



Source- Sink Regulation in Red Gram through Foliar Nutrition of Potassium and Growth Promoters in the Warm Humid Tropics of Kerala

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Abstract: The study was conducted to assess the influence of potassium and growth regulators on the source-sink efficiency in red gram [*Cajanus cajan* (L.) Millsp.]. The field experiment was laid out at College of Agriculture, Vellayani during 2019-2021 with combinations of four levels of potassium (0.5 % K₂SO₄, 1.0 % K₂SO₄, 0.25 % KNO₃, 0.5 % KNO₃) and three growth regulators (gibberellic acid 75 mg kg⁻¹, brassinosteroid 0.1 mg kg⁻¹ and humic acid 100 mg kg⁻¹) as treatments, along with a control of conventional practice with no foliar nutrition. Foliar application of KNO₃ and GA₃ significantly enhanced the growth attributes. Seed yield (1081.33 kg ha⁻¹) and haulm (4837.27 kg ha⁻¹) yields were superior with foliar application of KNO₃ (0.5 %) and GA₃. The interaction effects of KNO₃ (0.5 %) x GA₃ revealed the significantly highest values for yield attributes and seed yield revealing efficient source- sink regulation compared to the conventional practice of sole nutrient application in soil.

Keywords: Brassinosteroids, Gibberellic acid, Potassium, Red gram, Sink-efficiency

Pulses are climate smart crops can be imbibed in any cropping system and also act as catch crops on account of their deep rooting system, phenotypic plasticity, dehydration tolerance, high moisture retention capacity, and a wide range of photothermal sensitivity (Gull et al 2020). Red gram [*Cajanus cajan* (L.) Millsp.] belonging to the family Fabaceae is a perennial, woody shrub usually grown as an annual for its edible seeds. It is the second most important pulse crop after chickpea in India. Apart from its nutritional importance, red gram is also valued for its adaptability to arid conditions and is also considered a lifeline of subsistence agriculture. The crop enhances soil fertility by fixing atmospheric nitrogen and contributing organic matter and micronutrients through leaf fall (Bano 2015). Despite the several advantages, red gram is constrained by its low yield which is mainly attributed to its cultivation on poor soils with inadequate and imbalanced nutrient application, excessive vegetative growth, indeterminate growth habit and poor source-sink relationship (Patil et al 2018). Major physiological constraint limiting red gram productivity is abscission of flower and fruits (Kulkarni et al 2019). Among the major nutrients, potassium is of utmost significance, on account of its role in various plant growth functions such as enzyme activity, photosynthesis, mobilization of carbohydrates, fruit set, quality and disease resistance (Prajapati and Modi 2012). Use of plant growth regulators is one of the latest trends in agriculture. Plant growth regulators are chemically synthesized compounds,

which mimic natural hormones in their action and play an important role in shaping plant growth and development. The experiment was formulated to assess the influence of potassium and growth regulators on the source-sink efficiency in red gram.

MATERIAL AND METHODS

Experimental location: The field experiment was conducted at College of Agriculture, Vellayani, Thiruvananthapuram, Kerala during January to May 2021. The site located at 8.43° N latitude, 76.99° E longitude and at an altitude of 29 m above mean sea level, enjoys a humid tropical climate with the soil belonging to the order Ultisols. The soil nutrient status revealed medium organic carbon (1.21%), available K (121.6 kg ha⁻¹), low available N (257.15 kg ha⁻¹) and high available P (103.2 kg ha⁻¹) status.

