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Effect of Varieties, Planting Densities and Phosphorus Levels on Seed Yield and Post-Harvest Soil Physico-Chemical Properties of Rice Fallow Redgram

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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

Aim: To assess the effect of varieties, planting densities and phosphorus levels on yield and physico-chemical properties of post -harvest soil in rice fallow redgram.

Study Design: The experiment was laid out in strip-split plot design with three varieties as vertical factor *viz*., V_1: ICPV-21333, V_2: ICPV-21444 and V_3: ICPV-; two levels of spacings viz., P_1: 0 kg P_2O_5 ha^{-1}, P_2: 25 kg P_2O_5 ha^{-1}, P_3: 37.5 kg P_2O_5 ha^{-1} and P_4: 50 kg P_2O_5 ha^{-1}.

Place and Duration of Study: RL 12, block 3 and 4, International Crops Research Institute for Semi-Arid Tropics (ICRISAT), Patancheru, Hyderabad, during *rabi*, 2022-23 and 2023-24.

Methodology: The investigation consisted of three varieties as vertical factor, two levels of spacing as horizontal factor and four levels of phosphorus as sub-plots with a total of 24 treatment combinations and replicated thrice. Data recorded on various parameters was subjected to scrutiny by ANOVA technique for split plot design concept. Data was subjected to analysis of variance procedures as outlined for strip-split plot design.

Results: From this investigation, it was found that seed yield was significantly higher with the variety ICPV-21333 (812 and 750 kg ha^{-1}), but remained statistically comparable to ICPV-21444. Among the spacings, it was highest with 30 cm x 10 cm (792 and 740 kg ha^{-1}) and with respect to phosphorus levels, crop fertilized with 50 kg P_2O_5 ha^{-1} registered higher seed yield (797 and 740 kg ha^{-1}) but, was statistically at par with 37.5 kg P_2O_5 ha^{-1}. Available post- harvest soil N, and K_2O was not influenced by the various treatments, but available P_2O_5 was significantly influenced by phosphorus levels. Higher available P_2O_5 was observed with the application of 50 and 37.5 kg P_2O_5 ha^{-1} kg P_2O_5 ha^{-1}, while the lowest status was noticed with 0 kg P_2O_5 ha^{-1}. Similarly, bulk density, pH, EC and OC were not significantly influenced by varieties, spacings and phosphorus levels and due to their interaction during both the years of study.

Keywords: Rice fallow redgram; varieties; planting densities; phosphorus levels; yield; soil physico-chemical properties.

1. INTRODUCTION

In India, rice cultivation is spread over 46.5 million hectares [1] with various cropping systems across irrigated and rainfed areas. Rice fallows, approximately 18 mha, offer potential for pulse crop expansion [2]. Historically, blackgram and green gram were cultivated in rice fields, but due to yellow mosaic virus infestation, farmers turned to maize and sorghum [3]. However, this cereal-cereal cropping system exhausts soil fertility. Cultivating rice fallow pulses can enhance soil health by fixing nitrogen, reducing the need for synthetic fertilizers, which mitigates greenhouse gas emissions. This practice also promotes carbon sequestration in the soil, contributing to climate change mitigation. Introducing pulse crops, like redgram, after rice harvest can restore soil health while ensuring sustained yields.

Redgram, a vital pulse crop in India, especially in Telangana, enriches soil with its nitrogen-fixing properties and is essential for subsistence agriculture. Traditionally a *kharif* crop, it faces challenges like natural calamities and pod borer attacks. To expand cultivation, new niches like *rabi* cropping in areas with mild winters have been explored. Redgram's adaptation depends on temperature, photoperiod and thermal conditions, being a short-day species with late-maturing genotypes sensitive to photoperiod. This sensitivity can lead to delayed flowering and maturity, causing terminal drought and impacting yields. New cultivars, maturing in less than 100-120 days, are photo and thermo insensitive, allowing year-round cultivation [4]. Non-traditional areas like rice fallows show great potential for redgram cultivation. These cultivars, grown across various latitudes and altitudes, need optimal spacing due to compact growth. Additionally, redgram's minimal response to phosphorus fertilizer, due to its deep root system and symbiosis with VAM fungi [5] helps in utilizing iron-bound phosphorus, which enhances uptake efficiency. So, cultivating redgram in rice fallows improves phosphorus utilization and soil health, promoting sustainable agriculture, though further research is needed to optimize these practices.

