Research Article

Current Horticulture **13**(1): 35–41, January–March 2025

DOI: 10.5958/2455-7560.2025.00004.7

Received: 03 December 2023; Accepted: 11 November 2024

Evaluation of short-duration cassava (*Manihot esculenta*) cropping system for profitability, energy efficiency and soil restoration

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Abstract

A two-year field experiment was conducted at ICAR-CTCRI, Thiruvananthapuram, Kerala, India, to assess the possibility of nutrient saving and develop viable short-duration cassava cropping system during 2013-15. Rice (*Oryza sativa* L.) var. Aiswarya was sown during the first season, followed by greengram [*Vigna radiata* (L.) R. Wilczek.] (var. Co-Gg-7), blackgram [*Vigna mungo* (L.) Hepper] (var. Co-6) and soybean (*Glycine max* (L.) Merr.) (var. JS-95-60). Thereafter, short-duration cassava was planted in split plot design with two varieties, Sree Vijaya and Vellayani Hraswa, in main plots and combination of three preceding pulses and two fertility levels to cassava (full farmyard manure (FYM), N and K (FYM @ 12.5 t/ha, NPK @ 100:0:100 kg/ha); half FYM and N, full K (FYM @ 6.25 t/ ha, NPK @ 50:0:100 kg/ha) in subplots. Rice-pulse-short-duration cassava was productive, profitable, energy efficient and nutrient saving. Both varieties were suitable for crop intensification. During first year, pulse crops were equally compatible. In subsequent year, greengram proved superior. By the second year, pH, organic C, available N, P and K were not significantly affected, but available N, P and K status was higher under pulses. The tuber yield of cassava (30.82 t/ha), tuber equivalent yield (47.39 t/ ha), production efficiency (131.63 kg/ha/day), energy equivalent (234.07 x 10^3 MJ/ha) and profit (additional profit of ₹ 95,758/ha over sole cassava) were higher for rice (var. Aiswarya)-blackgram (var. Co-6)-short-duration cassava (var. Sree Vijaya) system at the reduced fertility level, resulting in a saving of half FYM and, N and full P.

Key words: Diversification, Cassava-based system, Tuber equivalent yield, Economics, Energy efficiency

Cassava (*Manihot esculenta* Crantz) plays a significant role in food and nutritional security (Sunitha *et al.*, 2024). It is the primary staple food for more than 800 million people in the world, mostly in the poorest tropical countries (Lebot, 2019). The normal duration of cassava is 9-24 months and most of the varieties give the maximum targeted yield at 10-12 months. Presently much emphasis is given to crop diversification, to increase productivity, especially under climate change (Nedunchezhiyan *et al.*, 2022). Hence there is a preference for early-maturing varieties of cassava (6-7 months) as a sequential crop. Short-duration cassava varieties proved promising for better utilization of resources, diversification of food basket and income (Suja *et al.*, 2010a; Suja *et al.*, 2010b; Suja *et al.*, 2011; Suja and Sreekumar, 2015).

The practice of growing a grain-or forage-legume like cowpea, peanut, pigeonpea, velvet bean, *Centrosema pubescens*, *Indigofera hirsuta* and *Pueraria phaseoloides* prior to cassava and incorporation of forages and crop residues into the soil was reported to improve soil fertility and yield of normal duration cassava cv. Mcol 1684 (Howeler, 2012). The intercropping of legumes and groundnut and vegetables like cucumber (*Cucumis sativus*), okra (*Abelmoschus esculentus*) and *Amaranthus* (*Amaranthus viridis*) reduced the yield of cassava of 10-month cycle (Prabhakar *et al.,* 1983; Mohankumar and Ravindran, 1990).

Earlier studies indicated that sequential cropping of vegetable cowpea followed by short-duration cassava was a profitable production system (Suja and Sreekumar, 2015). However, information on cropping systems involving short-duration cassava in rice (*Oryza sativa*)-based system is limited. Hence, an experiment was conducted to develop feasible cropping system involving short-duration cassava and pulses in rice-based system, to assess the scope for nutrient saving and evaluate growth dynamics, yield, soil productivity, system productivity, profitability and energy equivalent of the system.

