4 and 3.0 gm mixture of K_2SO_4 and $CuSO_4$ salts (9:1). Total N were determine by micro Kjeldahl's method (using alkaline potassium permagnate).

Total Phosphorus and Potassium content

For the P and K analysis, 1.0 g plant materials were digested at 250ºC in a digestion chamber with 10 ml of di-acid mixture of HNO_3 and $HClO_4$ acids (ration of 9:4). The completion of digestion was confirmed when the liquid becomes colourless. After the digestion, the digested material was filtered and transferred in to a 100 ml volumetric flask and the volumes made up to the 100 ml by distil water. Aliquots of this diluted digest were used for the determination of P and K content.

Total P was determine by vanadomolybdate phosphoric acid yellow colour method at 420 nm (Jackson; 1967) and potassium was determine by using Flame-photometer from the extract obtained by the digestion.

Phosphorus Uptake

P uptake was calculated using the grain and straw yields and potassium content.

$$\text{Total P uptake (kg ha}^{-1}\text{)} = \frac{\text{Yields (kg ha}^{-1}\text{) x P content (\%)}}{100}$$

Phosphorus balance

Phosphorus balance sheet was calculated by total quantity of P removed by rice was subtracted from the sum of fertilizers nutrient applied and initially available soil status

Statistical analysis

The experimental data were analyzed by the software "OPSTAT". All the parameters were analyzed in a Randomized block design to list the variance of different treatments at 5 per cent level of significance.

Results and Discussion

Effect of nutrient management practices on Phosphorus balance in soil

Phosphorus uptake

The result on P uptake by rice is presented in Fig. 3.1. Results revealed that P uptake by rice grain, straw as well as their total significantly affected by different fertilizer P application. The P uptake in grain varied from 3.45 kg/ha in T1 (control) to 14.30 kg/ha T5 (YT 6t ha^{-1} +FYM). The highest grain P uptake was noticed in T5 (YT 6t ha^{-1} +FYM) followed by T4 (YT6t/h), T2 (GRD), and lowest in T1 (control) treatment. Rice straw P uptake also followed the similar trend as with that of grain P uptake. All the plots receiving either chemical fertilizer alone or in combination with organics significantly increased P uptake over the control. It is evident from the data that the total P uptake also followed the similar trend as rice grain and straw since the total P uptake is their sum total. It is varied from 4.01kg/ha to 17.49 kg/ha in T1and T5, respectively. P uptake is the multiple of yield and P content and hence the trends of P uptake followed the yield trends. Similar results found in Sharma (2005), Prakash (2012), Nagumo *et al* (2013).

Phosphorus Balance

Phosphorus balance was estimated by total quantity of P removed by rice deducted from the sum total of fertilizers P applied and initially available soil status. Results presented in Fig 3.2 show the P balance in relation to nutrient management practices. P balance estimated were found in the range from 6.13 to 25.4 kg/ha among different treatments. Positive balance showed nutrients build up in soil whereas the negative balance showed depletion of nutrition from the soil. The estimation of P balance is necessary for sustainable management of P fertilization. This is because the application of low P fertilizer can lead to a negative balance results decreased soil fertility, yield and profitability of system resources. Initially soil P was high in GRD (25.4kg/ha) followed by YT 6t/ha+ FYM (24.36kg/ha) and lowest in control (6.13kg/ha) treatment. The P uptake by crop was higher in T5 YT 6t/ha+ FYM (17.49 kg/ha) followed by T4 YT 6t/ha (16.16kg/ha) and lowest in control (4.01kg/ha) treatment. The P balances in soil varied from 2.12 kg/ha in T1 (control) to 37.17 kg/ha in T2 (GRD). Phosphorus balance in soil after the harvesting of rice was positive. The highest positive balance was observed in T2 GRD (37.17 kg ha-1) followed by T4 YT 6t ha-1 (14.78 kg ha-1), T5 YT6t/ha with FYM (11.58kg ha-1) and lowest positive balance in control (2.12kg/ha). The results were in conformity with the findings of Sharma (2005), Barla (2006), Chaudhary (2007).

Chart.1 Effect of nutrient management practices on phosphorus uptake.

