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Soil test based nutrient management for short-duration cassava (*Manihot esculenta*): Analysis of growth, biomass, yield, quality, nutrient uptake and soil nutrient status

G. SUJA*, K. SUSAN JOHN AND J. SREEKUMAR

Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala 695 017

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ABSTRACT

Short-duration (6-7 months) cassava (*Manihot esculenta* Crantz) enables better utilization of resources and crop diversification than the normal duration crop (9-10 months). Field experiments were conducted for three years (2004-2007) at Thiruvananthapuram, Kerala, in a lowland situation akin to rice fallow to standardise nutrient management practices for short-duration cassava. Five short-duration cassava lines (Vellayani Hraswa, Kalpaka, Sree Jaya, Sree Vijaya and triploid 2-18) were evaluated under 4 levels of fertility (12.5 t FYM (100%)+ NPK, 75% FYM + NPK, 50% FYM + NPK and NPK fertilization based on soil test data) in split plot design with 3 replications. 'Triploid 2-18' yielded significantly higher fresh tubers (28.45 t/ha) than other four cultivars. The high yielders produced appreciably taller plants and more leaves, higher total and tuber biomass. Nutrient management based on soil test data for organic C, available P and K status along with 12.5 t/FYM, which resulted in the saving of full P, 10% N and 15% K by the third year, promoted plant height, leaf production and nutrient uptake, produced higher tuber yield (24.18 t/ha), tuber and total biomass, dry matter and starch content of tubers besides maintaining organic C, available N, P and K status of the soil, leading to positive nutrient balance.

Key words: Farmyard manure, HCN, Nutrient balance, Short duration cassava, Soil testing, Starch

Cassava (*Manihot esculenta* Crantz) is an important tropical tuber crop that plays a significant role in the food and nutritional security of the rural households as well as the coastal and tribal areas. During the past two decades, cassava cultivation in uplands has declined, whereas it has caught up in lowlands sequentially after main crop of rice or banana and vegetables. Short-duration or early-bulking lines of cassava that can be raised with the available moisture after harvest of rice enables small and marginal rice farmers for the effective utilization of resources like land, moisture and nutrients as well as diversification of on-farm enterprise and income.

Cassava is a highly nutrient exhausting crop, which responds well to manuring and fertilization. A crop of cassava yielding 30 t/ha of fresh tubers in 10-month-cycle removes 180 to 200-15 to 22-140 to 160 kg N-P-K/ha. The prevalent nutrient recommendation for cassava is farmyard manure (FYM) @ 12.5 t/ha and 100:22:83.3 kg N-P-K/ha. This high manurial dose is very expensive (Rs. 13,000/ha) and so many cassava farmers do not adopt the above recommendation. However, when short-duration varieties are integrated into the existing cropping systems, utilization of residual moisture and nutrients will be possible by modifying the current management practices. Hence, it is imperative to assess the possibility of saving costly nutrient inputs by formulating suitable nutrient management practices for short-duration cassava in lowland. Though preliminary investigations on the nutrient management of short-duration casava have been carried out (Pamila *et al*., 2006), sound recommendation on their nutrient management practices is still lacking. Hence the objectives of the present study were to have a comparison of biomass production, yield and quality of the short-duration/early-bulking lines of cassava as well as residual soil nutrient status under four levels of fertility in a lowland situation similar to rice fallows.

***Corresponding author** (E mail: sujagin@yahoo.com)

MATERIALS AND METHODS

Field experiments were conducted in a lowland situation akin to a rice fallow for three consecutive years during November-May in 2004-05, 2005-06 and 2006-07 at Central Tuber Crops Research Institute (CTCRI), Sreekariyam, Thiruvananthapuram (8^0 29'N, $76^0$57'E, 64 m altitude), Kerala. The soil of the site was a well drained acid Ultisol with pH 4.35 rated as medium for organic C (0.62%), and low for available N and K (234 and 142.3