MATERIALS AND METHODS

The field experiment was conducted during May-June for two consecutive years (2013-2015) at ICAR-CTCRI, Thiruvananthapuram, Kerala (8° 29'N, 76° 57'E, 52 m altitude. The site experiences a typical humid tropical climate. The total rainfall, maximum temperature, minimum temperature and relative humidity during the crop growth period during the first and second years were 1649 and 2046 mm, 31.37 and 31.46°C, 23.90 and 23.76°C and 76.31 and 78.94% respectively. The soil is a well-drained acid Ultisol with pH 4.65 and is characterized

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by low available N (145.30 kg/ha), high available P (26.50 kg/ha), medium available K (155.35 kg/ha) and organic C (0.75%) contents.

Rice var. Aiswarya was sown during first season, followed by short-duration greengram (var. Co-Gg-7), blackgram (var. Co-6) and soybean (var. JS-95-60). Thereafter short-duration cassava was planted. The experimental design followed was split plot, with two cassava varieties, Sree Vijaya and Vellayani Hraswa, in main plots and combination of three preceding pulses and two fertility levels to cassava [F1:full FYM, N and K ((FYM @ 12.5 t/ha, NPK @ 100:0:100 kg/ha); F2: half FYM and N, full K ((FYM @ 6.25 t/ha, NPK @ 50:0:100 kg/ha)] in subplots. Sole crop of cassava under full dose of manures and fertilizers were also maintained for comparison. The pulse crop was fertilized with P and cassava was not given P. The gross plot size was 5.4 m x 5.4 m (36 plants), accommodating 16 net plants of cassava.

Aiswarya (PTB 52), a medium-duration rice variety (120-125 days maturity) is resistant to blast and blight diseases, and brown planthopper (KAU, 2016). Sree Vijaya is an early maturing variety with 6-7 months duration. Vellayani Hraswa is a high-yielding early variety with 5-6 months duration. Co-Gg-7 is a short duration greengram variety that matures in 60-65 days. Co-6 is a short duration blackgram variety that matures in 60-65 days. JS-95-60 is an extra early culture that matures in 82-88 days.

Rice var. Aiswarya was sown on 15 May 2013 and 1 June 2014 directly under dry condition at a spacing of 20 cm x 15 cm. The agro-techniques and nutrient management practices were followed according to package of practices recommendation of KAU (KAU, 2016). After the harvest of rice crop in September, pulse crops were sown on 21 September and 8 October respectively during the two years at a spacing of 30 cm x 15 cm and seed rate of 20 kg/ha. Pulse crops were fertilized with NPK @ 20:30:30 kg/ha. Full dose of P and K and half N were applied basally at sowing and the remaining half N was applied 15-20 days after sowing (DAS). Pulse crops were harvested by 75-80 days and short-duration cassava varieties were planted in mounds spaced 90 cm x 90 cm on 11 December 2015 and 29 December 2016. Farmyard manure as per treatments was applied to cassava at the time of planting. For cassava, as per treatment, half N and K were applied immediately after sprouting of cassava setts. After one month, the remaining quantities of N and K were applied along with weeding and earthing up. Cassava was harvested at 6 months after planting.

Biomass measurements were taken 2, 4 and 6 months after planting by uprooting three cassava plants at random per plot at each stage. Plants were then separated into leaves, stems and tubers, air dried and then oven dried at 70°C to constant weight and dry weight of each plant part was recorded and the total plant dry weights were computed and expressed as g per plant. The tuber biomass and total biomass production of cassava at harvest were also calculated and expressed as t/ha. From values of dry matter, various growth indices were computed using growth analysis techniques (Hunt, 1982). These were: crop growth rate (CGR), tuber bulking rate (TBR), relative growth rate (RGR), mean TBR and harvest index (HI).

The yield of rice and pulses were taken and expressed in t/ha. At harvest, the fresh tuber yield of cassava was computed in t/ha based on the data taken from the net plants. The dry matter and cyanogenic glucoside contents of cassava tubers were determined by standard procedures (Indira and Sinha, 1969). Based on the yield of the component crops, tuber equivalent yield and production efficiency and energy equivalent yield were worked out (Devasenapathy *et al*., 2009).