2. MATERIALS AND METHODS

Based on the above background, a field experiment was carried out at RL 12, block 3 and 4, International Crops Research Institute for Semi-Arid Tropics (ICRISAT), Patancheru, Hyderabad, during rabi, 2022-23 and 2023-24. The field is geographically located at an altitude of 545 m above the mean sea level (MSL), 17º 52´ N latitude and 78º 28´ E longitude and falls under the Southern Zone of Telangana State. Experimental soil was sandy loam in texture, slightly alkaline in reaction with pH of 7.8 and EC of 0.37 dSm^{-1}. The soil was low in organic carbon (0.40 %) and available N (153.9 kg ha^{-1}), high in available P_2O_5 (66.8 kg ha^{-1}) and available K_2O (340.5 kg ha^{-1}).

The experiment was laid out in strip-split plot design with three varieties as vertical factor *viz*., V_1: ICPV-21333 (Early duration, indeterminate growth), V_2: ICPV-21444 (Mid-early, indeterminate growth) and V_3: ICPV-21777 (Super early, determinate growth); two levels of spacings as horizontal factor viz., S1: 30 cm x 10 cm and S2: 45 cm x 10 cm; four levels of phosphorus as sub plots *viz*., P_1: 0 kg P_2O_5 ha^{-1}, P_2: 25 kg P_2O_5 ha^{-1}, P_3: 37.5 kg P_2O_5 ha^{-1} and P_4: 50 kg P_2O_5 ha^{-1}. The seed was treated with thiram @ 3 g kg^{-1} seed, followed by the application of phosphobacteria and rhizobium cultures. The varieties selected were early and super early varieties of very short duration, suitable for rice fallow conditions. Sowing was done on 22nd December, 2022 and 15th December, 2023 under zero tilled condition with the help of zero till seed drill immediately after the harvest of kharif rice by adopting a seed rate of 15-25 kg ha^{-1}. Full dose of nitrogen @ 40 kg ha^{-1} was applied as basal at the time of sowing. Nitrogen and phosphorus were supplied in the form of urea and diammonium phosphate, respectively.

The crop was harvested at physiological maturity and seed yield was recorded. Post-harvest, soil samples were collected, processed, and analyzed for physico-chemical properties. Soil pH was measured in a 1:2.5 soil-water suspension using a pH meter and electrical conductivity was determined in the same suspension using an electrical conductivity (EC) meter. Organic carbon (OC) was determined by following Walkley and Black wet digestion method [6]. Available soil nitrogen (N) was estimated by 2 M KCl extraction with continuous flow analyzer at 560 nm [7]. Available phosphorus was extracted by 0.5 M Na HCO3 as per the procedure of Olsens method [8]. Available potassium in soil samples was determined by using neutral normal ammonium acetate method using ICP-OES [9]. Data was subjected to analysis of variance procedures as outlined for strip-split plot design [10]. Statistically significance was tested by F-value at p=0.05 (5 %) level of probability and critical difference was worked out where ever the effect was significant. Treatment differences that were non–significant were denoted as NS.

3. RESULTS AND DISCUSSION

3.1 Seed Yield (kg ha^{-1})

Seed yield varied significantly among the varieties in both the years of experimentation, but the interaction effect of varieties, planting densities and phosphorus levels was non-significant (Table 1). The data revealed that variety ICPV-21333 recorded considerably higher seed yield (812 and 750 kg ha^{-1}) compared to ICPV-21777 (557 and 522 kg ha^{-1}) but, remained statistically similar to ICPV-21444 (772 and 712 kg ha^{-1}). The variations in seed yield among the varieties could partly be attributed to their genetic efficiency in transforming biological yield into economic yield. Similar results were reported by Sujathamma et al. [11] in redgram.