kg/ha) and high for available P (28.3 kg/ha). The site experiences a typical humid tropical climate with mean annual rainfall of 1,846 mm and mean maximum temperature of 31.3°C and minimum temperature of 25.1°C. The experiment was laid out in split plot design with three replications. Five short-duration/early-bulking lines of cassava (Kalpaka, Sree Jaya, Sree Vijaya, Triploid 2-18 and Vellayani Hraswa) in main plots and four fertility levels (100% FYM (12.5 t/ha) + Recommended dose of 100% NPK fertilizers (RDF) i.e., @ 100:22:83.3 kg N-P-K/ha, 75% FYM + 75% RDF, 50% FYM + 50% RDF and fertility level based on soil test data (95:17.5:87.5, 95:15.3:79.2 and 90:0:70.8 kg N-P-K/ha along with 100% FYM were applied in 2004, 2005 and 2006, respectively) were assigned to the sub plots. 'Sree Jaya' and 'Sree Vijaya' are the released short-duration varieties and triploid 2-18 is a promising early bulking triploid line from CTCRI. 'Kalpaka' and 'Vellayani' 'Hraswa' are the released varieties from Kerala Agricultural University.

Prior to planting cassava, a crop of green manure (cowpea 'C-152') was raised and incorporated at 45-60 days that added 17.52, 15.85 and 18.45 t/ha fresh biomass, respectively during 2004, 2005 and 2006. The average nutrient content was 3.4-0.3-2.3% N-P-K, which contributed to N, P and K @ 160.8, 14.2, 108.8 kg/ha in 2004, 140.1, 12.36, 94.8 in 2005, 181.9, 16.1, 123.1 in 2006. Planting and the other agronomic practices were done in accordance to the package of practices recommendations (KAU, 2002). Cassava was planted in mounds of height 25-30 cm spaced at 90 cm x 90 cm. FYM (0.5-0.2-0.4% N-P-K) was applied at the time of planting as per the treatments. Urea, Mussorie rock phosphate and muriate of potash to supply N, P and K at the various fertility levels were used. The nutrient status of the soil after 2 weeks of incorporation of green manure cowpea was analysed. The soil test values for organic C, available N, P and K were 0.67%, 236.55, 14.2, 112.2 kg/ha in 2004; 0.66%, 162.1, 19.5, 151.3 kg/ha in 2005; 0.76% and 133.1, 66.4, 171.4 kg/ha in 2006, respectively. During each year, the fertility level based on soil test data was arrived at based on the nutrient status of the soil after cowpea incorporation. The whole of P and half the doses of N and K were applied immediately after the sprouting of the setts. After one month, the remaining quantities of N and K were applied along with weeding and earthing up. The crop was planted during November in each year, rain-fed and harvested after 6 months. The rainfall received during November-May in 2004-05, 2005-06 and 2006-07 was 585, 660.1 and 348.4 mm, respectively. The experiment was carried out in same field for three years.

The starch and cyanogenic glucosides in tubers, plant nutrient uptake soil fertility parameters were estimated by standard analytical procedures. The net income and benefit cost (B:C) ratio were also computed. Pooled analysis of data was also done.

RESULTS AND DISCUSSION

Growth attributes

Considering the average of 3 years, growth attributes (plant height, leaf production and stem girth) at different stages varied significantly among the varieties (Table 1). 'Triploid 2-18' was significantly taller, though on a par with 'Kalpaka' and/or 'Sree Jaya' during 2 and 4 MAP. 'Vellayani Hraswa' produced significantly more number of leaves throughout the growth cycle. Stem girth of 'Kalpaka', 'Sree Jaya', 'Sree Vijaya' and 'Triplod 2-18' was higher and almost same at various stages. 100% FYM+NPK, 75% FYM+NPK and fertility level based on soil test data favoured plant height at all stages. Full FYM+NPK produced maximum leaves at the early and mid-growth stage. Stem girth remained unaffected due to various fertility levels. The interaction between varieties and fertility levels was not significant.

Tuber biomass and total biomass production

Tuber and total biomass production did not vary significantly among the varieties, except during the first year, in which 'triploid 2-18' produced significantly higher tuber (12.39 t/ha) and total biomass (21.55 t/ha) (Table 1 and 2). Considering the mean of 3 years, 'triploid 2-18' produced significantly higher tuber (10.58 t/ha) and total biomass (16.93 t/ha). Suja *et al*. (2010) has reported the high biomass production potential of 'triploid 2-18', when harvested at 6 months, enabling its suitability for industrial exploitation.

