CASSAVA AGRONOMY IN INDIA – LOW INPUT MANAGEMENT

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ABSTRACT

Agronomic research on cassava in India during the past three decades was instrumental in the development of management practices that led to substantial increases in yield, mainly in Tamil Nadu and Kerala. Research efforts have recently focused on the development of low-input technologies with special emphasis on the identification of genotypes adapted to low-input conditions, the utilization of locally available organic wastes as soil amendments, exploitation of indigenous nutrient carriers, biofertilizers, and the economic use of irrigation water. The major accomplishments in the above mentioned areas and the recent progress in cassava agronomy research in India are briefly reviewed.

A series of field experiments were conducted from 1990 to 1998 at the Central Tuber Crops Research Institute (CTCRI) to identify cassava genotypes adapted to low input management. The genotypes were evaluated on the basis of fresh root yield, total biomass production, harvest index and low-P adaptation index. The land race *Mankuzhanthan* was found to be well adapted to low fertility conditions. It was also observed that the genotypes TCH-2 (Sree Prabha), *Mankuzhanthan* and Malayan 4 (M4) were capable of producing satisfactory yield in low-P soil, even in the absence of applied phosphorus. Monitoring the vesicular-arbuscular mycorrhiza (VAM) association on cassava roots indicated that in the absence of P-fertilization the fungal colonization was higher on all the genotypes. Research on low-cost soil fertility management practices for cassava showed that green manuring *in situ* with cowpea has both agronomic and economic advantages. The results of long-term fertility management studies conducted at CTCRI for the past 12 years also proved that green manuring *in situ* with cowpea or the incorporation of cassava crop residues can replace comparatively expensive farm-yard manure (FYM). Application of Mussoorie rock phosphate, a cheap indigenous source of P, was found to be equally effective as single superphosphate. In another experiment conducted at CTCRI, the response of cassava to locally available organic manures, such as mushroom spent compost, sawdust compost, press mud and coir pith compost, was also studied. These organic manures, especially coir pith compost and press mud, were found to be cheaper and very effective substitutes to FYM and they had no adverse effect on the available N, P and K status of the soil. Studies on integrated nutrient management practices for cassava grown on red lateritic soils indicate that the application of chemical fertilizers to cassava could be reduced to 50% if combined with biofertilizers and organic manures.

When cassava was intercropped with groundnut in Tamil Nadu, the application of 54 kg N, 72 P_2O_5 and 180 K_2O/ha along with biofertilizers, i.e., *Azospirillum* for cassava and *Rhizobium* for groundnut, promoted crop growth and yield and generated higher profits from the system. Sequential cropping studies conducted at Coimbatore, Tamil Nadu, and Peddapuram, Andhra Pradesh, sponsored by the All-India Coordinated Research Project on Tuber Crops, revealed that vegetable cowpea-cassava sequential cropping was a viable proposition and resulted in a saving of applied nutrients, especially P.

A comparison between surface and drip irrigation for cassava at Bhavanisagar, Tamil Nadu, showed that by using the drip system about 50% of irrigation water can be saved without affecting root yields.

Results of studies on nutrient management to obtain targeted yield, large-scale screening of cassava genotypes for drought tolerance, and storage of planting material of short-duration lines of cassava at Peddapuram, Andhra Pradesh, are also presented.

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INTRODUCTION

Cassava is cultivated in about 13 states in India as a source of food security in rural areas and as raw material for industries, mainly starch, sago and livestock feed. In Kerala, cassava is currently grown in an area of 111,000 ha producing 253,000 tonnes of roots (**Figure 1**), used mainly for food. Compared to 1991, the cassava area in Kerala has declined by 25% due to farmers' preference for more remunerative crops. On the other hand, cassava is now a major industrial crop in Tamil Nadu and is also gaining importance in Andhra Pradesh. The phenomenal growth in the starch and sago industries over the years has markedly increased cassava production in Tamil Nadu. **Figure 1** shows that in comparison to 1991 production of cassava in Tamil Nadu has increased by 55%, while the area increased by 20%.