Experimental details: The experiment was laid out in randomised block design with 12 combinations of two factors, four levels of potassium (a₁ - 0.5 % K₂SO₄, a₂ - 1.0 % K₂SO₄, a₃ - 0.25 % KNO₃, a₄ - 0.5 % KNO₃) and three growth regulators (b₁ - gibberellic acid (GA₃) 75 mg kg⁻¹, b₂ - brassinosteroid (BR) 0.1 mg kg⁻¹, b₃ - humic acid (HA) 100 mg kg⁻¹) as treatments in three replications. A control with recommended dose of nutrients without foliar application was also maintained. Short duration variety, APK 1 of Regional Research Station (RRS), Aruppokotai, Tamil Nadu was used for the study with an NPK dose of 40: 80: 40 kg ha⁻¹

(Devaraj and Isaac, 2021). Foliar sprays were given twice, potassium, at flower bud and pod formation stages and growth regulators, 30 days after sowing (DAS) and at flower bud stage. Urea, rock phosphate and muriate of potash were used as the sources of N, P and K respectively. The entire dose of P was applied as basal, N and K, in two splits, basal and 30 DAS. Threshing and winnowing were done manually to separate seeds. The growth and yield attributes were recorded and the seeds weighed after harvest. The yields per net plot area were used to compute the per hectare yields.

Statistical analysis: OP STAT software developed by Chaudhary Charan Singh Haryana Agricultural University was used for data analysis. Control vs treatment comparison was statistically analysed as contrast analysis using GRAPES software developed by the Department of Agricultural Statistics, College of Agriculture, Vellayani.

RESULTS AND DISCUSSION

Effect on Growth Characters

Plant height: Foliar application of potassium improved the various growth characters viz., plant height, number of branches, leaf area and LAI in red gram (Table 1). The plant height at 30 DAS did not vary significantly with potassium treatments whereas at 60 DAS, plants were the tallest (94.59 cm) in a_4 ($KNO_3 @ 0.5\%$ application) on par with a_3 ($KNO_3 @ 0.25\%$) and a_1 ($K_2SO_4 @ 0.5\%$). At 90 DAS, the significantly lowest plant height (139.96 cm) was in 0.25 per cent KNO_3 application and the maximum (148.87 cm) was in a_4 (0.5 % KNO_3). Growth regulators showed non-significant variations at 30 DAS, whereas b_1 ($GA_3 @ 75\text{ mg kg}^{-1}$) recorded the tallest plants at 60 and 90 DAS (100.84 and 150.31 cm respectively). It was significantly superior to BR and humic acid application. The interactions exerted significant

influence on plant height at 60 and 90 DAS. The combination, a_4b_1 ($KNO_3 @ 0.5\% \times GA_3 75\text{ mg kg}^{-1}$) recorded the maximum plant height (101.42 cm) at 60 DAS and was on par with a_1b_1 , a_3b_1 , a_2b_1 , but at 90 DAS, plants were the tallest (153.94 cm) in a_4b_1 and superior to all other combinations. Comparing the treatment effects with the control, at 30 DAS, the effect was non-significant. However, at 60 and 90 DAS, the treatments were significantly superior to the control.

Number of branches per plant: Foliar application of potassium sources at different concentrations recorded significant influence on number of branches per plant at flowering (Table 1). Superior number (8.73) was in a_4 ($KNO_3 @ 0.5\%$) and the lowest number (7.64) in a_2 ($K_2SO_4 @ 1\%$). Among growth regulators, b_1 produced the highest number of branches (9.95 per plant) and was significantly superior to BR and humic acid application. Among interactions the maximum number (11.81) was in a_4b_1 and was significantly higher than the other combinations. The lowest number of branches (6.80) was in a_3b_2 . The treatment effects were significantly superior to the control.

Leaf area per plant: Potassium sources applied on the foliage had significant influence on leaf area per plant. The significantly superior leaf area (1662.76 cm^2) was in a_4 (0.5 % KNO_3) and the lowest in a_2 (1.0 % K_2SO_4) (1430.59 cm^2). Growth regulators also had significant influence on leaf area. Leaf area (2068.75 cm^2) was maximum in b_1 ($GA_3 75\text{ mg kg}^{-1}$), followed by BR (1296.06 cm^2) and humic acid (1175.76 cm^2) and were markedly different from each other. The treatment interactions could not produce significant effect on leaf area per plant at flowering. However, the treatments were significantly superior to the control.

