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Impact of Nutrient Management Practices in Cassava on the Growth and Yield of Red Gram in an Additive Series Intercropping System in the Southern Laterites of Kerala

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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

Cassava-legume intercropping is widely promoted by virtue of the ecological, nutritional and productive benefits and the choice of the intercrop is crucial in realizing the potentials envisaged. The performance of red gram (*Cajanus cajan* (L.) Millsp.) as an intercrop in cassava was evaluated in randomized block design at College of Agriculture, Vellayani, Kerala Agricultural University in three replications with different nutrient management practices in the main crop as treatments.

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Potassium efficient cassava variety Sree Pavithra was tested with varying levels of N, P and K. The treatments included T_1 (100 % recommended dose of fertilizers), T_2 (100 % RD N and P + 50 % K), T_3 (100 % RD N and P + 25 % K), T_4 (100 % RD N and P + 0 % K), T_5 (50 % RDF), T_6 (50 % RDF + PGPR Mix 1), T_7 (50 % RD N and P + 25 % K), T_8 (50 % RD N and P + 25 % K + PGPR Mix 1), T_9 (50 % RD N and P + 0 % K), T_{10} (50 % RD N and P + 0 % K + PGPR Mix 1) and control (no fertilizer application). Cassava growth and yield was found to be superior in the treatments involving the consortium biofertilizer PGPR Mix 1 and was the highest in 50 % RD N and P + 0 % K + PGPR Mix 1 liquid application. The performance of red gram as an intercrop was found to be influenced by the canopy growth in cassava and yields were 80-89 per cent less than in sole cropping. The land equivalent ratio was more than one in PGPR included treatments alone indicating that intercropping was not advantageous in other treatments.

Keywords: Intercropping; potassium efficient cassava; red gram; nutrient management.

1. INTRODUCTION

Tuber crops play a significant role in food security, especially in developing countries, due to their nutritive value, versatility and easiness in storage and preservation. Tuber crops are often drought resistant and can grow in diverse climates and soil types. Cassava (*Manihot esculenta* Crantz) is indeed a vital tropical tuber crop, particularly in regions like Kerala, Tamil Nadu and Andhra Pradesh. Cassava growing area in Kerala is around 0.64 lakh ha [1], which is highest among tropical tuber crops.

Even though cassava is well known for its ability to grow on marginal soils with poor soil conditions, adequate supply of plant nutrients enhance both yield and quality. To produce a tuber yield of 30 t ha^{-1}, cassava removes about 180 kg nitrogen (N), 22 kg phosphorus (P) and 160 kg potassium (K) [2]. Potassium is considered a crucial nutrient for cassava, influencing various aspects of its growth and quality. Adequate K levels are essential for optimal tuber development, starch accumulation and reducing the content of cyanogenic glucosides. Considering the key role of K in cassava cultivation, a K efficient genotype (Sree Pavithra) has been released from Central Tuber Crops Research Institute (CTCRI), Sreekariyam, which can produce higher yields per unit of K applied compared to other varieties [3].

Intercropping is a multiple cropping system wherein two or more crops are grown simultaneously during a growing season. It helps to improve the diversity in an agriculture production system, ensure efficient utilization of resources and enhances overall production. The long duration of cassava combined with slow initial growth offers scope for intercropping short duration crops, which would increase the biological efficiency of the system. Intercropping short duration crops in cassava is beneficial as they ensure food and nutritional security and monetary benefits. The crops identified as suitable for intercropping in cassava include red gram [4], cowpea [5], groundnut [6] and maize [7].

Inclusion of a legume crop in intercropping is advantageous due to the ability of legume to fix atmospheric N and make it available later to the associated non-legume which in turn results in higher yield of non-legume than its sole crop yield. In addition, pulses play a vital role in meeting the protein needs of the population. Improving pulse production through the strategic inclusion of grain legumes in existing cropping systems is a valuable approach. Further this would also enhance agricultural productivity, improve soil health and support sustainable farming practices. Proper nutrient management for main crop and intercrop ensures better growth, yield and sustain soil health. In this background, a field experiment was conducted to standardize the nutrient management practice for Sree Pavithra intercropped with red gram and to assess the effect of intercropping on growth and yield of red gram.