Total cost of cultivation and gross returns were calculated from average input cost and labour cost for all operations and average market price of the produce, respectively during the period of investigation. Based on this net income and benefit:cost ratio (B:C ratio) were computed as follows:

Net income (₹/ha)=gross income−gross cost of cultivation

B:C ratio=gross income ÷gross cost

Soils were sampled at 0-15 cm depth after harvesting of the crop every year. Three samples were collected per plot. The soil samples were air-dried and sieved through 2-mm sieve before analysis and stored in plastic covers. The soils were analyzed for pH (1:2.5 soil: water suspension) using pH meter with glass electrode, organic carbon by Walkley and Black rapid titration method (Walkley and Black, 1934) available N by alkaline permanganate method (Subbiah and Asija, 1956), available P content was determined by Bray I method as described by Jackson (1973) and readings were taken in spectrophotometer and available K (in neutral 1 N ammonium acetate extract) using a flame photometer.

Two-way analysis of variance (ANOVA) for split plot design (analysing the data from different years separately) was carried out to compare treatment differences for different plant and soil parameters using SAS statistical software (SAS, 2010). The critical difference (CD) test was used at the 0.05 level of significance to compare the treatment means.

RESULTS AND DISCUSSION

Biomass production and growth dynamics

During first year, main effect of pulse was significant for tuber biomass and mean TBR, with soybean outperforming. The interaction effect between pulse and fertility level was significant for tuber biomass at 2 MAP, total biomass at 4 MAP and tuber and total biomass at 6 MAP (Fig.1). The total biomass production and its partitioning to leaf, stem and tuber at 2 and 4 MAP was higher when blackgram preceded and cassava was fertilized at the full dose. By 6 MAP (harvest stage) these attributes were favoured when soybean preceded and cassava was fertilized at the full dose (Fig. 1). At harvest, total and tuber biomass production, crop growth rate, tuber bulking rate, mean tuber bulking rate, relative growth rate and harvest index of short-duration cassava were significantly higher when soybean preceded and cassava was fertilized at the full dose (Table 1, Figs. 1, 2). As expected, pulse crops prior to cassava were beneficial for its growth compared to sole cassava.

During subsequent year, at 2 MAP, total dry matter production and its partitioning to leaf, stem and tuber were higher in cassava fertilized at reduced level of fertility and preceded by blackgram. Thereafter, sole cassava outperformed over different cropping systems (Fig. 1). At harvest, tuber biomass production (14.24 t/ha) and total biomass production (19.37 t/ha) of sole cassava was higher, which was on a par with cassava under reduced level of fertility preceded by blackgram (BG + F2) (10.04, 15.91 t/ha respectively) (Table 1). The CGR, TBR and HI of sole cassava was higher throughout different stages (Fig. 2). Mean TBR of blackgram + F1 (5.25 g/day) and soybean + F1 (5.48 g/day) were on a par with sole cassava (5.28 g/day) (Table 1). In first phase (2-4 MAP), RGR of cassava in systems preceded by all the pulses was equivalent to sole cassava. In second phase (4-6 MAP), RGR of cassava in systems preceded by blackgram and greengram was similar to that of sole cassava (Fig. 2). This indicates the scope of sequential cropping of rice, pulses and cassava.

Rice-pulse-short-duration cassava proved to be feasible. Both Vellayani Hraswa and Sree Vijaya were suitable for sequential cropping. During first year, greengram, blackgram and soybean were equally compatible in rice-based cropping systems involving short-duration cassava. In subsequent year, greengram proved superior and exerted significant impact on cassava tuber yield. There was a possibility to save half FYM and N and full P to short-duration cassava, especially when blackgram and greengram preceded cassava.