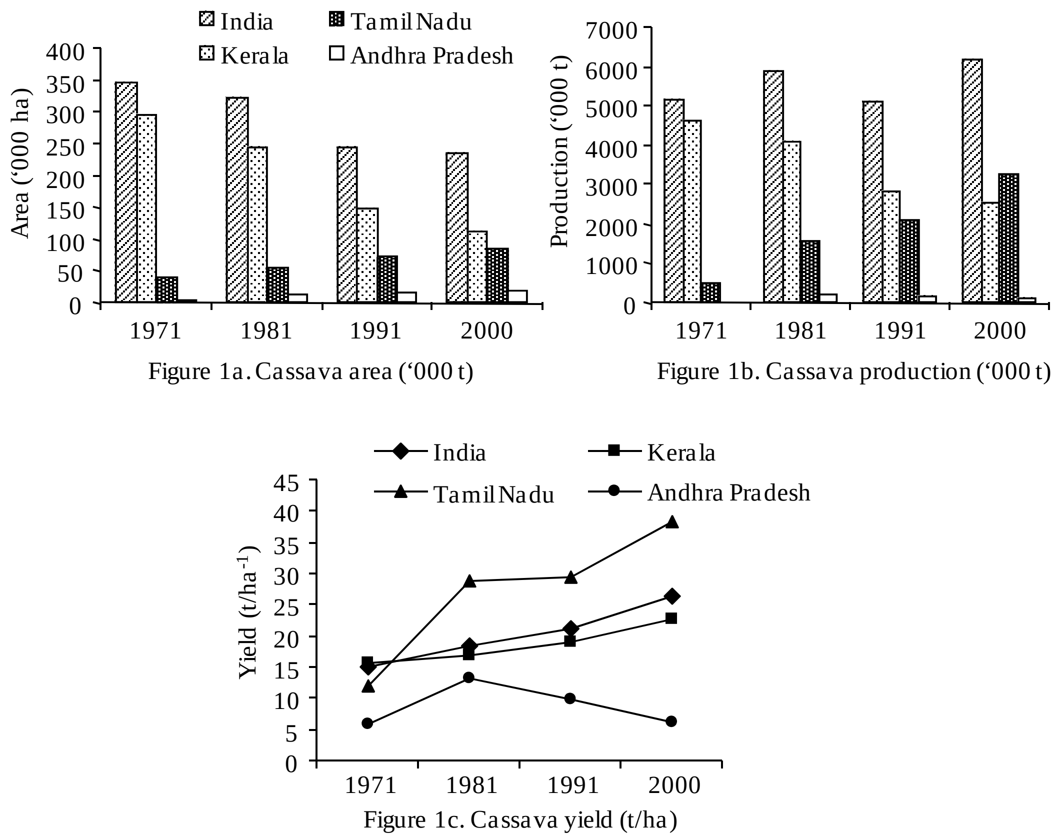

Figure 1. Cassava area, production and yield in major cassava growing states of India

Wide variation in soil type and climatic parameters exists within these cassava-growing areas (Nayar, 1993). In Kerala cassava is cultivated on Ultisols (lateritic soils), Alfisols (red soils) and Entisols (alluvial soils), under rainfed conditions, taking advantage of the bimodal precipitation prevalent in the region (Nayar and Nayar, 1997). In Tamil

Nadu the crop is grown on Vertisols (black soils) and Alfisols (red soils), usually with supplemental irrigation (Nayar, 1994). In Andhra Pradesh cassava is grown mainly on Entisols (sandy loams) as a rainfed crop.

Agronomic research on cassava in India during the past three decades was instrumental in the development of better management practices that led to substantial increases in productivity, especially in Tamil Nadu and Kerala. The productivity in Tamil Nadu is very close to 40 t/ha, the highest in the world. Research in the recent past has focused mainly on the development of low-input technologies with a thrust on the identification of genotypes adapted to low-input conditions, utilization of locally available organic wastes as soil amendments, exploitation of indigenous nutrient carriers, biofertilizers and on economizing irrigation water. An overview of the major accomplishments in the above fields and the recent progress in cassava agronomy in India is presented.