During 2004-05, tuber biomass and total biomass remained unaffected due to different soil fertility levels (Table 1 and 2). In 2005-06, the plots with full FYM+NPK resulted in significantly higher tuber biomass yield (7.69 t/ha). However, total biomass yield under 100% and 75% manures and fertilizers as well as fertilization based on soil test results were statistically similar. While in 2006-07, application of nutrients based on soil test data resulted in tuber dry biomass yield (11.58 t/ha) and total dry biomass production (18.53 t/ha) on par with that of full FYM+NPK (12.12 and 19.01 t/ha, respectively) indicating the possibility of saving fertilizer input. Pooled analysis indicated that application of nutrients based on soil test data was sufficient to realize the same tuber and total biomass production as with the full FYM+NPK. However, the interaction between varieties and fertility levels was not significant during all the years.

Fresh tuber yield

Varietal effect on tuber yield was significant during the first and second year. During the first year, 'triploid 2-18' out yielded all other varieties (Table 2). The other four varieties were on par. In the second year, 'triploid 2-18' and 'Vellayani Hraswa' being on par were superior to other varieties. This may be attributed to the substantially higher canopy size, crop growth rate, tuber bulking rate and total biomas production observed in these varieties (Suja *et al.*, 2010). During the third year, varietal effect on tuber yield was less pronounced and 'triploid 2-18', 'Vellayani Hraswa' and 'Kalpaka' performed equally well. The early bulking nature and superior yield performance of 'triploid 2-18' and 'Vellayani Hraswa' were reported earlier also Suja and Susan John, 2008; Suja *et al*., 2010)

During the first year of study, the tuber yield was not profoundly influenced by fertility levels and fertility level of 50% FYM+NPK produced satisfactory tuber yield of 27 t/ha, presumably due to native soil fertility. In the second year, application of full FYM+ NPK produced significantly higher yield (19.73 t/ha). During the third year, fertility level based on soil test data (FYM @ 12.5 t/ha and N:P:K @ 90:0:70.8 kg/ha) and 75% FYM+NPK produced almost similar tuber yield to that of full FYM+NPK, resulting in the saving of nutrients (Table 2). This is in accordance with the reports of earlier workers that soil test based fertilizer recommendation was feasible in different agro-climatic zones, wide range of soils and crops in India (Sanyal and Chatterjee, 2007; Naidu *et al.,* 2008).

Pooled analysis of yield data indicated the superiority of triploid 2-18 over other varieties. Further, nutrient management based on soil test data for organic C, available P and K status, resulted in the saving of full P, 10% N and 15% K by the third year and was found to be sufficient for short-duration cassava (Table 2). In the present study it was possible to save the entire quantity of fertilizer P, the costliest among the major nutrients on per unit nutrient basis, by following the soil test based nutrient management. Moreover a low recovery of applied P fertlizers (15-25%) due to fixation in the soil and the possibility that manufactured phosphatic fertilizers will become expensive in the near future due to the limited deposits of natural sources of sulphur and high grade rock phosphates, the two basic ingredients needed for the manufacture of phosphatic fertilizers, strongly suggests the importance of need based application of fertilizers.

Tuber quality

There was not much variation in the dry matter content of tubers among the short-duration lines tested, except during the first year, in which 'Vellayani Hraswa' had the highest dry matter content in tubers, on par with that of 'Sree Jaya' and 'Sree Vijaya' (Table 2). Starch content did not vary appreciably among the varieties in the first year. In the second and third years, 'Sree Jaya' had significantly higher starch content. Averaging across the three years, 'Vellayani Hraswa' had significantly highest tuber dry matter content and 'Sree Jaya' the highest starch content. 'Vellayani Hraswa', 'Kalpaka', 'Sree Jaya' and 'Sree Vijaya' had appreciably lower cyanogen content and good cooking quality, while 'triploid 2-18' exceeded the tolerable limit.