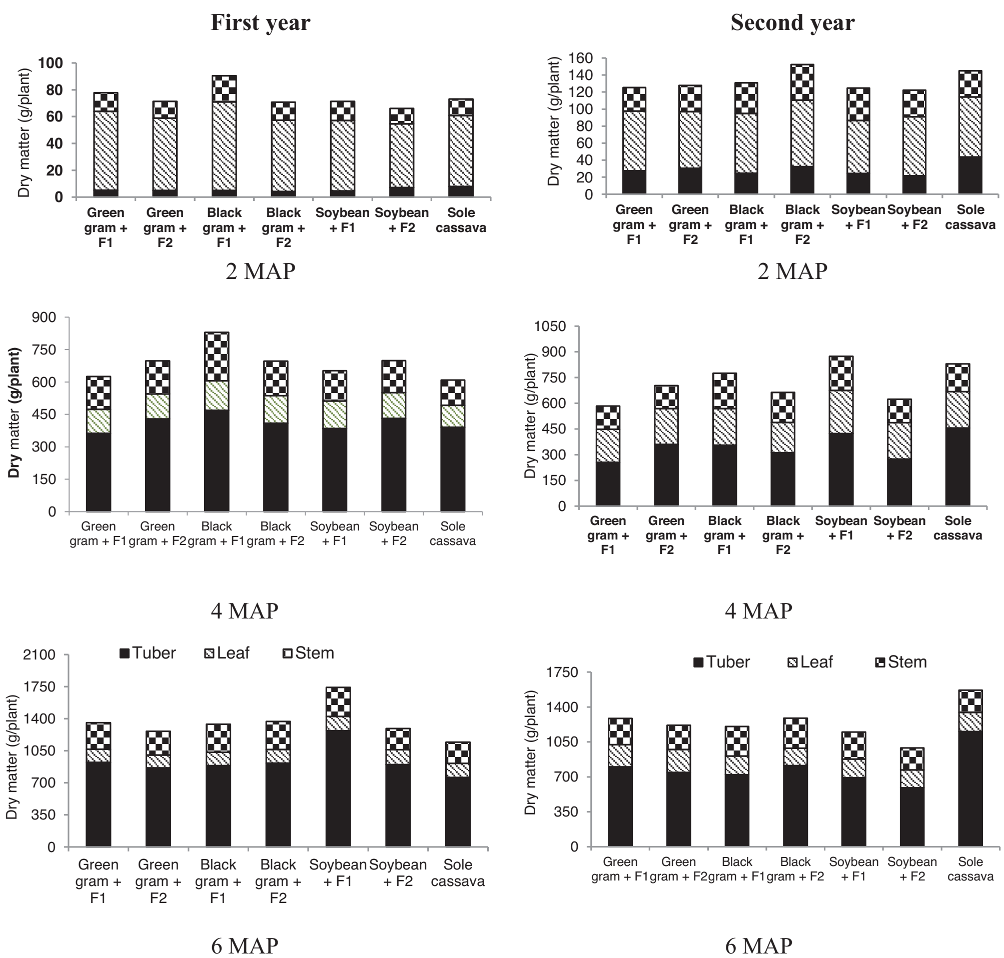

Fig. 1: Interaction effect between pulse crops and fertility levels on biomass production and partitioning at various phases in cassava

Table 1: Interaction effect between pulse crops and fertility levels on biomass production of cassava

Interaction effect between pulse and fertility level	Tuber biomass (t/ha)		Total biomass (t/ha)		Mean tuber bulking rate (g/day)	
	First year	Second year	First year	Second year	First year	Second year
Greengram + F1	11.41	9.88	16.74	15.87	5.14	4.28
Greengram + F2	10.66	9.19	15.59	15.02	4.80	4.60
Blackgram + F1	10.98	8.92	16.53	14.87	4.94	5.25
Blackgram + F2	11.30	10.04	16.91	15.91	5.09	4.87
Soybean + F1	15.64	8.53	21.51	14.20	7.04	5.48
Soybean + F2	11.10	7.28	15.95	12.22	4.99	4.25
Sole cassava	9.37	14.24	14.11	19.37	4.22	5.28
CD (p=0.05)	2.865††	4.736†	4.039††	5.631†	1.289††	0.165††

