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Growth and yield of redgram varieties under varying planting densitiy and phosphorus levels in rice fallows

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Abstract
Need for horizontal expansion of redgram led to new niches like rice fallows, which offer a huge potential for short duration pulses. Selecting suitable variety with an optimum planting density and fertilizer dose is necessary towards improved growth apart from higher yields. The present investigation was carried out to study the influence of varieties, planting densities and phosphorus levels on growth and yield of rice fallow redgram. The experiment was carried out during *rabi*, 2022-23 and 2023-24, at RL 12, block 3 and 4, International Crops Research Institute for Semi-Arid Tropics (ICRISAT), Patancheru, Hyderabad. The findings revealed that, among the varieties, ICPV-21333 registered higher plant height, leaf area, dry matter production and seed yield during both the years. While planting density at 30 x 10 cm resulted in higher plant height, dry matter and seed yield, but on the other hand leaf area plant^{-1} was highest with 45 cm x 10 cm. Application of 50 kg P_2O_5 ha^{-1} recorded higher growth and seed yield and remained at par with application of 37.5 kg P_2O_5 ha^{-1}, respectively.

Keywords: Rice fallow, redgram, varieties, planting density, phosphorus, growth, seed yield

Introduction

In India, rice cultivation covers 46.5 m ha (Statista, 2023-2024) [1] across various cropping systems in irrigated and rainfed regions. India accounts for nearly 18 m ha South Asia's 22.3 m ha of rice fallows (Naik *et al*., 2023) [2] due to multiple constraints. Rice fallows refer to lowland kharif rice areas that remain uncultivated during the Rabi season for several reasons. These rice fallow areas offer a huge potential niche for short season pulses. Historically, black gram and green gram were grown, but spread of yellow mosaic virus shifted farmers to maize and sorghum (Chapke and Tonapi, 2016) [3]. However, this cereal-cereal cropping system exhausts soil fertility. Introducing pulse crops, like redgram, after rice harvest can restore soil health while ensuring sustained yields.

Redgram, India's second most important pulse after chickpea, is grown on about 4.9 m ha, producing 4.2 MT with a productivity of 861 kg ha^{-1} (Indiastat, 2023) [4]. It plays a key role in soil restoration through symbiotic nitrogen fixation, enhancing organic matter, and improving soil structure. There is a need to expand red gram cultivation into new areas like rice fallows. Red gram is a short-day legume with late-maturing genotypes sensitive to photoperiod. Developing photo and thermo-insensitive, short-duration cultivars that mature in less than 100-120 days has addressed this issue. These varieties, suitable for various latitudes and altitudes, require optimal spacing due to their compact growth. Red gram's deep roots and symbiosis with VAM fungi can access phosphorus bound in the soil that is not readily available to other crops. Cultivation of redgram in rice fallows increases phosphorous uptake due to its unique property in utilizing iron bound phosphorous apart from ensuring higher phosphorous use efficiency and monetary returns. However, the information on these aspects in rice fallow redgram is meagre.

Material and methods

Based on this background, a field experiment was conducted at RL 12, blocks 3 and 4, at International Crops Research Institute for Semi-Arid Tropics (ICRISAT) in Patancheru, Hyderabad, during the rabi seasons of 2022-23 and 2023-24. The field is located at an altitude of

545 m above mean sea level (MSL), at 17º 52´ N latitude and 78º 28´ E longitude, in the Southern Zone of Telangana State. The soil in the experimental area is sandy loam, slightly alkaline with a pH of 7.8 and non-saline with an EC of 0.37 dSm^{-1}. The soil was low organic carbon content (0.40%) and available nitrogen (153.9 kg ha^{-1}), but high levels of available P_2O_5 (66.8 kg ha^{-1}) and K_2O (340.5 kg ha^{-1}).

The experiment was laid out in strip-split plot design with three varieties as the vertical factor: 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). The horizontal factor consisted of two spacing levels: S_1 (30 x 10 cm) and S_2 (45 x 10 cm). Four levels of phosphorus were used as subplots: 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}). Seeds were treated with thiram at 3 g/kg, followed by the application of phosphobacteria and rhizobium cultures. The selected varieties were early and super early, suitable for rice fallow conditions. Sowing took place on December 22, 2022, and December 15, 2023, under zero till conditions using a zero till seed drill right after the kharif rice harvest, with a seed rate of 15-25 kg/ha. A week before sowing, glyghosate 41% SL @ 6 ml $litre^{-1}$ was sprayed on rice stubbles to prevent their regrowth. Accordingly pre (1 DAS) and post-emergence (20 DAS) herbicidal spraying was done for controlling the weeds. A uniform basal dose of 40 kg N ha^{-1} and phosphorus as per the treatments were applied as basal dose during sowing, in the form of urea and diammonium phosphate (DAP).