Table 1. Influence of nutrient management levels in short-duration cassava varieties on growth attributes (mean of 3 years)

Treatment	Plant height (cm)		Leaves/plant		Stem girth (cm)		Total dry matter production (t/ha)		
	4 MAP	6 MAP	4 MAP	6 MAP	4 MAP	6 MAP	2004-05	2005-06	2006-07
Variety									
Kalpaka	162.3	205.6	204	237	6.75	8.21	14.87	10.84	18.11
Sree Jaya	168.9	212.2	200	241	6.98	8.26	16.95	11.13	15.14
Sree Vijaya	135.6	182.3	160	213	6.65	7.67	17.18	10.07	15.07
Triploid 2-18	178.5	248.1	136	170	6.75	8.36	21.55	11.95	17.30
Vellayani Hraswa	112.7	145.1	255	323	5.42	6.85	17.31	12.76	16.77
SEm±	4.3	6.7	9	10	0.16	0.23	0.45	0.63	1.30
CD (P=0.05)	12.1	19.0	26	29	0.47	0.64	1.79	NS	NS
Fertility level									
100% FYM+100%NPK	160.1	210.2	215	264	6.69	8.28	18.57	12.76	19.01
75% FYM+NPK	150.3	203.5	190	240	6.50	7.81	17.40	11.31	15.11
50% FYM+NPK	141.9	181.1	172	202	6.33	7.68	16.51	9.87	13.27
NPK based on soil test data+FYM	154.1	199.9	187	241	6.51	7.70	17.80	11.45	18.53
SEm±	3.8	6.0	8	9	0.15	0.20	0.61	0.52	0.69
CD (P=0.05)	10.8	17.0	23	26	NS	NS	NS	1.56	2.08

100% FYM; 12.5 t/ha; 100% NPK; 100:22:83.3 kg N:P:K/ha; MAP: months after planting

Table 2. Tuber yield, biomass production, tuber quality and economics of short-duration cassava varieties as affected by fertility levels

	Fresh tuber yield (t/ha)				Tuber dry matter production (t/ha)			Starch content (%) FW basis		HCN content*	Cost of cultivation*	Net income*	Net B:C ratio
	2004-05	2005-06	2006-07	Mean	2004-05	2005-06	2006-07	2005-06	2006-07	(µg/g)	(Rs/ha)	(Rs/ha)	
Variety													
Kalpaka	22.47	15.46	27.49	21.81	8.48	5.85	11.81	23.96	21.88	29.51	56,658	8,765	0.16
Sree Jaya	24.49	17.42	20.30	20.74	10.36	6.55	8.41	28.49	25.58	27.99	56,658	5,547	0.10
Sree Vijaya	26.57	16.92	25.63	23.04	10.21	6.05	9.82	24.40	20.31	35.70	56,658	12,462	0.22
Triploid 2-18	34.77	20.72	29.86	28.45	12.39	7.36	12.00	23.36	23.50	37.22	56,658	28,767	0.51
Vellayani Hraswa	26.26	20.40	27.64	24.77	11.07	8.20	11.32	22.76	21.57	60.98	56,658	17,645	0.31
SEm±	0.82	0.60	2.77	0.98	0.24	0.43	1.09	0.77	0.61	3.27			
CD (P=0.05)	2.68	1.90	NS	2.87	0.93	NS	NS	3.01	2.40	12.82			
Fertility level													
100% FYM+100%NPK	27.18	19.73	28.24	25.05	10.69	7.69	12.12	26.45	23.45	34.63	59,256	15,894	0.27
75% FYM+NPK	26.76	18.39	25.28	23.48	10.55	6.80	9.77	23.93	22.43	43.83	56,098	14,342	0.26
50% FYM+NPK	26.69	16.69	23.61	22.33	10.38	5.94	9.22	23.03	20.89	43.57	52,750	14,300	0.27
NPK based on soil test data+FYM	27.02	17.29	27.61	24.18	10.40	6.78	11.58	25.17	23.50	31.07	58,528	14,012	0.24
SEm±	0.71	0.45	1.22	0.49	0.53	0.27	0.62	0.36	0.18	2.87			
CD (P=0.05)	NS	1.31	3.52	1.39	NS	0.83	1.86	1.09	0.54	NS			

*Mean of 3 years

Table 3. Effect of nutrient management levels in short-duration cassava varieties on nutrient uptake (Pooled mean of 3 years)