1. CASSAVA GENOTYPES ADAPTED TO LOW-INPUT MANAGEMENT

Cassava is mostly cultivated by small-scale farmers, especially in Kerala, in marginal environments and on soils of low fertility. To realize the production potential of high-yielding cassava varieties, application of farm-yard manure (FYM) at 12.50 t/ha and chemical fertilizers to provide 100 kg/ha of N, P_2O_5 and K_2O has been recommended (KAU, 1986). This high manurial dosage is very expensive and many cassava farmers are not in a position to adopt the above recommendation (Anantharaman *et al.,* 1986). Hence, identification and popularization of cassava genotypes adapted to lower levels of soil fertility management will be an appropriate low-input technology. With this objective, field experiments were conducted at the Central Tuber Crops Research Institute (CTCRI). In the experiment undertaken during 1990-1993 six genotypes, having characteristics described in **Table 1**, were evaluated at lower levels of soil fertility management (Nayar *et al.,* 1998). The results showed that the land race 'Mankuzhanthan' (MK) was adapted to low soil fertility management as measured by higher fresh root yield, storage root biomass production, total biomass production and harvest index (**Table 2**).

Table 1. Characteristics of several cassava genotypes in India.

Genotype	Characteristics
H22/86	Hybrid of Sree Prakash (short duration) and Malayan 4 (M4). Medium yielder with roots of good cooking quality.
H2/82	Hybrid of H-165 and Malayan 4. Early bulking, with roots of good cooking quality.
Triploid 237/84	Spontaneous triploid resulted from the hybridzation between Sree Sahya and H-165. High yielding but having low root dry matter content.
Triploid 76/9	Obtained from the cross of OP4 (2x) and S 300 (4x). High yielder with high root dry matter content.
Mankuzhanthan	Land race adapted to partially shaded conditions. Roots have high dry matter and starch contents.
Sree Prakash	Short duration variety, having roots with good cooking quality.

Source: *Nayar et al.,1998.*

Table 2. Cassava varietal response to low-input management (mean of three years).

Treatments $N:P_2O_5: K_2O$ in kg/ha and varieties	Fresh root yield (t/ha)	Dry root yield (t/ha)	Dry top yield (t/ha)	Dry total biomass (t/ha)	Harvest Index
50:50:50					
H22/86	19.73	5.77	5.60	11.37	50.64
H2/82	16.79	4.25	5.46	9.71	41.90
Triploid 237/84	18.90	5.11	5.66	10.33	47.39
Triploid 76/9	19.65	6.82	5.65	12.46	54.24
Mankuzhanthan	23.14	8.02	5.49	13.51	59.11
Sree Prakash	20.68	6.24	5.52	11.83	52.70
75:50:75					
H22/86	20.45	6.01	5.72	11.73	51.18
H2/82	17.11	4.97	5.52	10.49	46.61
Triploid 237/84	24.16	6.82	5.76	12.58	53.84
Triploid 76/9	23.86	8.32	5.63	13.96	58.84
Mankuzhanthan	23.10	7.90	5.58	13.49	58.22
Sree Prakash	21.64	6.61	5.54	12.14	54.23
100:50:100					
H22/86	19.37	5.93	5.74	11.66	50.48
H2/82	18.66	5.39	5.58	10.97	48.61
Triploid 237/84	26.66	7.08	5.77	12.85	54.79
Triploid 76/9	27.11	9.23	5.79	15.01	60.86
Mankuzhanthan	23.30	7.94	5.60	13.54	58.62
Sree Prakash	24.18	7.32	5.57	12.89	56.41

***Source**: Nayar et al., 1998*

At CTCRI field experiments were also carried out during 1996-1999 to identify cassava genotypes adapted to low-P soil. Eight contrasting genotypes of cassava were grown with and without application of phosphatic fertilizer, in lateritic soil (Ultisol) having low (9 kg/ha) initial available P status. Recommended levels of N and K (100 kg ha) were also applied, but no farm-yard manure (FYM) was given as basal dressing. From this study it was observed that the genotypes TCH-2 (later released as Sree Prabha), Mankuzhanthan (MK) and Malayan 4 (M4) were capable of producing satisfactory yields (CTCRI, 1998) even in the absence of applied phosphorus. (**Figure 2**). The P-adaptation index, calculated according to the formula used at CIAT (CIAT, 1993) had higher values in the case of the above genotypes, indicating their ability to yield well in low-P soils. Monitoring the VAMF association on cassava roots indicated that for all the genotypes the colonization was higher in the absence than in the presence of phosphorus fertilization (**Table 3**). However, total microbial activity, particularly the population of bacteria and fungi in the rhizosphere of cassava, was significantly higher in plots that received phosphatic fertilizer (**Figure 3**).