Crop was harvested manually with sickle and tied in bundles with tags from each plot and left for sun drying. Threshing operations were also performed plot wise manually. The growth parameters, *viz*. leaf area at pod formation, plant height (cm) and dry matter (kg ha^{-1}), at the time of harvest were recorded. The seed yield was recorded for the net plot area and computed per hectare. Data was subjected to analysis of variance procedures as outlined for strip-split plot design (Gomez and Gomez, 1984) [5] and statistically significance was tested by F-value at p=0.05 (5%) level of probability.

Results and Discussion

Plant height (cm)

During both years of the experimentation, plant height was significantly influenced by varieties and phosphorus levels (Table 1). However, planting density could not significantly influence plant height. Among the varieties, ICPV-21333 had the tallest plants, followed by ICPV-21444 and ICPV-21777, due to its genetic traits and indeterminate growth habit. These results align with Sujathamma *et al*. (2022) [6] in redgram. The planting density of 30 x 10 cm recorded the tallest plants, followed by 45 x 10 cm. With regard to phosphorus levels tested, the highest plant height was observed with 50 kg P_2O_5 ha^{-1}, which was statistically similar to 37.5 kg P_2O_5 ha^{-1}. On the contrary, the lowest plant height was registered in the control (0 kg P_2O_5 ha^{-1}). Phosphorus application improved plant height due to its crucial role in physiological and biochemical processes, supporting by the findings of Goswami (2023) [7] in redgram. The interaction effect of varieties, planting densities and phosphorus levels was found non-significant during both the years.

Leaf area (cm^2 $plant^{-1}$)

Varieties, planting densities, and phosphorus levels had significant variation on leaf area during the pod formation stage (Table 1). Over two years of field studies, variety ICPV-21333 had put forth significantly higher leaf area per plant, but was statistically comparable to ICPV-21444. Leaf area is largely influenced by the number of branches and growth habit. Varieties ICPV-21333 and ICPV-21444, being indeterminate varieties, exhibited vigorous growth coupled with higher number of branches and reflected in greater assimilatory surface. These results corroborate with the findings of Kumar *et al*. (2022) [8]. Planting density at 45 x 10 cm resulted in higher leaf area per plant as compared to 30 x 10 cm due to reduced competition for resources, enhancing photosynthesis and overall crop growth. Fanish *et al*. (2023) [9] also documented similar findings of improved leaf area under wider spacing in redgram. Among phosphorus levels, crop fertilised with 50 kg P_2O_5 ha^{-1} produced higher leaf area per plant, but statistically at par with 37.5 kg P_2O_5 ha^{-1}, while no phosphorus application resulted in lowest leaf area. Phosphorus improved nutrient availability and uptake, enhancing photosynthesis and branch growth, ultimately higher leaf area. These findings are consistent with Ade *et al*. (2018) [10]. The interaction effect of varieties, planting densities and phosphorus levels was found non-significant during both the years.

Table 1: Influence of varieties, planting densities and phosphorus levels on plant height and leaf area of rice fallow redgram

Treatment	Plant height (cm)			Leaf area (cm^2 $plant^{-1}$)		
	2022-23	**2023-24**	**Mean**	**2022-23**	**2023-24**	**Mean**
Varieties						
V_1: ICPV-21333	74.1	73.8	74.0	783.5	747.8	765.7
V_2: ICPV-21444	60.1	59.1	59.6	739.4	703.9	721.7
V_3: ICPV-21777	47.1	45.9	46.5	433.3	407.1	420.2
SEm±	0.34	0.60	-	19.87	24.20	-
CD (P=0.05)	1.35	2.39	-	78.02	95.03	-
Planting densities						
S_1: 30cm x 10cm	62.7	60.7	61.7	595.9	563.0	579.5
S_2: 45 cm x 10 cm	58.2	57.5	57.9	708.2	676.2	692.2
SEm±	0.85	0.80	-	17.65	15.81	-
CD (P=0.05)	NS	NS	-	107.36	96.20	-
Phosphorus levels						
P_1: 0 kg P_2O_5 ha^{-1}	55.0	53.4	54.2	543.2	506.7	525.0
P_2: 25 kg P_2O_5 ha^{-1}	59.1	58.4	58.8	631.1	607.8	619.5
P_3: 37.5 kg P_2O_5 ha^{-1}	63.1	62.6	62.9	703.5	671.4	687.5
P_4: 50 kg P_2O_5 ha^{-1}	64.6	64.3	64.9	730.4	692.5	711.5
SEm±	0.77	0.68	-	25.08	21.00	-
CD (P=0.05)	2.23	1.94	-	71.93	60.23	-
Interaction	All two way and three way interactions are non-significant					