Leaf area index: The superior LAI (2.08) was in a_4 (0.5 % KNO_3) and the lowest LAI (1.79) in a_2 (1.0% K_2SO_4) (Tables 1,

Table 1. Effect of potassium and growth regulators on growth and yield in red gram

Treatments	Plant height (cm) (Days after sowing)			No. of branches per plant	Leaf area (cm^2 per plant)	Leaf area index	Number of pods per plant	Average pod length (cm)	Average pod weight (g)	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})
	30	60	90								
Potassium (a)											
a_1 (0.5% K_2SO_4)	48.72	93.96	144.72	7.89	1451.33	1.81	43.57	5.43	0.39	1040.41	4399.17
a_2 (1.0% K_2SO_4)	47.51	92.76	144.84	7.64	1430.59	1.79	42.74	5.47	0.38	1006.13	4199.82
a_3 (0.25 % KNO_3)	48.70	93.53	139.96	7.94	1509.41	1.89	43.97	5.44	0.39	1014.44	4140.25
a_4 (0.5 % KNO_3)	48.23	94.59	148.87	8.73	1662.76	2.08	44.42	5.62	0.44	1081.33	4837.27
CD (p=0.05)	NS	1.205	0.730	0.407	124.816	0.156	0.998	0.049	0.023	14.804	189.769
Growth regulators (b)											
b_1 (GA_3)	48.32	100.84	150.31	9.95	2068.75	2.59	48.24	5.64	0.45	1100.13	4780.82
b_2 (BR)	49.25	91.09	144.82	7.07	1296.06	1.62	45.37	5.37	0.38	1072.74	4618.95
b_3 (HA)	47.30	88.65	134.48	7.30	1175.76	1.47	37.41	5.46	0.37	934.02	3781.86
CD (p=0.05)	NS	1.043	0.633	0.352	108.094	0.135	0.864	0.042	0.020	12.821	164.345

but superior to a_2 (42.74). The growth regulators, b_1 (GA_3 @ 75 mg kg⁻¹) recorded the highest number of pods per plant (48.24) and was significantly superior to BR and humic acid application. Interaction of potassium and growth regulators exerted significant influence on the number of pods per plant, with the maximum number of pods (50.11) in a_4b_1 , on par with a_1b_1 (48.74). Pod number was the lowest number (36.30) in a_4b_3 . The treatments were found to be significantly higher than control.

Average pod length: The significantly longest pods (5.62 cm) were in a_4 and the shortest pods (5.43 cm) in a_1 . Variations in pod length with growth regulators were also significant. GA_3 application proved superior with the longest pods (5.64 cm). In response to the interactive effects, pods were the longest (5.78 cm) in a_4b_1 and was on par with a_1b_1 (5.72 cm) and a_2b_1 (5.75 cm) whereas, the shortest pods (5.19 cm) was in a_1b_2 . Except in combination with 0.25 percent KNO_3 , b_1 recorded the longest pods with a_1 , a_2 and a_4 . The treatments were significantly superior to control.

Average pod weight: Pod weight was significantly higher in a_4 (0.5 % KNO_3), GA_3 application (b_1) and the combination a_4b_1 (0.51 g). The lowest weight (0.33 g) was in a_2b_3 . The treatments were significantly superior to control.

Seed yield: The highest yield (1081.33 kg ha⁻¹) was with 0.5 % KNO_3 spray. The higher concentration of K_2SO_4 (1.0 %) recorded the lowest yield (1006.13 kg ha⁻¹). Among growth regulators, maximum seed yield (1100.13 kg ha⁻¹) was in b_1 (GA_3 75 mg kg⁻¹) which was significantly superior to the BR and humic acid treatments. Seed yield was the lowest (934.02 kg ha⁻¹) in b_3 (HA 100 mg kg⁻¹). Interactions indicated significant variations with the maximum yield (1186.33 kg ha⁻¹) in the combination of 0.5 % KNO_3 and GA_3 (a_4b_1) and was significantly superior. The lowest yield (930.10 kg ha⁻¹) was in a_4b_3 . The treatment mean was significantly superior to control.