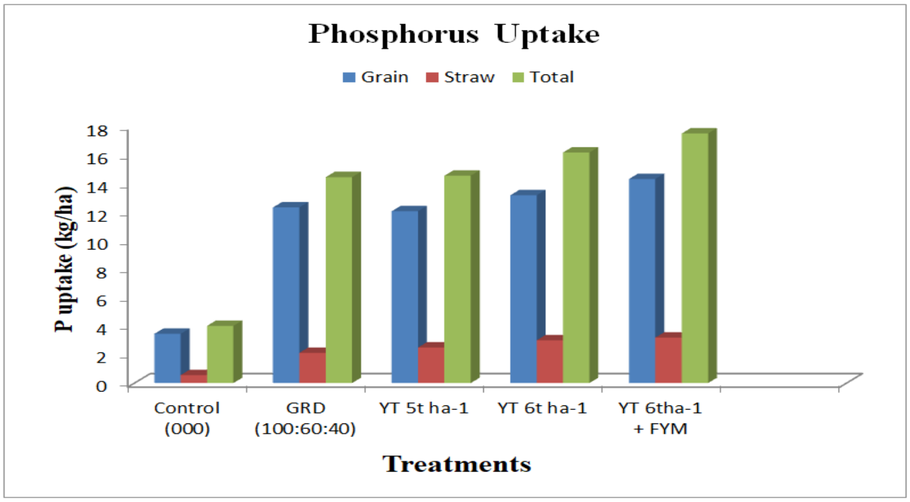


Chart.2 Effect of nutrient management practices on Phosphorus balance in soil

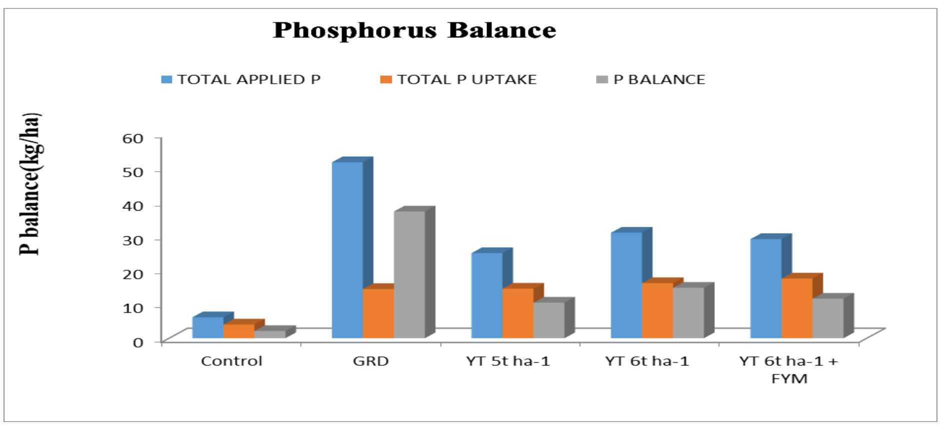


Chart.3 Rice grain yield response to Available-P

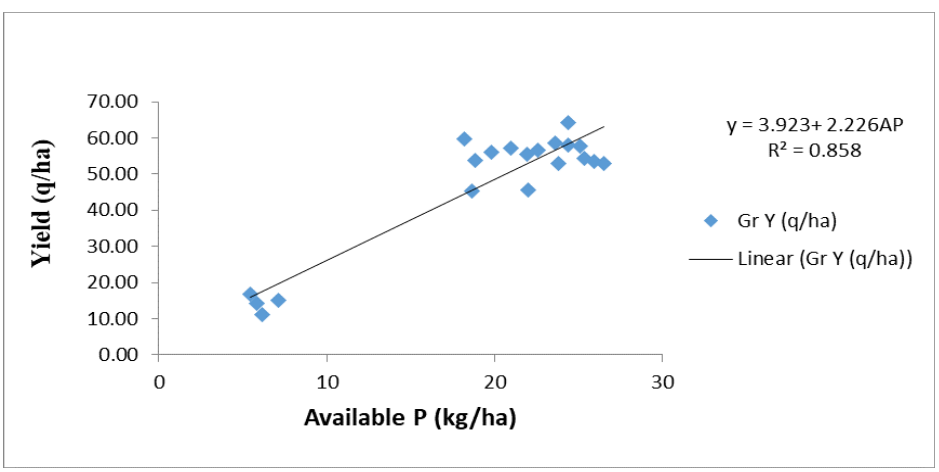


Chart.4 Rice grain yield response to Saloid-P

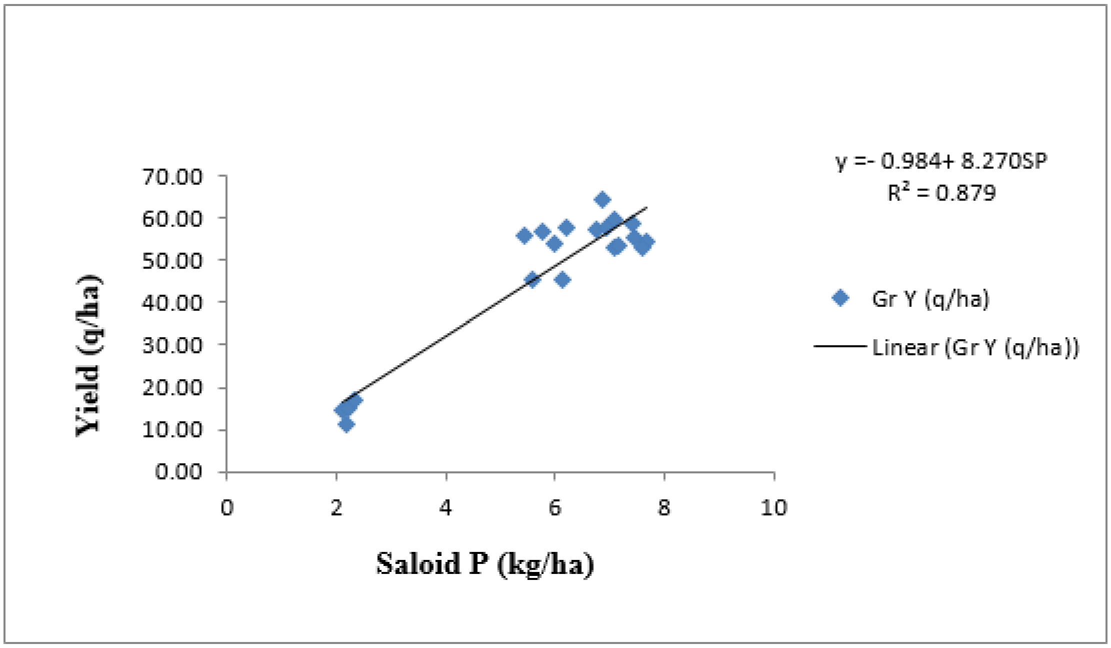


Chart.5 Rice grain yield response to Al-P

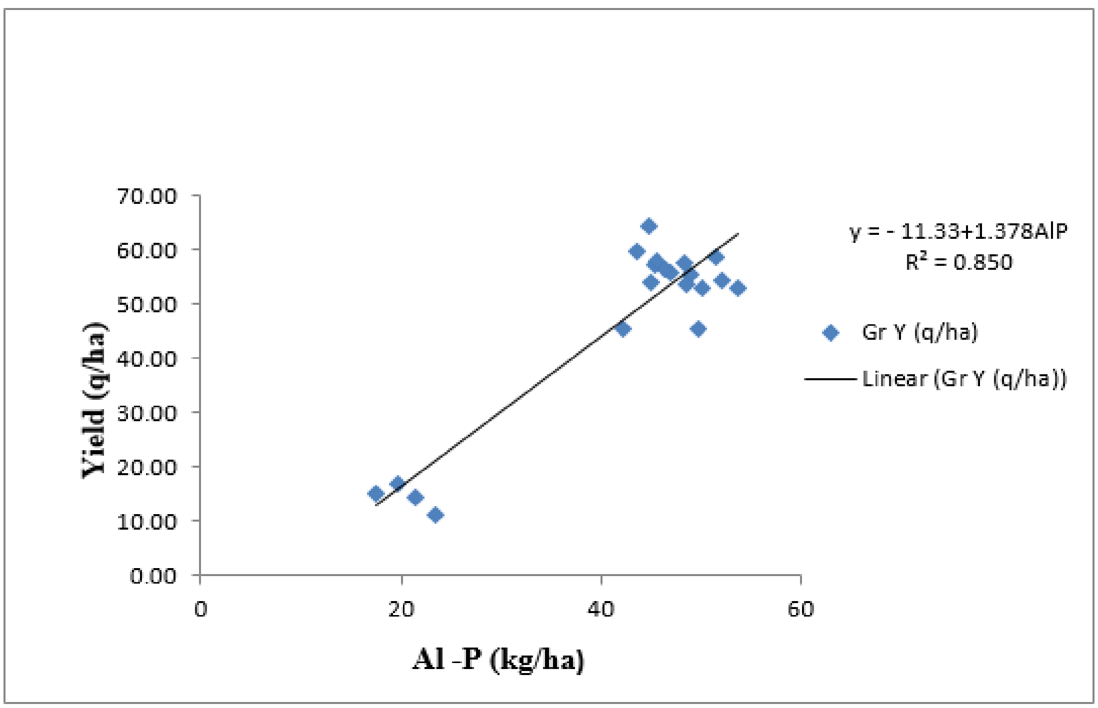


Chart.6 Rice grain yield response to Red-P

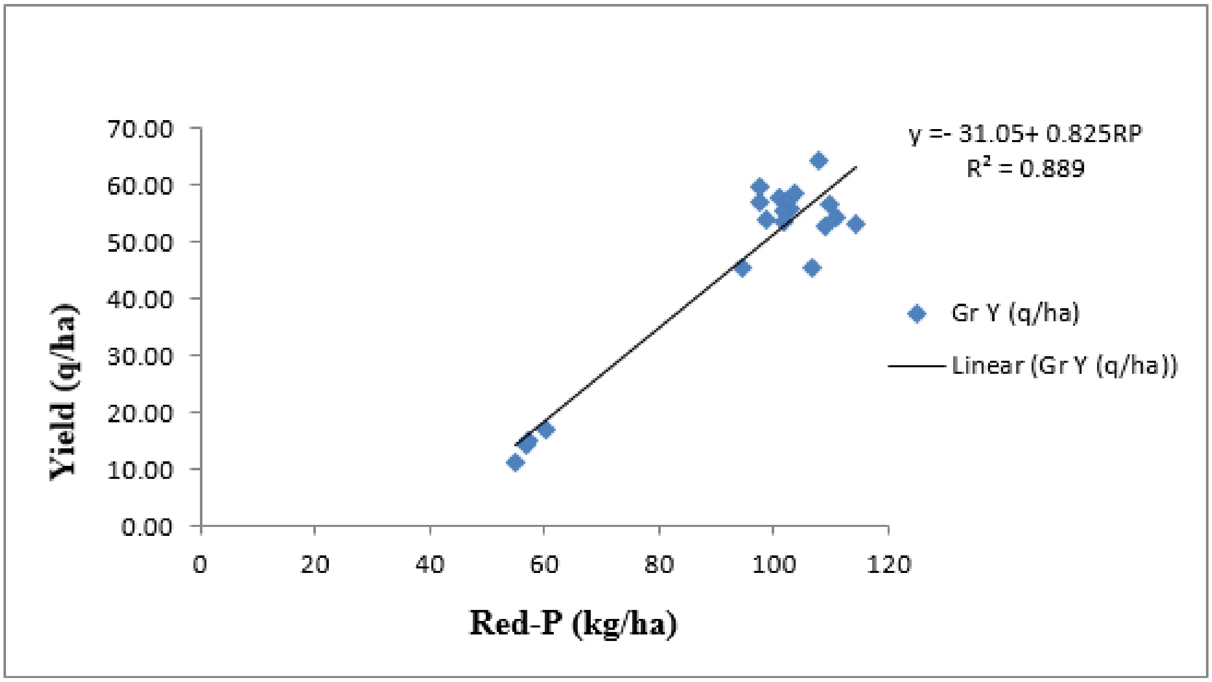


Chart.7 Rice grain yield response to Fe-P

