

RICE GENOTYPING VARIATION FOR PHOSPHORUS HARVEST INDEX AND UTILIZATION EFFICIENCIES

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ABSTRACT

A field experiment was conducted during kharif 2015 at the research farm of the ICAR–Indian Institute of Rice Research, Hyderabad, to evaluate the response of 30 rice genotypes to four phosphorus levels, viz., P0 (control), P20, P40 and P60. The experiment was conducted in a randomized block design with three replications. Varieties with high PUE under P0/P20 are ideal for resource-poor farmers and sustainable agriculture. Genotypes with high PHI under moderate phosphorus are valuable for improving grain nutrient content and yield stability. The study reveals that low to moderate phosphorus supply enhances utilization efficiency and harvest index, while higher doses reduce efficiency due to nutrient dilution. Varieties such as MAHSURI, KRH2, TRIGUNA, RP BIO226, and SUGANDHAMATI are promising for cultivation under phosphorus-limited conditions, as they combine high PUE with favorable PHI. At higher phosphorus levels (P40, P60), PHI declined sharply, indicating reduced efficiency of phosphorus allocation to grain. The CV values (12–17%) suggest moderate variability among genotypes. LSD (1%) values confirm significant differences among varieties, especially at lower phosphorus levels (P0, P20). Substantial differences in PUE and PHI highlight genetic diversity in phosphorus efficiency. Mahsuri, RP Bio226, KRH2, Triguna, PA6444 consistently performed well, suggesting potential as donor parents in breeding programs for phosphorus-efficient rice.

KEYWORDS: Rice, phosphorus, genotypic variation, PUE, PHI

INTRODUCTION

Phosphorus (P) is one of the most critical macronutrients for rice, influencing root development, tillering, grain formation, and overall yield. Despite its importance, phosphorus availability in soils is often limited due to fixation, leaching, and imbalanced fertilizer use. This makes phosphorus management central to sustainable rice production, especially in regions with resource-poor farmers. Phosphorus management in rice is not merely a question of yield but of sustainability, equity, and environmental stewardship. By combining genetic improvement, agronomic innovation, and policy support, rice cultivation can move toward a future where productivity is maintained with minimal ecological footprint. The challenge lies in balancing uptake efficiency with nutrient partitioning, ensuring that rice remains both a staple food and a model for sustainable agriculture. Plants have evolved several mechanisms to adapt to P deficiency. These mechanisms include improved P acquisition through changes in root morphology, root exudation and P uptake processes, as well as improved P utilization within plant tissues. Considerable genetic variation exists among crop genotypes for these mechanisms, making the identification of P-efficient genotypes an important component of sustainable nutrient management. Rice is moderately sensitive to P deficiency, and substantial variation exists among rice genotypes in their ability to tolerate low-P conditions. Phosphorus application can improve biomass production, tillering and P uptake and can influence several yield-related traits. Efficient genotypes can reduce fertilizer dependency, lower costs, and minimize environmental impacts. Rice genotypes differ significantly in phosphorus utilization and partitioning efficiency. Therefore, the present study was undertaken to evaluate the response of different rice genotypes to varying levels of phosphorus and to identify genotypes showing superior performance for phosphorus harvest index and utilization efficiencies under contrasting P levels.

MATERIALS AND METHODS

Experimental site

The field experiment was conducted during kharif 2015 at the research farm of the ICAR–Indian Institute of Rice Research (IIRR), Rajendranagar, Hyderabad, Telangana, India. The experimental site was located at 17°19' N latitude

and 78°23' E longitude. The study was conducted under field conditions to evaluate the response of rice genotypes to different phosphorus levels.

Weather conditions

The climate of the experimental site is subtropical, with rainfall mainly received from the southwest monsoon during June to October. Weather observations during the crop-growing period were obtained from the meteorological observatory at the Agricultural Research Institute, Rajendranagar. During the experimental period, mean maximum temperature ranged from 28.4 to 34.8°C, with an average of 31.8°C, whereas mean minimum temperature ranged from 17.4 to 24.4°C, with an average of 21.7°C. Mean relative humidity ranged from 70.7 to 96.0%, with an average of 87.8%. Total rainfall during the crop-growth period was 393.8 mm over 28.5 rainy days. Mean sunshine duration ranged from 1.7 to 8.9 h day⁻¹, while mean evaporation ranged from 2.5 to 7.3 mm day⁻¹.