†Control vs treatment; †† pulse x fertility level

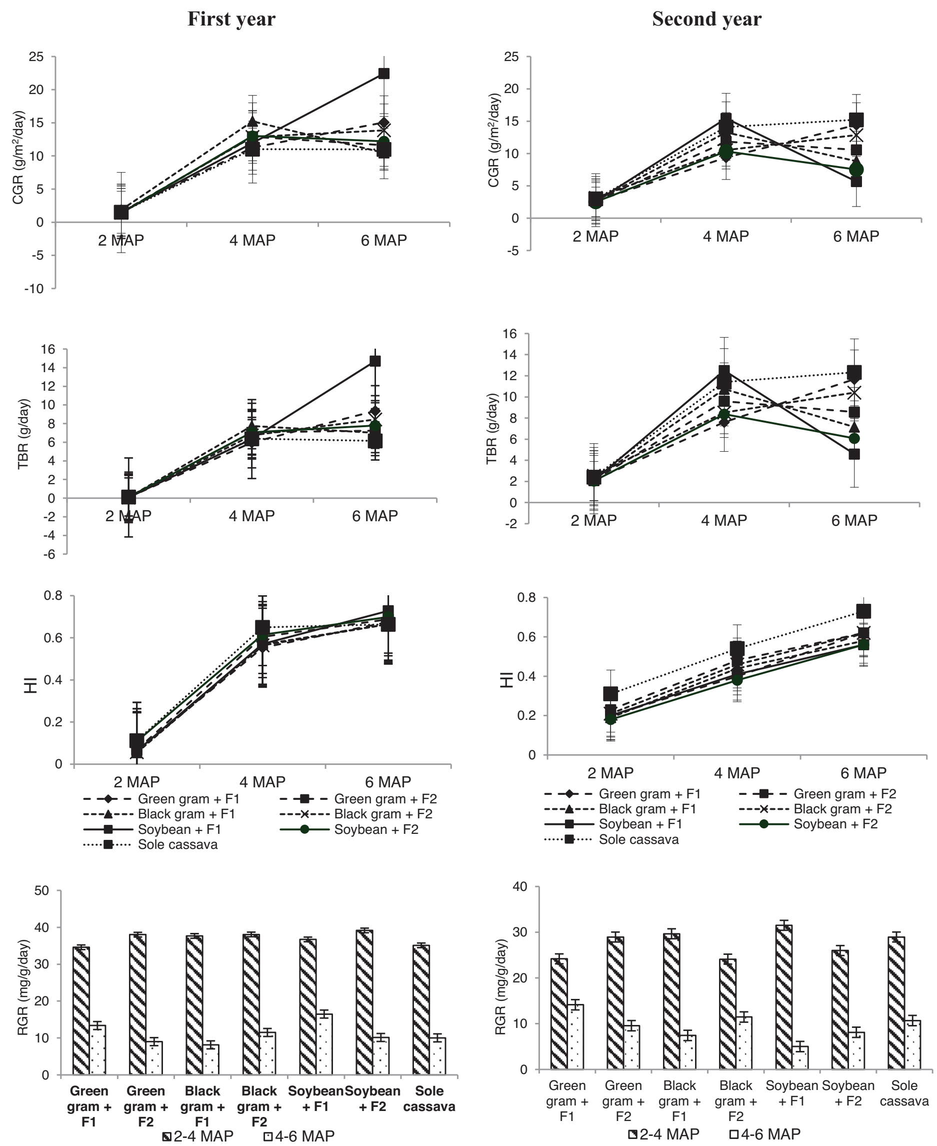

Fig. 2: Growth parameters of cassava at various stages as affected by pulse crops and fertility levels

Yield, and quality of cassava

The control vs treatment was significant for tuber yield during both years, number of tubers in first year and mean weight of a tuber in second year (Table 2). During first year, rice-blackgram-short duration cassava at reduced fertility level resulted in highest yield on a par with sole cassava (both varieties). This may be due to the significantly higher number of tubers produced and almost similar mean tuber weight in above system. Moreover, cassava crop might have benefitted from residual nitrogen fixed by blackgram as well as organic matter added by blackgram residues after its harvest as reported by Njoku and Muoneke (2008) in cowpea-cassava system. However, in the subsequent year, sole cassava out yielded, followed by rice-greengram/blackgram-short duration cassava. This might be due to significantly higher mean weight of tuber in sole cassava due to lack of resource constraints. The tuber length, tuber girth, dry matter and cyanogenic glucoside content of tubers remained unaffected due to cropping systems and fertility levels. This indicates there is a scope for crop diversification involving sequential cropping of pulses and cassava in rice-based systems (Table 2).