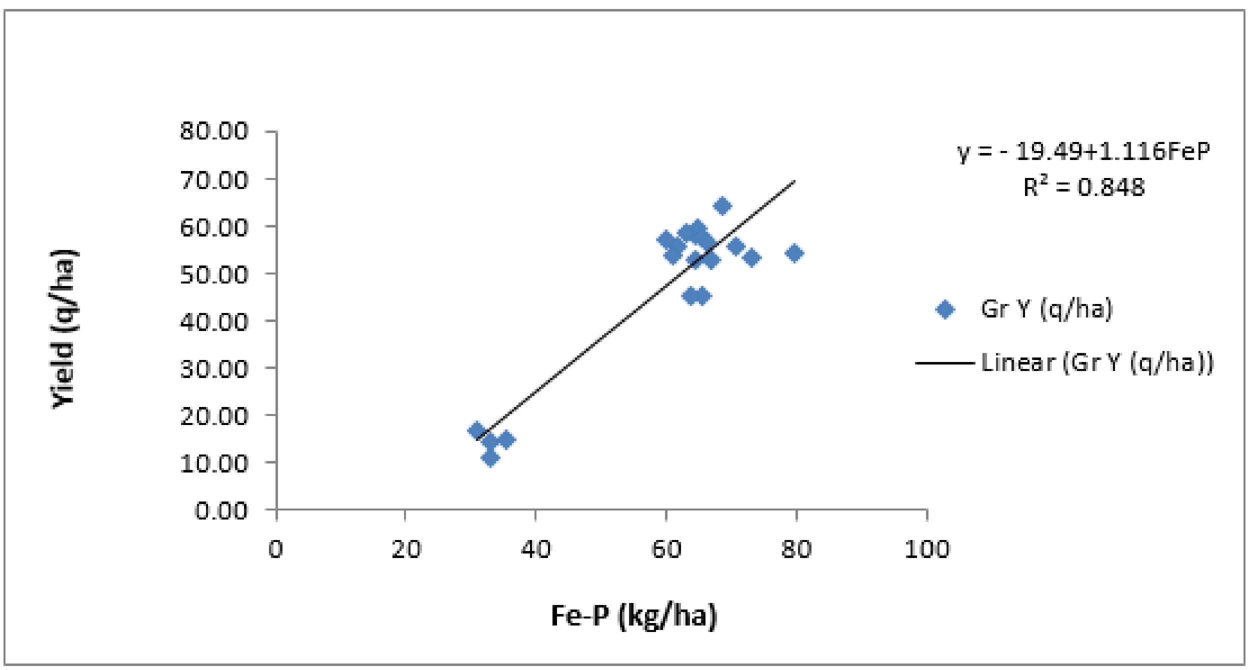


Chart.8 Rice grain yield response to Ca-P

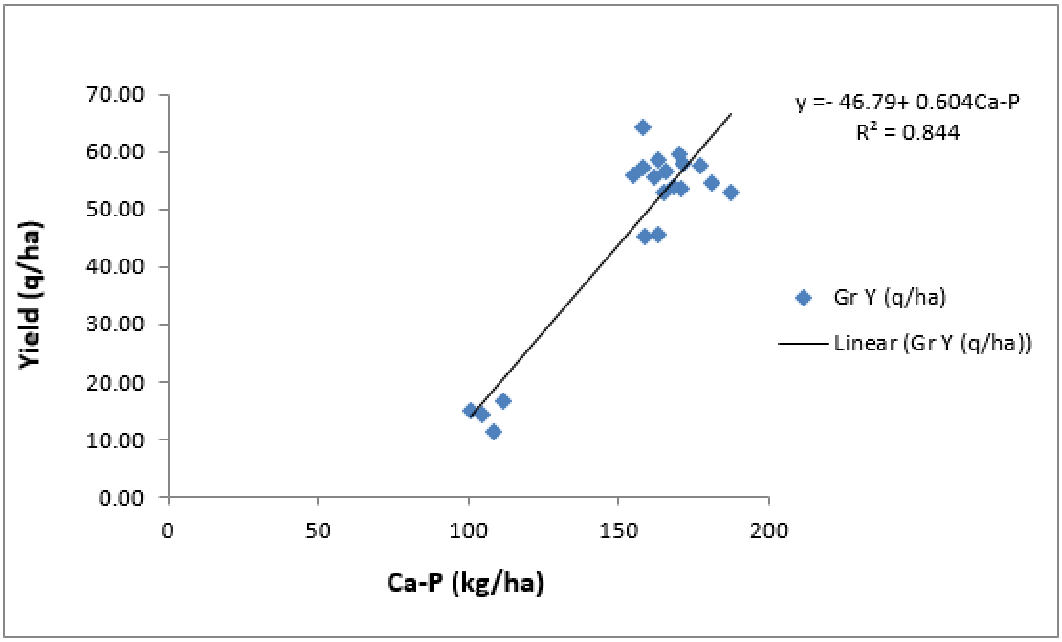
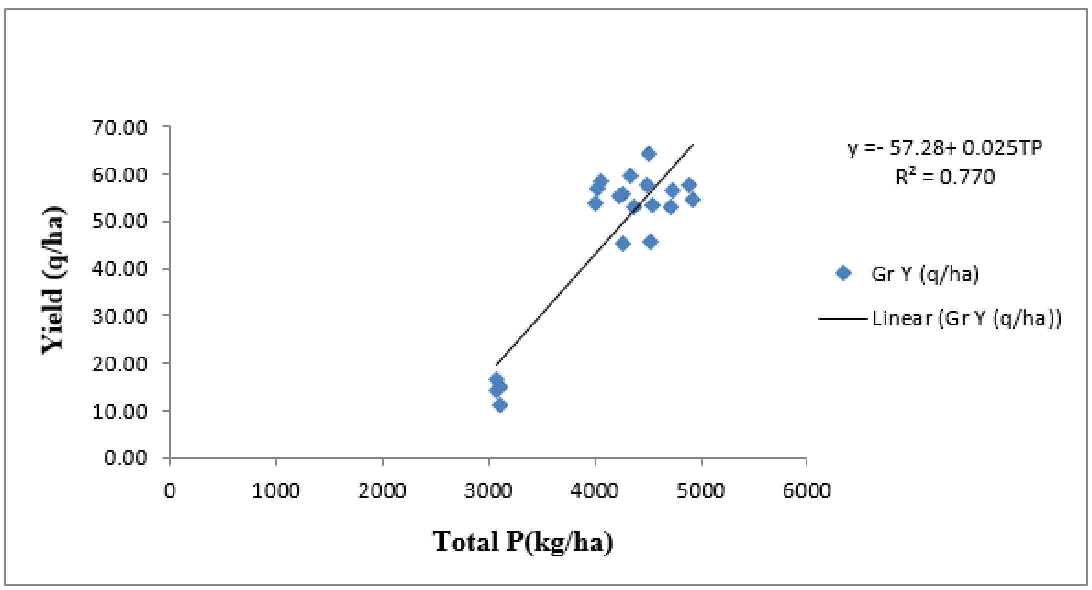


Chart.9 Rice grain yield response to Total-P



Relationship between rice yield and P fractions

The relationship between rice yields and P fractions as independent variables were derived by regression analysis to yield variations due to various fractions and presented in figures 3.3 to 3.9. Results indicated that the large proportions of yield variations were accounted for Red-P fractions.