2. MATERIALS AND METHODS

The field experiment was conducted during May 2022 to May 2023 at farmer's field in agro ecological unit (AEU) 8, located at 8° 25' 3" North latitude, 77° 1' 39" East longitude and at an altitude of 28 m above mean sea level. Composite soil sample was collected from the experimental site, processed and tested for various chemical properties as per the standard analytical procedures. pH of the soil was measured using pH meter, organic carbon content was determined by Walkely and Black rapid titration [8], available N status of soil by alkaline potassium permanganate method [9], available P and K status were determined by bray No. 1 extraction and spectrophotometry and neutral normal ammonium acetate extraction and flame photometry respectively [8].

The soil of the experimental site was sandy clay loam in texture with extremely acidic soil pH (4.27). Organic carbon (0.81%), available nitrogen (288.51 kg ha^{-1}) and available potassium (142.5 kg ha^{-1}) were medium and available phosphorus status of the soil (237.81 kg ha^{-1}) was high. The experiment was laid out in randomized block design with 11 treatments replicated thrice. The treatment details are given in Table 1.

The RDF for cassava variety Sree Pavithra is 100:50:100 kg NPK ha^{-1}. The recommended dose of N, P and K were supplied through urea, rajphos and muriate of potash. 1/3 dose of N and K and full dose of P were applied as basal and remaining N and K were applied in two equal splits at 2 months after planting (MAP) and 3 MAP. Farm yard manure @ 12.5 t ha^{-1} was applied to all the treatments. The biofertilizer, PGPR Mix 1 liquid formulation (5 per cent @ 250 mL per plant) was applied thrice, basal, 2 MAP and 4 MAP.

Green manure cowpea seeds were sown uniformly in all the treatments before planting cassava at a seed rate of 25 kg ha^{-1} and the whole biomass were incorporated *in situ* at flowering stage. After three weeks of incorporation, the plots were limed based on soil test results. Cassava stem cuttings were planted at a spacing of 90 cm × 90 cm on the mounds and red gram seeds of APK 1 variety were sown in between two rows of cassava at a spacing of 20 cm between red gram plants (one row of red gram between two rows of cassava). The crop residues of red gram were incorporated into cassava mounds after the harvest of red gram. Sole crops of cassava and red gram were raised as per recommended cultural practices and nutrient management. Farm yard manure @ 20 t ha^{-1} and NPK @ 40:80:40 kg ha^{-1} were applied for red gram. Half dose of N and K and full dose of P were given as basal and remaining half dose of N and K were applied at 1 month after sowing (MAS).

Growth parameters of cassava such as plant height, number of total leaves and functional leaves were measured at bimonthly intervals till harvest (2 MAP, 4 MAP, 6 MAP, 8 MAP and at harvest) and tuber yield was recorded at harvest. Plant height was measured from the base to the terminal bud of the longest stem in observational plants. Fully opened leaves, unopened leaves and leaf scars on the stem were counted to obtain total number of leaves per plant. The number of fully opened leaves alone were considered to obtain functional leaves per plant. Total weight of tubers obtained from observational plants were noted and expressed as tuber yield per plant.

Plant height of red gram was measured from the base to the tip of growing point. Leaf area of red gram was assessed using linear measurement method suggested by Sharma et al. [10]. Total number of pods that were obtained from observational plants from all the harvests were counted and expressed as number of pods per plant. Eight pods were randomly selected and weighed to obtain average pod weight. The number of seeds per pod were obtained by counting the number of seeds in selected pods. The pods obtained from observational plants from all the harvests were sun dried, weighed and the mean was expressed as pod yield per plant. The seeds obtained from observational plants were weighed and was expressed as seed yield per plant.

Table 1. Treatments used for field experiment

Treatments	Description
T_1	100 % Recommended dose of fertilizer (RDF)
T_2	100 % RD of N and P + 50 % K
T_3	100 % RD N and P + 25 % K
T_4	100 % RD N and P + 0 % K
T_5	50 % RDF
T_6	50 % RDF + PGPR Mix 1 liquid
T_7	50 % RD N and P + 25 % K
T_8	50 % RD N and P + 25 % K + PGPR Mix 1 liquid
T_9	50 % RD N and P + 0 % K
T_{10}	50 % RD N and P + 0 % K + PGPR Mix 1 liquid
Control	No fertilizer application