Haulm yield: Haulm yields followed similar trends of growth and seed yields. The highest haulm yield (4837.27 kg ha⁻¹) was in a_4 (0.5 % KNO_3) and the lowest (4140.25 kg ha⁻¹) in a_3 (0.25 % KNO_3). The effect of growth regulators was also significant, the highest haulm yield (4780.82 kg ha⁻¹) was recorded in b_1 (GA_3 75 mg kg⁻¹) but statistically comparable to that in b_2 . Among the treatment combinations, a_4b_1 recorded the highest haulm yield (5815.05 kg ha⁻¹) in line with the individual effects and was significantly superior to other treatment combinations. The lowest haulm yield (3562.19 kg ha⁻¹) was recorded in a_3b_3 . The significant difference between treatments means and control was also evident.

The indeterminate growth habit of red gram ensues a continuous competition for available assimilates between vegetative and reproductive sinks throughout the growth

period. In pulses, yield is in general highly constrained by the lowered translocation of assimilates to the growing reproductive sinks. Insufficient partitioning of assimilates, poor pod setting due to flower abscission and lack of nutrients during critical stages of crop growth are crucial. In the present study, potassium nutrition was found to favourably influence the sink efficiency in red gram. Foliar application of KNO_3 at 0.5 per cent concentration was found to be superior. The results accords the reports on efficient utilisation of nutrients thereby reducing flower shedding and enhancing yields (Sathishkumar et al 2020, Singh et al 2021). The increased leaf area indicated higher source strength, increased photosynthesis and hence, higher photo assimilate production. Foliar application of potassium enhanced the rapid availability of the nutrient; redistribution of carbohydrates and translocation of assimilates to the economically important parts, the sink. In addition, potassium aids in acceleration of the physiological processes within, resulting in improved plant growth and yield attributes, and these were manifested in the seed yields. It is deciphered that the supply of potassium and nitrogen to supplement the soil contribution was effective in enhancing the production by virtue of the increased translocation of assimilates to the sinks, and a higher pod set, nearly 20 per cent greater than the lowest (24.18%) among potassium treatments. The impacts on the leaf area, number and weight of pods would have attenuated the higher yields.

Growth regulators had significant influence on average pod weight, seed and haulm yields and the values were superior in GA application which could be attributed to the significant role in stimulating physiological responses and altering the source-sink metabolism through their effect on photosynthesis and sink formation. Gibberellic acid is closely related to cell division and enlargement during fruit development (Zhang et al 2007) and the exogenous application increased seed weights. Application at 30 DAS and at pod formation stage might have improved the vegetative and reproductive development of red gram crop and supported efficient translocation of photosynthates from source to sink, as illustrated by Kumar and Sharma (2021). The increase in sink strength, number of pods, might be due to increased leaf area which leads to better utilization of sunlight and the plants remaining physiologically more active to build up sufficient food material for developing more number of pods. The enhanced sink potential and capacity through efficient translocation of photosynthates from source to sink with GA_3 application would also have complimented the higher yields. The results of the experiment are in line with the reports of Giri et al (2018) Kumar et al (2018) and Bhanu et al (2024).

CONCLUSION

The foliar application of KNO₃ and GA₃ significantly enhanced growth and seed yields in red gram. Growth attributes that represent the source strength, and seed yields, the sink capacity, were significantly superior with KNO₃ @ 0.5 % and GA₃ application. The individual effects were reflected in the interaction effects of KNO₃ (0.5 %) x GA₃ also. Therefore, source- sink regulation through the foliar applications of KNO₃ (0.5 %) at flower bud and pod formation stages and GA₃ (75 mg kg⁻¹), 30 DAS and at flower bud stage, proved superior and can be recommended for cultivation of short duration red gram in the warm humid tropics of Kerala.

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