Among different P fractions, Red-P was the most important P fractions contributing toward grain yield with 'R^2'values 0.88. A critical examination of this equation indicated that Red-P was the most important variable computed to the yield variation observed by regression analysis. Reductant soluble P or occluded P is highly insoluble and this fraction is very important for rice soil under submergence. The R^2 value indicated that about 88% variations in grain yield were attributed only to this fraction of P. The second most important variable was Saloid-P in (87%) followed by Available-P (85.8%) and lowest in Total-P (77%). Similar results found in Verma (2002), Sepehya (2011).

In Conclusion, this study demonstrates that nutrient management, particularly STCR-based fertilizer prescriptions with or without FYM, markedly influences phosphorus (P) dynamics in a rice–wheat system and drives corresponding yield responses. Regression analyses indicated that P fractions, especially Red-P, explain a substantial portion of yield variation, highlighting the pivotal role of readily available P pools in sustaining rice productivity under flooded Vertisol conditions. Among P fractions, Red-P emerged as the most influential predictor of grain yield, followed closely by Saloid-P and available P, while Total-P showed comparatively weaker association. Treatments incorporating targeted P doses to achieve higher yield targets (e.g., 6 t/ha with FYM) enhanced P uptake in grain and straw and elevated soil P reserves (Ca–P, Red–P, Fe–P, Al–P, RS–P), contributing to improved nutrient use efficiency and potential long-term soil fertility. FYM generally augmented yield and P pools, though the magnitude of FYM–fertilizer interactions depended on the underlying fertilization regime.