3. RESULTS AND DISCUSSION

3.1 Growth Attributes and Yield in Cassava

The effect of nutrient management practices on the growth and tuber weight of cassava are presented in Tables 2, 3, 4 and 5. It is evident that the nutrient management practices could significantly influence plant height and leaf production. In the early stages (2 MAP) the effect was comparable, but from 4 months onwards significant variations were observed. Application of 50 % RDF + PGPR Mix 1 liquid (T_6) resulted in the tallest plants both at 6 MAP (289.33 cm) and 8 MAP (327.33 cm), on par with T_{10} (50 % RD N and P + 0 % K + PGPR Mix 1 liquid), T_3 (100 % RD N and P + 25 % K), T_1 (100 % RDF) and T_8 (50 % RD N and P +25 % K + PGPR Mix 1liquid). However, the effects were non significant at final harvest. The total leaf number and number of functional leaves per plant were also significantly higher and comparable in T_{10} and T_6 at all stages of observation. The values were superior to the control of no fertilizer application.

Perusal of the data on tuber yield per plant revealed that the tuber weight (9.00 kg) was significantly greater with treatment T_{10} and on par with treatments T_6 and T_8, the treatments involving PGPR consortium, with tuber weights of 8.00 and 7.83 kg respectively. The control treatment had the significantly lowest tuber weight (3.33 kg).

Table 2. Plant height of cassava as influenced by different nutrient levels

Treatments	Plant height (cm)				
	2 MAP	**4 MAP**	**6 MAP**	**8 MAP**	**Harvest**
T_1	119.95	230.83	278.67	322.00	360.33
T_2	117.55	221.17	273.67	300.33	341.00
T_3	114.42	230.00	278.67	316.17	349.00
T_4	117.75	223.17	262.33	303.33	349.00
T_5	114.58	225.00	254.00	302.33	337.00
T_6	115.67	225.83	289.33	327.33	380.33
T_7	113.13	223.50	248.17	284.00	340.33
T_8	110.75	223.67	276.00	313.17	340.67
T_9	110.83	223.50	269.17	290.50	349.33
T_{10}	121.88	229.83	286.50	313.67	370.00
Control	101.17	192.33	230.33	264.33	328.67
SE m (±)	5.60	5.80	5.73	5.06	13.10
CD (*P*=0.05)	NS*	12.097	16.913	14.915	NS

* *Non significant*

Table 3. Effect of different nutrient levels on total number of leaves per plant in cassava

Treatments	Total number of leaves produced per plant				
	2 MAP	**4 MAP**	**6 MAP**	**8 MAP**	**Harvest**
T_1	70.33	122.33	280.33	356.33	400.00
T_2	69.67	127.50	292.00	349.67	401.33
T_3	69.83	135.17	310.33	349.67	403.00
T_4	51.33	120.33	248.33	338.00	380.33
T_5	65.17	122.67	285.67	319.00	388.67
T_6	70.67	136.17	371.67	398.33	447.00
T_7	52.83	106.00	257.33	313.67	369.67
T_8	69.50	131.33	276.33	368.67	407.67
T_9	58.17	94.67	255.67	317.00	368.00
T_{10}	71.83	124.67	384.00	417.67	478.00
Control	45.83	80.67	192.67	268.00	313.67
SE m (±)	1.86	7.54	17.99	13.58	17.86
CD (*P*=0.05)	5.476	22.241	53.070	40.047	52.696

Table 4. Effect of different nutrient levels on number of functional leaves per plant

Treatments	Number of functional leaves per plant				
	2 MAP	**4 MAP**	**6 MAP**	**8 MAP**	**Harvest**
T_1	64.67	106.83	109.67	101.33	127.33
T_2	64.00	115.17	121.00	72.00	116.00
T_3	63.50	118.17	139.33	96.00	120.00
T_4	45.50	109.50	86.00	80.33	111.67
T_5	59.50	110.83	105.33	54.67	115.33
T_6	64.50	119.67	200.67	120.00	198.67
T_7	47.50	93.50	84.33	61.33	91.00
T_8	63.50	118.67	113.67	88.00	155.00
T_9	52.83	88.67	84.33	45.67	66.00
T_{10}	66.17	111.17	213.67	91.00	192.00
Control	40.00	71.83	66.67	31.00	45.00
SE m (±)	1.59	6.33	17.83	11.85	20.74
CD (*P*=0.05)	4.686	18.665	52.606	34.943	61.181