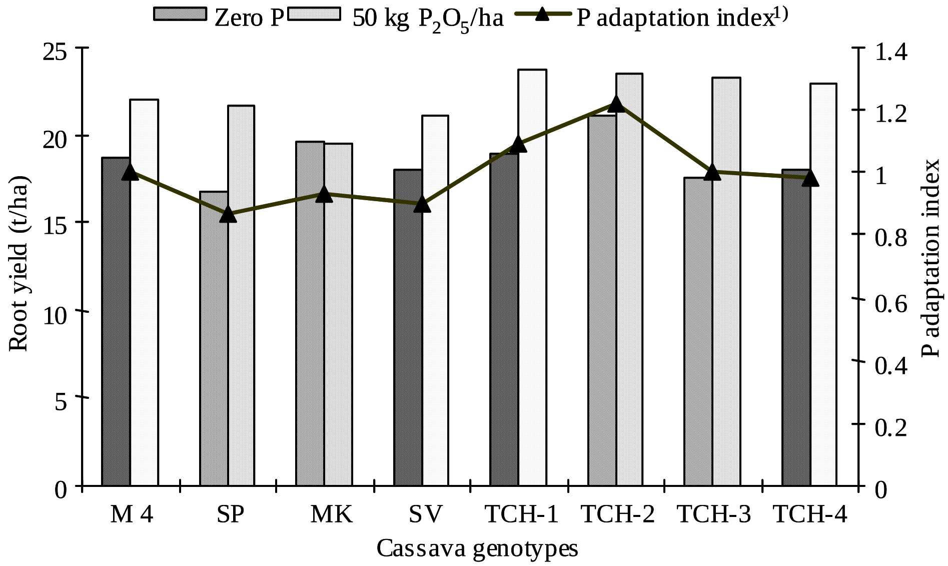

Figure 2. Cassava genotypes adapted to low phosphorus soil.

[1)] P-adaptation index = {Yield (-P) x Yield (+P)} / {Av. Yield (-P) x Av. Yield (+P)}

Source: *Nayar and Potty, 1998.*

Table 3. Percentage VA mycorrhizal root infection and soil spore population in the rhizosphere of eight cassava varieties at 3 and 6 months after planting, with and without P application.

	VAM colonization (%)				Spore population (per 100 ml soil)			
	3rd month		6th month		3rd month		6th month	
Treatments	P_0	P_1	P_0	P_1	P_0	P_1	P_0	P_1
TCH-4	90	50	80	60	300	100	400	200
Sree Prakash	80	40	80	30	300	200	300	150
Mankuzhantan	80	30	90	40	300	100	350	120
H-1687	90	60	100	57	200	-	200	110
M4	90	30	90	40	400	-	300	210
TCH-2	80	40	90	63	400	-	570	140
TCH-1	90	40	100	51	200	100	300	150
TCH-3	100	40	100	60	100	-	230	140