With respect to spacings, crop sown at 30 cm x 10 cm recorded significantly higher seed yield (792 and 740 kg ha^{-1}) compared to spacing at 45 x 10 cm spacing (636 and 583 kg ha^{-1}) during 2022-23 and 2023-24. Improved seed yield with closer spacing might be due to higher number of plants per unit area, which could have neutralized the higher vegetative and reproductive growth observed under wider spacing. The results align with the findings of Ramanjaneyulu et al. [12] and Tigga et al. [13] in redgram.

During both the years of study, phosphorus levels exerted a significant influence on seed yield and it was significantly highest with the application 50 kg P_2O_5 ha^{-1} (797 and 746 kg ha^{-1}) in comparison to 25 kg P_2O_5 ha^{-1} and control, but 50 kg P_2O_5 ha^{-1} was at par with 37.5 kg P_2O_5 ha^{-1} (755 and 698 kg ha^{-1}). Phosphorus is crucial for higher yield as it stimulates root development, energy transformation and metabolic processes, leading to greater translocation of photosynthates to reproductive organs, resulting in higher seed yields. Nathan et al. [14] also documented improvement in seed yield with phosphorus application in redgram.

Table 1. Effect of varieties, spacings and phosphorus levels on seed yield and available N, P_2O_5 and K_2O of post-harvest soil

Treatment	Seed yield (kg ha^{-1})			Available N (kg ha^{-1})			Available P_2O_5 (kg ha^{-1})			Available K_2O (kg ha^{-1})		
	2022-23	2023-24	Mean	2022-23	2023-24	Mean	2022-23	2023-24	Mean	2022-23	2023-24	Mean
Varieties												
V_1: ICPV-21333	812	750	781	156.3	160.5	158.4	66.7	60.1	63.4	317.0	309.6	313.3
V_2: ICPV-21444	772	712	742	155.2	159.2	157.2	65.7	59.3	62.5	314.3	307.0	310.7
V_3: ICPV-21777	557	522	540	154.3	157.8	156.1	64.8	58.2	61.5	310.5	304.1	307.3
SEm±	22	20	-	3.53	3.44	-	1.28	1.34	-	5.53	4.72	-
CD (P=0.05)	85	80	-	NS	NS	-	NS	NS	-	NS	NS	-
Spacing												
S_1: 30cm x 10cm	792	740	766	153.7	157.5	155.6	64.6	58.6	61.6	311.7	304.7	308.2
S_2: 45 cm x 10 cm	636	583	610	156.0	160.9	158.5	66.8	59.8	63.3	316.2	309.1	312.7
SEm±	20	19	-	5.16	4.00	-	0.91	1.02	-	3.94	3.61	-
CD (P=0.05)	118	113	-	NS	NS	-	NS	NS	-	NS	NS	-
Phosphorus levels												
P_1: 0 kg P_2O_5 ha^{-1}	603	557	580	151.3	155.7	153.5	57.3	52.9	55.1	308.5	300.0	304.3
P_2: 25 kg P_2O_5 ha^{-1}	700	644	672	154.3	158.8	156.6	64.4	58.3	61.4	313.1	306.7	309.9
P_3: 37.5 kg P_2O_5 ha^{-1}	755	698	727	156.5	160.4	158.5	68.8	61.8	65.3	314.9	308.4	311.7
P_4: 50 kg P_2O_5 ha^{-1}	797	746	772	157.3	161.8	159.6	72.4	63.8	68.1	319.3	312.6	316.0
SEm±	23	21	-	4.09	5.06	-	1.40	1.51	-	7.28	6.23	-
CD (P=0.05)	65	60	-	NS	NS	-	4.02	4.81	-	NS	NS	-
Interaction	All two way and three way interactions are non-significant											
Initial value	-			153.9			66.8			340.5		