Table 5. Tuber yield of cassava as influenced by different nutrient levels

Treatments	**Tuber yield (kg plant^{-1})**
T_1 - 100 % RDF	7.00
T_2 - 100 % RD N and P + 50 % K	6.17
T_3 - 100 % RD N and P + 25 % K	6.67
T_4 - 100 % RD N and P + 0 % K	5.33
T_5 - 50 % RDF	5.67
T_6 - 50 % RDF + PGPR Mix 1 liquid	8.00
T_7 - 50 % RD N and P + 25 % K	5.50
T_8 - 50 % RD N and P + 25 % K + PGPR Mix 1 liquid	7.83
T_9 - 50 % RD N and P + 0 % K	5.17
T_{10} - 50 % RD N and P + 0 % K + PGPR Mix 1 liquid	9.00
Control (No fertilizer application)	3.33
SE m (±)	0.45
CD (*P*=0.05)	1.384

The influence of nutrient management practices in cassava is evident from the supremacy of nutrient addition over the control of no fertilizer application. Although cassava performs well under marginal fertility conditions [11], it is a nutrient demanding crop and responds adeptly to nutrient application. As evident from Table 5, yields were nearly 55-170 percent higher than the control. Nitrogen in cassava plays a significant role in canopy development especially during the early stages of growth [12], P even though required in smaller quantity, it is necessary for the formation of storage roots [13] and K is important for synthesis and accumulation of starch in storage roots of cassava [14].

Among the treatments, the inclusion of PGPR consortium was found to be superior over other nutrient management practices. The consortium biofertilizer contains N fixers *Azospirillum lipoferum*, *Azotobacter chroococcum*, P solubiliser, *Bacillus megaterium* and K solubiliser, *Bacillus sporothermodurans* [15]. The efficacy of these microorganisms in nutrient solubilisation coupled with plant growth promoting ability through the release of plant hormones (auxins, gibberellins and cytokinins) as demonstrated by Lavakush et al. [16] favourably influenced nutrient acquisition, vegetative growth and photosynthetic ability in the plants. The data on the leaf production confirms the observation. The treatments T_{10} (50 % RD N and P + 0 % K + PGPR Mix 1 liquid), T_8 (50 % RD N and P + 25 % K + PGPR Mix 1 liquid) and T_6 (50 % RDF + PGPR Mix 1 liquid) included PGPR with 50 % N, P and different levels of K. As mentioned earlier K is vital nutrient in tuber crops. However, in the present study, the treatment of zero K addition (T_{10}) was found to perform best. The K efficiency of the variety Sree Pavithra assumes significance in this context. The research works conducted at CTCRI revealed the K efficient character of Sree Pavithra, wherein they obtained comparable tuber yields at both zero and 100 kg of K [2].

However, yields in T_3, T_4, T_7 and T_9, treatments with zero or 25 per cent K despite the variety being K efficient could not evoke yields on par with T_8 and T_{10} which is presumed to be the effects of the PGPR consortium. The better source strength in cassava would have enhanced translocation and bulking in tubers resulting in better tuber yields in the plants receiving PGPR consortium at 50 % N, P and 0/25/50 % K, and did not differ markedly among them.

3.2 Growth and Yield in Red Gram

The variations in the growth and yield performance of the intercropped red gram are depicted in Tables 6, 7 and 8. The plant height of red gram was not affected by the treatments given to cassava during the initial stages. Red gram intercropped in cassava were the tallest (180.50 cm) in treatment T_4 at 3 MAS and was comparable with treatments T_9, T_7, T_5, T_2 and T_8. The shortest plants (165.50 cm) were noted in control treatment, statistically on par with all treatments except T_4, T_9, T_7 and T_5. At 4 and 5 MAS also, T_4 recorded the tallest plants on par with T_9, T_7, T_5 and T_2. Irrespective of the growth stages, the lowest plant heights were recorded in control.

Perusal of the data on the leaf area in red gram revealed the highest leaf area (5165.68 cm^2) in treatment T_4 at 2 MAS and was statistically on par with treatments T_7, T_5, T_9, T_2 and T_3. At 4 MAS, significantly higher and comparable leaf area was observed in treatments T_4 and T_7 (2188.90 and 2150.56 cm^2 respectively). The treatment T_7 recorded the highest leaf area (1356.32 cm^2) at harvest, on par with treatments T_9 (1278.40 cm^2) and T_4 (1140.75 cm^2). Leaf area was found to be the lowest in control treatment irrespective of the stages of observation.