Initial soil characteristics

Before establishing the experiment, representative soil samples were collected from the experimental field and analyzed for their physical and chemical properties. The soil was classified as sandy clay loam, with 40% sand, 25% silt and 35% clay. The bulk density was 1.45 Mg m⁻³. The soil was alkaline (pH 8.01) and non-saline, with an electrical conductivity of 0.27 dS m⁻¹. Soil organic carbon was 0.44%. Available nitrogen and phosphorus were 253 and 10.95 kg ha⁻¹, respectively, and were classified as low, whereas available K₂O was 370 kg ha⁻¹ and was classified as high. Available sulphur was also low (6 mg kg⁻¹). Available Ca, Mg, Fe, Zn, Cu and Mn were reported as high in the experimental soil.

Experimental design and treatments

The experiment was conducted using a randomized block design (RBD) with three replications. The plot size was 35 m × 10 m (350 m²), with a 1.4-m fallow strip surrounding the experimental plots. Four phosphorus treatments were evaluated: control (P0), 33% recommended dose of phosphorus (P20), 66% recommended dose of phosphorus (P40), and 100% recommended dose of phosphorus (P60).

Plant material

Thirty rice genotypes were evaluated in the experiment: AKSHAYADHAN, VASUMATHI, SUGANDHAMATI, T. HAMSA, VARDHAN, VIKAS, TULASI, MAHSURI, MTU1010, RPBIO226, IR64, VANDANA, RASI, KASALATHA, SWARNA, BPT5204, KRH2, IET24036, RAVI, IET24003, TRIGUNA, SAMPADHA, DRRH3, ADITHA, PA6444, PR133, RNR15048, INH10001, INH10002 and INH12013.

Phosphorus

Digestion of the plant samples: For nutrients other than N, the plant material can be digested in a diacid mixture or a triacid mixture or dry ashed and dissolved in acid.

Phosphorus Uptake

Phosphorus uptake was calculated using the grain and straw yields and phosphorus content.

$$\text{Total P uptake (kg ha}^{-1}\text{)} = \frac{\text{P content (\%)} \times \text{Dry matter production (kg ha}^{-1}\text{)}}{100}$$

Phosphorus Use Efficiency (PUE)

The broadest measure of PUE is the ratio of yield to the amount of applied P, of applied P, which declines with increasing P application rates and expressed in terms of kg grain produced per kg nutrient uptake.

$$\text{PUE (kg kg}^{-1}\text{ P)} = \frac{\text{Grain yield}}{\text{Amount of (Fertilizer) P applied (kg/ha)}}$$

Harvest index

It is the proportion of total dry matter represented by economic yield as suggested by Donald and Humblin (1962).

$$\text{Harvest Index} = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Biological yield (Grain + Straw) (kg ha}^{-1}\text{)}}$$

Observations and statistical analysis

Observations were recorded for plant height, effective tillers, panicle length, test weight and grain yield. Treatment means and genotypic differences were compared using the reported standard error and least significant difference (LSD) at the 1% probability level. Coefficients of variation (CV) were also calculated to assess variability in the experimental observations.

RESULTS AND DISCUSSIONS

P Utilization Efficiency (PUE %): PUE ranged widely across varieties and phosphorus levels. At P0 (no phosphorus), values were highest in MAHSURI (82.82%), RPBIO226 (80.40%), KRH2 (81.14%), and TRIGUNA (81.72%). At P20, SUGANDHAMATI (64.85%) and IR64 (61.45%) recorded superior values. At P40, VASUMATHI (56.55%) and RNR15048 (57.25%) were notable. At P60, VARDHAN (56.70%) and INH10001 (51.60%) showed relatively higher efficiency. The mean PUE across treatments was 65.41% at P0, declining to 38.93% at P60, indicating reduced efficiency with higher phosphorus supply. The highest PUE values were observed under low or no