Variety (V)	Fertility level (F)					Fertility level (F)					Fertility level (F)				
	Full FYM + NPK	75% FYM + NPK	50% FYM + NPK	Based on soil test data	Varietal means	Full FYM +NPK	75% FYM + NPK	50% FYM + NPK	Based on soil test data	Mean	Full FYM+ NPK	75% FYM + K uptake NPK	50% FYM+ NPK	Based on soil test data	Varietal means
	N uptake					P uptake									
Kalpaka	174.7	119.6	121.1	177.0	148.1	55.28	46.41	39.78	60.75	50.56	111.6	104.5	103.1	128.5	111.9
Sree Jaya	145.9	130.2	105.8	143.2	131.3	60.20	64.83	35.77	55.46	54.07	139.0	110.7	97.2	133.7	120.1
Sree Vijaya	168.9	127.9	101.8	147.2	136.4	63.96	49.85	32.04	51.99	49.46	128.1	108.7	88.7	116.8	110.6
Triploid 2-18	227.5	152.4	141.3	158.6	170.0	63.21	45.82	52.18	53.25	53.61	173.5	119.6	120.4	155.3	142.2
Vellayani Hraswa	136.5	136.8	120.3	122.6	129.0	51.79	48.99	39.53	58.87	49.79	120.2	122.1	95.2	104.8	110.6
Mean	170.7	133.4	118.1	149.7		58.89	51.18	39.86	56.07		134.5	113.1	100.9	127.8	
CD (P=0.05)	V:14.26, F: 12.75, VxF: 28.52					V:NS, F: 4.657, VxF: 10.414					V:15.98, F: 14.29, VxF:NS				

In general, the dry matter and cyanogen contents were not found to be under the influence of fertility levels (Table 2). However during the third year as well as on mean basis fertility level based on soil test data resulted in tuber dry matter content (41%) on par with that of full FYM+NPK (42%). Moreover, the data of 2 years and the mean values suggest that the nutrient level based on soil test data favoured starch content similar to that of full FYM + NPK. This further reiterates that nutrient management based on soil test results promotes both tuber yield as well as the quality of tubers.

Nutrient uptake and balance

Varieties varied considerably in N and K uptake. 'Triploid 2-18' had significantly higher N and K uptake (Table 3). The N, P and K uptake was significantly influenced by fertility levels. Application of full FYM+NPK resulted in significantly higher N uptake. Uptake of P and K was higher and almost the same due to addition of 100% FYM and NPK and fertility level based on soil test data. This further indicates the scope of reducing fertilizers based on soil test data. The interaction between varieties and fertility levels significantly influenced N and P uptake. The varieties followed almost similar trend and N and P uptake under fertility level based on soil test data was equal to that of full FYM and NPK.

During the first year, the effect of fertility levels on soil chemical properties was not significant. However, the soil rated as medium for organic C status, low for available N, sufficient for available P and K in plots that received full FYM+NPK or nutrients based on soil test results, which indicates that except for N, the soil fertility level was sufficient. This underscores the importance of nutrient management based on soil test data. In the subsequent 2 years, available N, P and K status of the soil after harvest of the crop under fertility level based on soil test data was higher and on a par with that of full FYM + NPK.

There was considerable loss of N during the first 2

Table 4. Nutrient balance for N, P and K (kg/ha) under different fertility levels in short-duration cassava

Fertility level	N added			N uptake			Available N status			N balance		
	2005	2006	2007	2005	2006	2007	2005	2006	2007	2005	2006	2007
Full FYM+NPK	162.5	162.5	162.5	204.9	128.1	179.1	134.3	161.4	138.0	-59.9	-35.1	21.5
75% FYM+NPK	121.9	121.9	121.9	165.8	104.2	130.1	128.7	131.8	124.7	-63.9	-48.0	-0.2
50% FYM+NPK	81.3	81.3	81.3	153.5	93.8	106.8	123.9	103.5	110.4	-40.4	-46.0	2.9
Based on soil test data	157.5	157.5	152.5	181.4	98.6	169.2	135.9	176.2	135.4	-76.8	-44.8	19.0
Initial status							236.6	162.1	133.1			
Fertility level	P added			P uptake			Available P status			P balance		
	2005	2006	2007	2005	2006	2007	2005	2006	2007	2005	2006	2007
Full FYM+NPK	45.0	45.0	45.0	67.8	44.5	64.3	40.1	41.0	45.7	48.8	22.9	-1.3
75% FYM+NPK	35.3	35.3	35.3	61.3	41.0	51.2	32.7	39.8	38.7	44.6	28.5	-11.6
50% FYM+NPK	23.5	23.5	23.5	50.8	31.8	37.0	32.9	34.1	32.3	45.7	24.9	-20.5
Based on soil test data	42.5	40.3	25.0	64.7	40.0	63.5	39.7	35.2	46.7	47.6	14.8	18.8
Initial status							14.2	19.5	66.4			
Fertility level	K added			K uptake			Available K status			K balance		
	2005	2006	2007	2005	2006	2007	2005	2006	2007	2005	2006	2007
Full FYM+NPK	133.3	133.3	133.3	153.3	101.4	148.7	144.6	215.3	252.7	52.1	32.1	96.8
75% FYM+NPK	100.0	100.0	100.0	135.6	87.7	116.0	129.3	165.9	219.1	52.4	2.3	63.7
50% FYM+NPK	66.7	66.7	66.7	127.6	76.0	99.2	128.6	147.6	177.7	77.0	5.5	38.7
Based on soil test data	137.5	129.2	120.8	145.5	89.2	148.7	151.6	189.9	237.8	47.1	-1.4	94.3
Initial status							112.5	151.3	171.4			