Table 6. Plant height of red gram as influenced by different nutrient levels of cassava

Treatments	Plant height (cm)				
	1 MAS	**2 MAS**	**3 MAS**	**4 MAS**	**5 MAS**
T_1	58.82	152.75	165.50	170.67	173.00
T_2	59.13	158.52	173.25	175.33	177.67
T_3	64.58	158.42	169.00	172.50	175.25
T_4	68.25	159.00	180.50	181.67	185.00
T_5	66.92	158.03	175.25	176.83	178.25
T_6	58.75	158.15	170.00	171.50	174.75
T_7	68.50	162.50	175.50	177.00	178.75
T_8	60.08	156.75	172.75	174.17	177.00
T_9	68.47	161.62	177.50	180.67	185.00
T_{10}	58.08	156.00	167.25	170.67	173.75
Control	68.75	153.75	165.50	168.33	172.75
SE m (±)	3.19	1.95	2.69	2.18	2.51
CD (*P*=0.05)	NS*	NS	7.920	6.417	7.404

** Non significant*

Table 7. Leaf area of red gram as influenced by different treatments in cassava

Treatments	Leaf area (cm^2)				
	1 MAS	**2 MAS**	**3 MAS**	**4 MAS**	**5 MAS**
T_1	279.90	3612.45	4962.93	1231.99	912.08
T_2	371.97	4145.65	6897.72	1761.50	1064.06
T_3	280.84	4093.06	5832.14	1638.82	957.09
T_4	315.91	5165.68	5964.56	2188.90	1140.75
T_5	381.03	4503.41	5971.19	1602.08	1001.55
T_6	270.49	3707.33	4643.53	1474.57	623.28
T_7	433.69	4956.30	7312.48	2150.56	1356.32
T_8	313.88	3282.90	5477.85	1565.74	822.21
T_9	614.68	4178.26	7782.61	1778.76	1278.40
T_{10}	183.04	3500.92	5038.80	1088.74	425.63
Control	234.05	2875.96	4177.81	954.32	347.44
SE m (±)	68.43	400.65	414.26	124.97	86.82
CD (*P*=0.05)	201.859	1181.924	1222.074	368.661	256.115

The yield attributes and yield of red gram are depicted in Table 8. In general, the treatments with 100 % RD N and P with 50 or 0 % K and 50 % RD N and P with 25 % or 0 % K in cassava were found to show markedly higher values for the number of pods per plant, pod weight, numbers of seeds per pod, pod and seed yields in red gram. Although slight variations were seen in the significantly higher effects, they remained comparable. The values were greater than that in PGPR inclusions and the lowest was noted in the control treatment.

Nutrient management was adopted for cassava alone and red gram was fertilized uniformly as per the recommendations of the crop (40:80:40 kg NPK ha^{-1}) and hence, the variations in growth seen would have been impacted by the growth of the main crop. It was evident that the treatments in which cassava growth was luxuriant as recorded in T_{10}, T_8 and T_6, red gram growth was shy, whereas in the other treatments, growth was significantly higher. Shading would have interfered with the growth in these treatments. The dominance of cassava with better nutrient acquisition in PGPR applied treatments in terms of leaf production and taller plants is evident in the data presented in Tables 3 and 4. This was reflected in the reproductive behaviour of red gram also. Pod yield was the highest in T_7, on par with T_9, T_2, T_4 and T_5 and seed yield was highest in T_9, on par with T_7, T_5, T_2 and T_4.

3.3 Competitive Indices

Comparison of the sole crop and intercrop yields of red gram reveal the yields to be nearly 31-64 per cent less under intercropping, affirming the poor performance of red gram as inter crop in cassava. This was again confirmed with the biological efficiency of the system as evaluated in terms of land equivalent ratio (LER) and land equivalent coefficient (LEC), computed based on the sole crop and inter crop yields. The LEC of none of the treatments was more than 0.25 and hence intercropping red gram with cassava is not considered advantageous with respect to LEC. However, treatments T_{10}, T_8 and T_6 registered LER of more than one, reflecting the advantage of intercropping in these treatments and intercropping red gram was considered unfavourable in all other treatments with respect to LER (Fig. 1).