Dry matter production (kg ha^{-1})

The data (Table 1) depicted that variety ICPV-21333 had recorded significantly higher dry matter production compared to ICPV- 21777, but it was statistically comparable to ICPV-21444 during both 2022-23 and 2023-24. Kumar *et al.* (2022) [8] also documented similar findings of improved dry matter production with super early photo-insensitive redgram cultivars. With respect to planting densities, 30 x 10 cm yielded more dry matter than 45 x 10 cm (Table 2), due to higher number of plants per unit area coupled with efficient resource use (Sepat *et al.* (2021) [11] in redgram. Among phosphorus levels, crop fertilized with 50 kg P_2O_5 ha^{-1} rescorded higher dry matter production, but significantly at par with 37.5 kg P_2O_5 ha^{-1}, during both the years of experimentation. This could be attributed to the improved growth parameters (plant height, number of branches and leaf area) in the respective treatments coupled with improved assimilation, in line with the findings of Singh *et al.* (2017) [12]. The interaction effect of varieties, planting densities and phosphorus levels was found non-significant during both the years.

Table 2: Influence of varieties, planting densities and phosphorus levels on dry matter production and seed yield of rice fallow redgram

Treatment	Dry matter production (kg ha^{-1})			Seed yield (kg ha^{-1})		
	2022-23	2023-24	Mean	2022-23	2023-24	Mean
Varieties						
V_1: ICPV-21333	3700	3571	3636	812	750	781
V_2: ICPV-21444	3493	3368	3431	772	712	742
V_3: ICPV-21777	2587	2451	2519	557	522	540
SEm±	74	65	-	22	20	-
CD (P=0.05)	289	257	-	85	80	-
Planting densities						
S_1: 30cm x 10cm	3783	3655	3719	792	740	766
S_2: 45 cm x 10 cm	2737	2611	2674	636	583	610
SEm±	46	42	-	20	19	-
CD (P=0.05)	279	255	-	118	113	-
Phosphorus levels						
P_1: 0 kg P_2O_5 ha^{-1}	2845	2729	2787	603	557	580
P_2: 25 kg P_2O_5 ha^{-1}	3223	3086	3155	700	644	672
P_3: 37.5 kg P_2O_5 ha^{-1}	3418	3289	3354	755	698	727
P_4: 50 kg P_2O_5 ha^{-1}	3555	3429	3492	797	746	772
SEm±	66	62	-	23	21	-
CD (P=0.05)	190	177	-	65	60	-
Interaction	All two way and three way interactions are non-significant					

Seed yield (kg ha^{-1})

Seed yield varied significantly among the varieties in both the years of experimentation (Table 2). The data revealed that significantly higher seed yield was registered by ICPV-21333 (812 and 750 kg ha^{-1}) over ICPV-21777 (557 and 522 kg ha^{-1}), but it was statistically comparable to ICPV-21444 (772 and 712 kg ha^{-1}). Superior yield registered with ICPV-21333 was due to its high genetic yield potential and indeterminate growth habit. Similar results were reported by Sujathamma *et al.* (2022) [6] in redgram. While, planting density at 30 x 10 cm produced significantly higher seed yield (792 and 740 kg ha^{-1}) compared to planting density at 45 x 10 cm spacing (636 and 583 kg ha^{-1}). The increased yield with higher planting density might be due to higher number of plants per unit area. The results find support from Ramanjaneyulu *et al.* (2017) [13] and Tigga *et al.* (2017) [14] in redgram.

Among the phosphorus levels, highest seed yield was recorded with the application of 50 kg P_2O_5 ha^{-1} (797 and 746 kg ha^{-1}), 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}), respectively. Phosphorus is crucial for higher yield as it stimulates root development, nodulation apart from translocation of photosynthates to reproductive organs. Nathan *et al.* (2021) [15] also documented increase in seed yield with phosphorus application in redgram. The interaction effect of varieties, planting densities and phosphorus levels was found non-significant during both the years.

Conclusion

From the present experiment results, it can be concluded that redgram variety ICPV-21333, sown at planting density at 30 x 10 cm and application of 37.5 kg P_2O_5 ha^{-1} recorded improved plant height, leaf area, dry matter production and higher seed yield under rice fallow situations.

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