Varieties	Nutrients added			Nutrient uptake*			Available nutrient status*			Nutrient balance*		
	N	P	K	N	P	K	N	P	K	N	P	K
Kalpaka	130.4	34.9	107.3	148.1	50.6	111.9	136.5	40.8	198.0	-23.1	23.1	57.6
Sree Jaya	130.4	34.9	107.3	131.3	54.1	120.1	135.2	48.4	185.3	-41.2	34.2	53.0
Sree Vijaya	130.4	34.9	107.3	136.4	49.5	110.6	143.9	34.4	166.5	-27.3	16.4	24.7
Triploid 2-18	130.4	34.9	107.3	169.9	53.6	142.2	136.1	31.3	170.1	-1.6	18.1	59.9
Vellayani Hraswa	130.4	34.9	107.3	129.0	49.8	110.6	116.8	36.5	180.0	-61.8	18.0	38.3

*Mean of 3 years

years (Table 4) under all fertility levels, though the magnitude of loss was comparatively lower in the second year. High mobility of N and its rapid loss through leaching due to high rainfall (585 and 680 mm respectively during November-May in 2004-05 and 2005-06 respectively) contributed to net loss incurred in the balance sheet of N. In third year there was net gain of N under full FYM+NPK (22 kg/ha) and fertility level based on soil test data (19 kg/ha), which can be attributed to lower leaching due to receipt of less rainfall (348 mm).

Available P content of soil showed positive balance (Table 4) in 2005 and 2006 under all fertility levels, which became deficit in the third year, especially under 75% and 50% FYM+NPK. This may be because major portion of P added as manures and fertilizers might have undergone reversion. In the fertility level based on soil test data there was considerable saving of fertilizer P (up to 100% by third year) due to lesser addition and corresponding lesser chances of temporary conversion of mineralized inorganic form to organically bound ligands resulting in positive balance of P.

Distinct gain in the quantity of available K was observed in the first and third year (Table 4), though it reduced slightly or even became negative for certain treatments in the second year on account of higher rainfall. Normally excessive mineralization and leaching due to high rainfall results in greater loss of nutrients under humid tropics. Thus judicious application of nutrients based on soil testing resulted in positive balance for N, P and K due to lower losses due to lesser addition of fertilizer inputs.

Economics

Economic analysis (mean) indicated that full FYM+NPK resulted in the highest net income (Rs. 15,894/ha) and B:C ratio (0.27) due to higher yield (Table 2). Among the varieties 'triploid 2-18' produced the heighest profit (Rs 28,767/ha) and B:C ratio (0.51) due to higher tuber production. With reduction in fertility levels, there was reduction in production costs, but due to slightly lower yields than the full dose the net income and B:C ratio were lower. However, the other benefits of soil test based fertilizer recommendation viz., positive nutrient balance, maintenance of soil health, reduction of pollution, preservation of deposits of natural sources of these nutrients and conservation of non-renewable sources of energy for out weighs the monetary benefits.

Among short-duation cassava varieties 'Trippid 2-18' proved ideal for industrial use owing to its high tuber dry biomass production, however, 'Vellayani Hraswa' and 'Sree Vijaya' appeared promising for cultivation in rice fallows for food purpose due to their good cooking quality and low cyanogen content. The present study suggest the significance of soil test based balanced fertilizer application for short-duration cassava in order to maximize production, maintain soil health, minimize fertilizer misuse and reduce cost of production.

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