3.2 Post-Harvest Soil Physico-Chemical Properties

3.2.1 Available nitrogen (kg ha^{-1})

Data pertaining to available (N, P_2O_5, and K_2O) as influenced by varieties, planting densities and phosphorus levels are presented in Table 1. Available nitrogen in soil was not significantly influenced by the treatments during both the years of experimentation. However, maximum available soil nitrogen was observed in variety ICPV-21333 (156.3 and 160.5 kg ha^{-1}) and minimum in ICPV-21777 (154.3 and 157.8 kg ha^{-1}) during 2022-23 and 2023-24. Similarly, higher available soil nitrogen was noticed at 30 cm x 10 cm (156.0 and 160.9 kg ha^{-1}), followed by 45 cm x 10 cm (153.7 and 157.5 kg ha^{-1}). Among the phosphorus levels, application of 50 kg P_2O_5 ha^{-1} registered comparatively higher post-harvest soil available nitrogen (157.3 and 161.8 kg ha^{-1}), while the lowest was recorded with 0 kg P_2O_5 ha^{-1} (151.3 and 155.7 kg ha^{-1}).

3.2.2 Available phosphorus (kg ha^{-1})

Available soil P_2O_5 was not significantly influenced by varieties and planting densities, but it varied significantly with the phosphorus levels during both the years of study. Available soil P_2O_5 during both the years was maximum in the plots sown with variety ICPV-21333 (66.7 and 60.1kg ha^{-1}) and minimum with ICPV-21777 (64.8 and 58.2 kg ha^{-1}). Among the spacings, available soil P_2O_5 ranged between 64.6 to 66.8 kg ha^{-1} and 58.6 to 59.8 kg ha^{-1} during 2022-23 and 2023-24. Among the phosphorus levels, significantly higher available soil P_2O_5 was recorded with the application of 50 kg P_2O_5 ha^{-1} (72.4 and 63.8 kg ha^{-1}) over other levels of phosphorus (25 kg P_2O_5 ha^{-1} and 0 kg P_2O_5 ha^{-1}), but it was at par with 37.5 kg P_2O_5 ha^{-1} (68.8 and 61.8 kg ha^{-1}) during both the years. The findings are in line with the results of Kumar et al. [15].

3.2.3 Available potassium (kg ha^{-1})

Available potassium in soil was also not influenced during both the years of experimentation. In general, among the varieties it ranged between 317.0 to 310.5 and 309.6 to 304.1 kg ha^{-1} during both the years of experimentation. While, it ranged between 311.7 to 316.2 kg ha^{-1} and 304.7 to 309.1 kg ha^{-1} across the spacings of 30 x 10 cm and 45 x 10 cm, respectively. With respect to phosphorus levels, available soil potassium ranged between 319.3 and 312.6 kg ha^{-1} with the application of 50 kg P_2O_5 ha^{-1} and varied between 308.5 and 300.0 kg ha^{-1} with 0 kg P_2O_5 ha^{-1}, respectively during 2022-23 and 2023-24.

3.2.4 Bulk density (g cm^{-3})

The bulk density of post-harvest soil was not significantly affected by the varieties, spacings and phosphorus levels in redgram (Table 2). Among the varieties, the bulk density ranged from 1.57 to 1.59 g cm^{-3} and 1.53 to 1.54 g cm^{-3} during 2022-23 and 2023-24, respectively. However, there was a slight reduction in bulk density with spacing at 30 cm x 10 cm compared to 45 cm x 10 cm and it ranged between 1.56 to 1.60 g cm^{-3} and 1.51 to 1.54 g cm^{-3} during both the years of experimentation. Bulk density was also slightly lower with phosphorus application than control. Applying 50 kg P_2O_5 ha^{-1} resulted in bulk density of 1.57 and 1.52 g cm^{-3}, while control plot (no phosphorus) had a higher bulk density (1.61 and 1.56 g cm^{-3}). The reduction in bulk density was due to better plant performance, leading to increased biomass production and higher organic matter content in the soil.