phosphorus application (P0, P20), reflecting the ability of certain varieties (MAHSURI, KRH2, TRIGUNA, RPBIO226) to efficiently utilize limited phosphorus. As phosphorus supply increased (P40, P60), efficiency declined, suggesting luxury consumption and reduced utilization efficiency. Genotypes such as MAHSURI, KRH2, TRIGUNA, and RPBIO226 consistently maintained high PUE under low P conditions, indicating strong adaptation to phosphorus-deficient soils. Conversely, varieties like VANDANA and SWARNA showed lower efficiency, reflecting weaker nutrient utilization capacity. Earlier these finding are reported by Brajendra et al. (2012), Caon et al. (2017), Gorlapalli et al. (2022), Kale et al. (2020), Vishwakarma et al. (2023) and Parmar et al. (2026),

Phosphorus Harvest Index (PHI): PHI values were highest in SUGANDHAMATI (76.85% at P0), SWARNA (76.50% at P20), and KRH2 (77.75% at P20). At P40, VASUMATHI (56.55%) and RNR15048 (57.25%) recorded superior PHI. At P60, VARDHAN (56.70%) and INH10001 (51.60%) were notable. The mean PHI was 61.32% at P0, 66.76% at P20, 47.03% at P40, and 38.93% at P60, showing a decline with higher phosphorus levels. PHI trends mirrored PUE, with higher values under low phosphorus supply. Varieties like SUGANDHAMATI, SWARNA, and KRH2 demonstrated superior partitioning of absorbed phosphorus into seeds, highlighting their efficiency in nutrient allocation. Declining PHI at higher phosphorus levels suggests that excess P was retained in stover rather than translocated to grains. Earlier these finding are reported by Kale et al. (2021), Kumar et al. (2014), Parmar et al. (2022), Rathod et al. (2021), Sharma et al. (2022) Sahoo et al. (2022), and Sawant et al. (2026).

Phosphorus Supply Response:

Efficiency was highest under low phosphorus (P0, P20), declining with higher doses (P40, P60). This indicates that many genotypes are adapted to low-input conditions, but excess phosphorus reduces efficiency due to luxury consumption and poor partitioning. Some varieties (e.g., Sugandhamati, Swarna, KRH2) maintained high PHI even when PUE declined, showing better nutrient allocation to grain. Others (e.g., Mahsuri, RP Bio226) excelled in PUE but showed moderate PHI, suggesting strong uptake but less efficient partitioning. Across varieties, PUE under P0 (no phosphorus) ranged from 46.33% (Akshayadhan, INH12013) to 82.82% (Mahsuri), with a mean of 65.41%. At P20, efficiency declined in most varieties, averaging 52.96%, though some genotypes (Sugandhamati, IR64, PA6444) maintained relatively higher values. At P40 and P60, PUE further decreased (mean 47.03% and 38.93%, respectively), indicating diminishing efficiency with higher phosphorus supply. High PUE performers across treatments included Mahsuri, RP Bio226, KRH2, Triguna, PA6444, and IR64, suggesting inherent efficiency in phosphorus uptake and utilization. PHI values were generally higher than PUE, with means of 61.32% (P0), 66.76% (P20), but declining at P40 (47.03%) and P60 (38.93%). Varieties like Sugandhamati, Swarna, KRH2, PA6444, DRRH3 showed superior PHI under moderate phosphorus (P20), reflecting better partitioning of absorbed phosphorus into grain. Trade-off between phosphorus utilization efficiency (PUE) and phosphorus harvest index (PHI) in rice genotypes under varying phosphorus levels (P0–P60). High PUE genotypes (e.g., Mahsuri, RP Bio226, KRH2, PA6444) excel in uptake efficiency, while high PHI genotypes (e.g., Sugandhamati, Swarna, DRRH3) demonstrate superior partitioning efficiency. The central “trade-off zone” highlights the balance between uptake and allocation strategies. Earlier these finding are reported by Srilatha et al. (2019), Tuli et al. (2022), Sharma et al. (2020), Indoria et al. (2024), Parmar et al. (2023) and Sawant et al. (2023)

CONCLUSION:

Phosphorus utilization efficiency and harvest index varied significantly across varieties and phosphorus levels. Efficiency was highest under low P conditions, with MAHSURI, KRH2, TRIGUNA, RPBIO226, and SUGANDHAMATI emerging as superior performers. These genotypes demonstrate strong potential for sustainable cultivation in phosphorus-deficient soils, emphasizing the importance of varietal selection in nutrient management strategies. Excess phosphorus (P40, P60) not only reduced efficiency but also increased variability among genotypes, underscoring the need for site-specific phosphorus management. Mahsuri, RP Bio226, KRH2, Triguna, and PA6444 emerged as promising candidates for phosphorus-efficient breeding. Moderate phosphorus application (P20) optimizes PHI, while low-input conditions highlight genotypes with superior PUE. These findings support sustainable nutrient management and genetic improvement strategies in rice.

Table-1 Effect of different phosphorus levels on P utilization efficiency and PHI of rice genotypes under field conditions

Variety	P utilization efficiency (%)				PHI			
	(P0)	(P20)	(P40)	(P60)	(P0)	(P20)	(P40)	(P60)
AKSHAYADHAN	46.33	52.55	47.55	33.30	59.05	72.00	47.55	33.30
VASUMATHI	73.36	46.45	56.55	34.55	62.35	67.30	56.55	34.55
SUGANDHAMATI	56.70	64.85	49.20	42.60	76.85	73.60	49.20	42.60
T.HAMSA	69.02	51.20	34.20	34.00	70.10	67.85	34.20	34.00

VARDHAN	66.86	53.85	38.55	56.70	55.85	53.05	38.55	56.70
VIKAS	74.19	48.95	39.35	35.75	60.10	68.35	39.35	35.75
TULASI	52.38	55.55	55.50	30.65	60.50	71.10	55.50	30.65
MAHSURI	82.82	43.80	47.95	37.95	66.25	69.80	47.95	37.95
MTU1010	54.84	59.30	43.60	39.90	51.30	67.60	43.60	39.90
RPBIO226	80.40	46.40	54.20	32.90	72.00	67.75	54.20	32.90
IR64	76.13	61.45	59.35	40.00	38.80	69.75	59.35	40.00
VANDANA	65.20	44.90	29.20	34.85	68.15	64.95	29.20	34.85
RASI	61.81	56.25	48.20	45.10	53.80	70.05	48.20	45.10
KASALATHA	59.23	48.25	52.75	45.35	68.45	65.90	52.75	45.35
SWARNA	52.38	45.55	34.90	32.60	66.80	76.50	34.90	32.60
BPT5204	60.40	45.00	50.70	31.90	69.75	64.60	50.70	31.90
KRH2	81.14	48.15	55.60	43.70	63.75	77.75	55.60	43.70
IET24036	59.14	57.35	31.20	38.80	56.50	61.70	31.20	38.80
RAVI	71.97	46.95	48.50	34.50	51.80	64.80	48.50	34.50
IET24003	54.39	49.40	48.15	43.60	58.00	67.90	48.15	43.60
TRIGUNA	81.72	58.60	54.55	36.50	57.25	69.15	54.55	36.50
SAMPADHA	64.19	59.25	43.60	40.95	56.80	60.15	43.60	40.95
DRRH3	79.50	51.75	52.50	30.55	64.00	75.80	52.50	30.55
ADITHA	50.78	61.70	44.20	38.95	55.60	55.20	44.20	38.95
PA6444	80.16	61.30	50.45	46.55	68.55	73.85	50.45	46.55
PR133	55.82	62.15	41.85	35.20	57.80	48.80	41.85	35.20
RNR15048	69.06	45.55	57.25	43.65	63.20	62.70	57.25	43.65
INH10001	59.30	60.15	45.00	51.60	55.50	61.05	45.00	51.60
INH10002	76.75	49.65	55.05	39.30	71.80	61.80	55.05	39.30
INH12013	46.33	52.55	41.35	35.95	59.05	72.00	41.35	35.95
Mean	65.41	52.96	47.03	38.93	61.32	66.76	47.03	38.93
CV (%)	17.38	12.04	17.07	15.94	12.78	10.07	17.07	15.94
SE(d)	2.94	1.65	2.07	1.6	2.02	1.74	2.07	1.6
LSD (1%)	7.71	4.32	5.44	4.21	5.32	4.56	5.44	4.21

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