Acknowledgements

The authors gratefully acknowledge the facilities and support provided by Indira Gandhi Krishi Vishwavidyalaya (IGKV), Raipur. We thank the Department of Soil Science and Agricultural Chemistry for enabling long-term field trials and for access to experimental plots and data management. Special thanks are due to the field staff and technicians at IGKV, Raipur, for their meticulous assistance in plot preparation, sample collection, and routine laboratory analyses. We also acknowledge the contributions of colleagues in the lab.

Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Author Contributions

Swati Sahu: formal analysis, methodology, writing–original draft; Lalit Kumar Srivastava: conceptualization, data curation, formal analysis, methodology, writing – original draft. Anusuiya Panda: formal analysis, data curation, methodology, writing – original draft, Vinay Bachkaiya: formal analysis, writing – original draft.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

References

Akiyama, K.; Matsuzaki, K.-I.; Hayashi, H. Plant sesquiterpenes induce hyphal branching in arbuscular mycorrhizal fungi. Nature 2005, 435, 824–827.

Barla, S. *Integrated Nutrient Management In Rice-Wheat Cropping System* (Doctoral dissertation, Birsa Agricultural University; Ranchi).

Bird J. A., Horwath W. R., Eagle A. J., Van Kessel C. 2001. Immobilization of fertilizer nitrogen in rice: effects of straw management practices. Soil Sci. Soc. America 65, 1143–1152.

Chang, S.C. and Jackson, M.L. 1957. Fractionation of soil phosphorus. Soil Science 84:133-144.

Choudhary, M. 2007. *Studies on Integrated Phosphorus Management in Maize (Zea mays L.) on Typic Haplustept* (Doctoral dissertation, Maharana Pratap University of Agriculture and Technology).

Nagumo, T., Tajima, S., Chikushi, S., & Yamashita, A. 2013. Phosphorus balance and soil phosphorus status in paddy rice fields with various fertilizer practices. *Plant Production Science*, *16*(1), 69-76.

Prakash Bhanu, M. *Response of low land rice (oryza sativa l.) to nitrogen and phosphorus levels in alfisols* (doctoral dissertation, acharya ng ranga agricultural university rajendranagar, Hyderabad).

Sawargaonkar, G.L., Rakesh, S., Kale, S., Kamdi, P.J., Karanam, P., Pasumarthi, R., Choudhari, P., Singh, A., Patil, M., Murali, G. and Singh, R., 2026. Regenerative Rice Farming for Sustaining Productivity, Reducing Energy Demand, and Methane Emissions in India: A Comprehensive Review. Results in Engineering, p.109197.

Sepehya, S. 2011. Long-term effect of integrated nutrient management on dynamics of nitrogen, phosphorus and potassium in rice-wheat system.

Sharma SP, Singh MV, Subehia SK, Jain PK, Kaushal V and Verma TS. 2005. *Long term effect of fertilizer, manure and lime application on the changes in soil quality, crop productivity and sustainability of maize-wheat system in alfisol of North Himalaya*. Research Bulletin No.2. AICRP on Long-term Fertilizer Experiments, IISS, Bhopal (M.P) and Department of Soils, CSK HPKV, Palampur, H.P. pp 1-88

Verma S. 2002. Studies on long-term effects of chemical fertilizers and amendments on phosphorus dynamics and its budgeting in wet temperate zone soils of Western Himalayas. *M.Sc. Thesis*, Department of Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, India

How to cite this article:

Swati Sahu, Lalit Kumar Srivastava, Anusuiya Panda and Vinay Bachkaiya. 2026. Correlation Between Rice Yield and Soil Phosphorus Fractions under STCR-Based Nutrient Management. *Int.J.Curr.Microbiol.App.Sci.* 15(1): 246-254. **doi:** https://doi.org/10.20546/ijcmas.2026.1501.030