Table 2: Effect of cropping systems on yield, yield attributes and quality of short-duration cassava

Cropping systems and fertility levels	Tuber yield (t/ha)		No. of tubers		Mean weight of a tuber (kg)		Tuber length (cm)	Tuber girth (cm)	Tuber dry matter content (%)	Cyanogenic glucoside (μg/g)
	First year	Second year	First year	Second year	First year	Second year				
R-GG-SV (F1)	29.98	26.97	11	9	0.227	0.232	23.22	19.88	36.10	45.9
R- GG-SV (F2)	27.96	25.15	8	10	0.270	0.206	25.22	15.33	39.75	27.2
R- BG-SV (F1)	33.28	24.34	10	10	0.280	0.204	26.33	16.67	36.74	27.7
R- BG-SV (F2)	34.78	26.86	10	10	0.287	0.222	25.78	16.00	35.00	26.4
R- SB-SV (F1)	30.07	25.85	8	8	0.291	0.246	24.22	15.66	39.40	47.4
R- SB-SV (F2)	30.14	21.19	7	7	0.331	0.233	26.11	16.89	39.52	41.4
R-GG-VH (F1)	27.17	26.65	6	7	0.370	0.351	30.22	17.33	43.84	24.9
R- GG-VH (F2)	33.43	26.11	7	7	0.386	0.294	29.22	17.11	36.39	40.5
R- BG-VH (F1)	25.51	22.07	7	6	0.314	0.264	28.33	16.11	41.84	29.1
R- BG-VH (F2)	29.18	24.34	7	7	0.328	0.281	29.89	15.89	44.29	38.4
R- SB-VH (F1)	33.32	16.02	6	4	0.490	0.285	29.11	17.33	44.10	24.0
R- SB-VH (F2)	22.80	15.45	6	5	0.324	0.221	26.89	14.44	41.61	36.6
Sree Vijaya (sole)	29.83	32.49	8	8	0.298	0.325	26.77	17.44	35.96	41.8
Vellayani Hraswa (sole)	31.47	34.95	7	6	0.384	0.450	27.33	17.89	43.45	41.8
CD (p=0.05)	7.622	3.36	1.325	NS	NS	0.033	NS	NS	NS	NS

R Rice, *SV* Sree Vijaya, *VH* Vellayani Hraswa, *GG* Greengram, *BG* Blackgram, *SB* Soybean, *F1* full dose of FYM and NPK, *F2* half dose N, full FYM, P and K

Gbanguba *et al.* (2014) also reported that cultivating rice after harvesting cassava + legume intercropping, enhanced soil fertility and had beneficial effects on growth and productivity of rice crop.

System productivity and profitability

Averaging over two years, tuber yield of cassava (30.82 t/ha), tuber equivalent yield (47.39 t/ha), production efficiency (131.63 kg/ha/day) and energy equivalent (234.07 x 10^3 MJ/ha), were higher for the system, rice (Aiswarya)-blackgram (Co-6)-short-duration cassava (Sree Vijaya) (at reduced fertility level) (Table 3). The above system was productive, profitable (additional profit of ₹ 95,758/ha over sole cassava), energy efficient and nutrient saving (could save half FYM and N and full P to short-duration cassava) (Table 4). This corroborates the earlier findings that vegetable cowpea or grain cowpea in sequence before short-duration cassava is a viable proposition than sole cassava (Suja and Sreekumar, 2015).

Table 3: System productivity, tuber equivalent yield, production efficiency and equivalent energy of cropping systems involving short-duration cassava vs sole cassava (mean of two years)