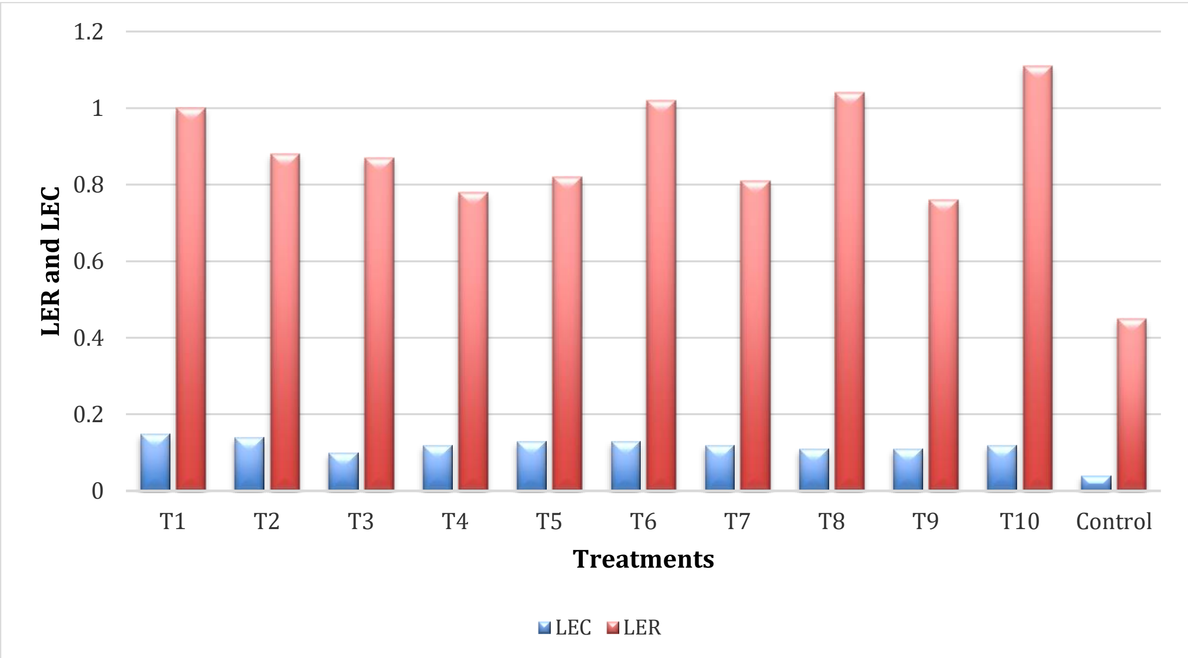

Fig. 1. Effect of treatments on LEC and LER in cassava + red gram intercropping

Table 8. Effect of different treatments in cassava on yield attributes and yield of red gram

Treatments	Number of pods per plant	Average pod weight (g)	Number of seeds per pod	Seed yield per plant (g)	Pod yield per plant (g)
T_1	24.00	0.26	4.25	4.83	6.46
T_2	24.33	0.32	4.63	5.80	8.18
T_3	22.33	0.26	4.25	4.09	5.16
T_4	28.33	0.34	4.59	5.79	8.03
T_5	26.00	0.29	4.62	5.81	7.93
T_6	23.00	0.22	4.00	4.24	5.66
T_7	27.00	0.35	4.54	5.90	8.50
T_8	20.00	0.19	4.04	3.34	4.64
T_9	27.33	0.30	4.42	5.92	8.31
T_{10}	19.00	0.23	4.02	3.52	4.87
Control	18.00	0.19	4.00	3.04	4.12
SE m (±)	1.62	0.02	0.10	0.23	0.26
CD (*P*=0.05)	4.791	0.057	0.294	0.678	0.774

4. CONCLUSION

The present study assessed the performance of different nutrient management practices on the growth and yield of K efficient cassava Sree Pavithra intercropped with red gram and the performance of the intercropped red gram. Application of consortium biofertilizer PGPR Mix 1 liquid formulation enhanced the growth and yield of cassava. The treatment with lower level of K combined with PGPR application (T_{10}) performed better in terms of plant height, total leaf number and number of functional leaves throughout the growth period. Tuber yield was also the highest with this treatment. The canopy growth of cassava affected the performance of red gram as an intercrop and the treatments with better plant growth of cassava was found inferior in terms of red gram production. Biological efficiency of cassava-red gram intercropping system was poor in terms of LER and LEC. The treatments with PGPR application only found beneficial as LER in these treatments were more than one. Intercropping red gram in cassava was ineffectual on considering LEC of the system.

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 the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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