3.3 Soil pH, EC (dS m^{-1}) and OC (%)

Varieties, spacings and phosphorus levels did not significantly affect soil pH. A slight increase in pH was observed with higher phosphorus levels. A similar trend was observed with respect to EC and OC. The pH, EC and OC among the varieties ranged from 7.43 to 7.57, 0.34 to 0.35 dS m^{-1} and 0.36 to 0.37 % during 2022-23, while it ranged between 7.37 to 7.47, 0.37 to 0.38 dS m^{-1} and 0.34 to 0.36 % during 2023-24, respectively (Table 2). Across the spacings, pH ranged from 7.38 to 7.58 and 7.32 to 7.52 during both the years. Similarly, EC varied between 0.34 to 0.35 dS m^{-1} and 0.37 to 0.38 dS m^{-1}, OC between 0.35 to 0.37 % and 0.34 to 0.36 % during both the years of experimentation. Among the phosphorus levels, during 2022-23 and 2023-24, pH ranged from 7.30 to 7.63 and 7.31 to 7.55, EC from 0.33 to 0.35 dS m^{-1} and 0.36 to 0.38 dS m^{-1}, OC from 0.34 to 0.37 % and 0.35 to 0.36 %, respectively. Similar findings of non-significant influence of phosphorous levels on pH and OC were reported by Nyekha et al. [16] in greengram.

Table 2. Effect of varieties, spacings and phosphorus levels on post-harvest soil physico-chemical properties

Treatment	Bulk density (g m^{-3})			pH			EC (dS m^{-1})			OC (%)		
	2022-23	2023-24	Mean	2022-23	2023-24	Mean	2022-23	2023-24	Mean	2022-23	2023-24	Mean
Varieties												
V_1: ICPV-21333	1.57	1.53	1.56	7.43	7.37	7.40	0.34	0.37	0.36	0.37	0.36	0.37
V_2: ICPV-21444	1.58	1.53	1.56	7.54	7.41	7.48	0.34	0.38	0.36	0.36	0.35	0.36
V_3: ICPV-21777	1.59	1.54	1.57	7.57	7.47	7.52	0.35	0.38	0.37	0.36	0.34	0.35
SEm±	0.04	0.03	-	0.04	0.05	-	0.004	0.003	-	0.003	0.003	-
CD (P=0.05)	NS	NS	-	NS	NS	-	NS	NS	-	NS	NS	-
Spacing												
S_1: 30cm x 10cm	1.56	1.51	1.54	7.38	7.32	7.35	0.34	0.37	0.36	0.37	0.36	0.37
S_2: 45 cm x 10 cm	1.60	1.54	1.57	7.58	7.52	7.55	0.35	0.38	0.37	0.35	0.34	0.35
SEm±	0.01	0.01	-	0.06	0.06	-	0.004	0.004	-	0.002	0.003	-
CD (P=0.05)	NS	NS	-	NS	NS	-	NS	NS	-	NS	NS	-
Phosphorus levels												
P_1: 0 kg P_2O_5 ha^{-1}	1.61	1.56	1.59	7.30	7.31	7.31	0.33	0.36	0.35	0.34	0.35	0.35
P_2: 25 kg P_2O_5 ha^{-1}	1.58	1.54	1.56	7.47	7.38	7.43	0.34	0.37	0.36	0.36	0.35	0.36
P_3: 37.5 kg P_2O_5 ha^{-1}	1.57	1.53	1.55	7.51	7.43	7.47	0.35	0.37	0.36	0.37	0.35	0.36
P_4: 50 kg P_2O_5 ha^{-1}	1.57	1.52	1.55	7.63	7.55	7.59	0.35	0.38	0.37	0.37	0.36	0.37
SEm±	0.04	0.03	-	0.09	0.08	-	0.004	0.005	-	0.008	0.004	-
CD (P=0.05)	NS	NS	-	NS	NS	-	NS	NS	-	NS	NS	-
Interaction	All two way and three way interactions are non-significant											

4. CONCLUSION

From the present investigation, it can be concluded for rice fallow situation, redgram variety ICPV-21333 sown at 30 x 10 cm spacing with the application of 37.5 kg P_2O_5 ha^{-1} fetched higher seed yield. There was no significant variation with respect to soil physico-chemical properties except, that the post-harvest soil available P_2O_5 was higher in the plots applied with 37.5 kg P_2O_5 ha^{-1}.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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