Cropping system and fertility level	System productivity			Tuber equivalent yield (t/ha)				Production efficiency (kg/ha/day)	Equivalent Energy (*10³ MJ/ ha)
	Rice (t/ha)	Pulse (kg/ha)	Cassava (t/ha)	Rice	Pulse	Cassava	Total		
R-GG-SV (F1)	4.34	727.24	28.48	10.85	4.24	28.48	43.57	121.02	217.77
R-GG-SV (F2)	4.10	715.30	26.56	10.25	4.17	26.56	40.98	113.83	204.13
R-BG-SV (F1)	4.20	1177.09	28.81	10.50	6.38	28.81	45.69	126.91	223.34
R-BG-SV (F2)	4.23	1108.68	30.82	10.57	6.01	30.82	47.39	131.63	234.07
R-SB-SV (F1)	4.05	757.63	27.96	10.13	4.10	27.96	42.19	117.19	211.92
R-SB-SV (F2)	3.98	720.25	25.67	9.94	3.90	25.67	39.50	109.73	197.77
R-GG-VH (F1)	4.32	710.08	26.91	10.79	4.14	26.91	41.84	116.22	208.52
R-GG-VH (F2)	4.07	709.25	29.77	10.16	4.14	29.77	44.06	122.40	221.63
R-BG-VH (F1)	4.32	1025.33	23.79	10.80	5.55	23.79	40.14	111.51	194.81
R-BG-VH (F2)	3.98	930.38	26.76	9.94	5.04	26.76	41.74	115.94	206.37
R-SB-VH (F1)	4.25	705.58	24.67	10.63	3.82	24.67	39.12	108.66	195.18
R-SB-VH (F2)	4.11	687.75	19.13	10.28	3.73	19.13	33.13	92.01	162.31
Sree Vijaya (sole)			31.16			31.16	31.16	86.56	174.50
Vellayani Hraswa (sole)			33.22			33.22	33.22	92.28	186.03

R Rice, *SV* Sree Vijaya, *VH* Vellayani Hraswa, *GG* Green gram, *BG* Black gram, *SB* Soybean, *F1* full dose of FYM and NPK, *F2* half dose N, full FYM, P and K

Table 4. Economics of cropping systems involving short-duration cassava vs sole cassava (mean of two years)

Cropping system and fertility level	Net returns (₹/ha)	Added profit (₹/ ha)	B:C ratio
R-GG-SV (F1)	374386	11614	2.80
R- GG-SV (F2)	345422	-17351	2.70
R- BG-SV (F1)	428215	65443	3.06
R- BG-SV (F2)	458531	95759	3.26
R- SB-SV (F1)	362836	63.63	2.74
R- SB-SV (F2)	329894	-32879	2.63
R-GG-VH (F1)	349295	-44377	2.68
R- GG-VH (F2)	392478	-1194	2.93
R- BG-VH (F1)	342567	-51105	2.64
R- BG-VH (F2)	377654	-16019	2.86
R- SB-VH (F1)	314103	-79570	2.51
R- SB-VH (F2)	232381	-161291	2.15
Sree Vijaya (sole)	362772		4.47
VellayaniHraswa (sole)	393672		4.76

R Rice, *SV* Sree Vijaya, *VH* Vellayani Hraswa, *GG* Greengram, *BG* Blackgram, *SB* Soybean, *F1* full dose of FYM and NPK, *F2* half dose N, full FYM, P and K

Soil nutrient status

Chemical analysis of soil samples in first year, after rice crop, indicated that the pH was 4.851, organic C was medium (0.62) and available N and K contents, low and P content, high (65.54, 34.91 and 54.51 kg/ha). After the second crop of pulse, on an average, pH did not change (4.84), but there was improvement in organic C, available N and P and considerable increase in K status of the soil (0.87%, 84.31, 54.95, 193.16 kg/ha respectively). After short-duration cassava, interaction, pulse x fertility level, which is more important in the present study, was significant for pH, organic C and available P. The pH and available P status was significantly higher under full nutrient dose, when black gram preceded cassava. Greengram when preceded cassava could enhance the organic C status significantly under full nutrient dose. Available N and K were not affected by the various treatments. However, it can be seen that taking a pulse crop before cassava could maintain a higher available K status.

By second season, pH, organic C, available N, P and K was not significantly affected, but available N, P and K status was higher under cropping systems involving pulses. Gbanguba *et al.* (2014) also observed higher soil organic carbon, total N, available P, K, secondary nutrients such as Ca and Mg and cation exchange capacity under cassava-legume association relative to natural fallow. Thus, it can be concluded that growing pulses before short-duration cassava helped maintain soil fertility and impact was more pronounced with blackgram, which may be due to its greater biomass production.

CONCLUSION

Thus, rice-blackgram-short-duration cassava was productive, profitable and energy efficient, besides maintaining soil health. The system will also help to diversify our food basket and achieve self-sufficiency in pulse production in India.

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