[1)] P_0 = 100 N-0 P-100 K_2O; P_1 = 100 N - P_2O_5-100 K_2O

***Source*:** *CTCRI ,1997*

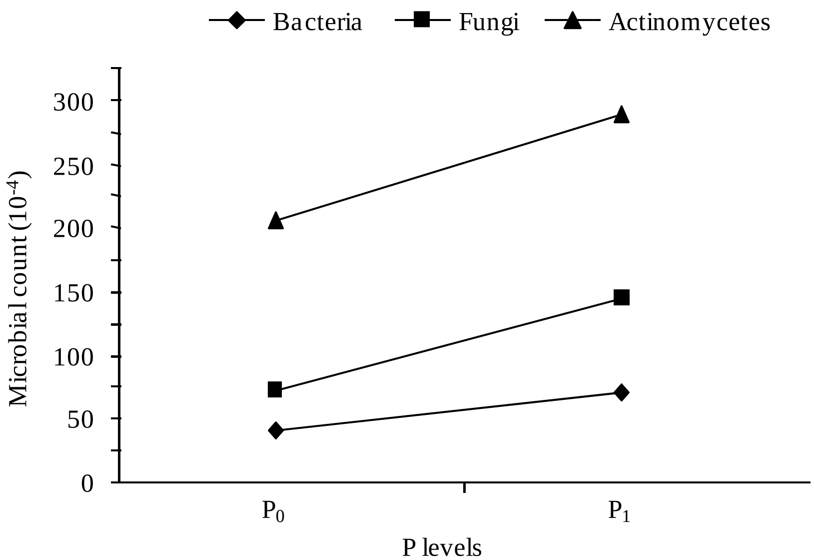

Figure 3. Average total microbial activity in the rhizosphere of eight cassava varieties planted with (P_1) and without (P_0) phosphorus application.
***Source**: CTCRI, 1997.*

2. LOW-COST SOIL FERTILITY MANAGEMENT PRACTICES

2.1 Green manuring in situ with cowpea

Research on low-cost soil fertility management practices for cassava showed that green manuring *in situ* with cowpea has agronomic and economic advantages (Nayar *et al*., 1993). There were no statistically significant differences in cassava yields between plots with FYM and those with *in situ* green manuring with cowpea varieties Arkagarima and C-152 (**Figure 4**). It was also found that by practicing green manuring *in situ* with cowpea the FYM application can be eliminated and the nitrogen and phosphorus can be reduced to 50% of the recommended rates (Nayar and Potty, 1996).

The results of long-term fertility management experiments conducted at CTCRI for the past 12 years also indicate that green manuring *in situ* with cowpea or incorporation of cassava crop residues (CR) can replace the rather expensive farm-yard manure (**Figure 5**). However, in years of delayed onset of the Southwest monsoon or insufficient rainfall, the practice of green manuring *in situ* may reduce the productivity of long-duration varieties of cassava.

The long-term impact of green manuring *in situ* with cowpea on chemical properties of lateritic soil (Ultisol) was also investigated. There was no significant difference in soil pH and organic carbon content between green manuring and FYM. Under all treatments there was a slight increase in the soil organic carbon content (**Table 4**) by the 11th year. The available nitrogen status determined at the 5th and 11th year, showed no significant variation. However, the plots with incorporation of crop residues had lower available N when compared to other treatments, i.e. FYM at 12.5 t/ha and green manuring in *situ* with cowpea (**Figure 6**). There was considerable accumulation of available soil P and K in both the 5th and 11th year of cropping (**Figures 7 and 8**).

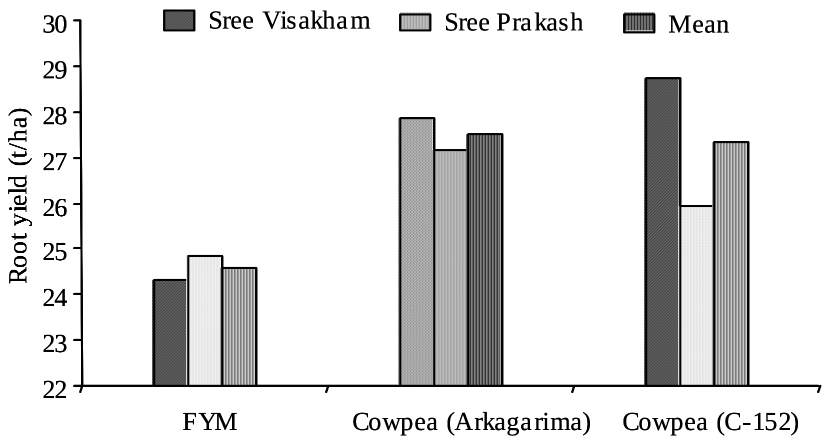

Figure 4. Root yields of three cassava varieties as influenced by green manuring in situ with cowpea.
***Source:** Nayar et al., 1993.*

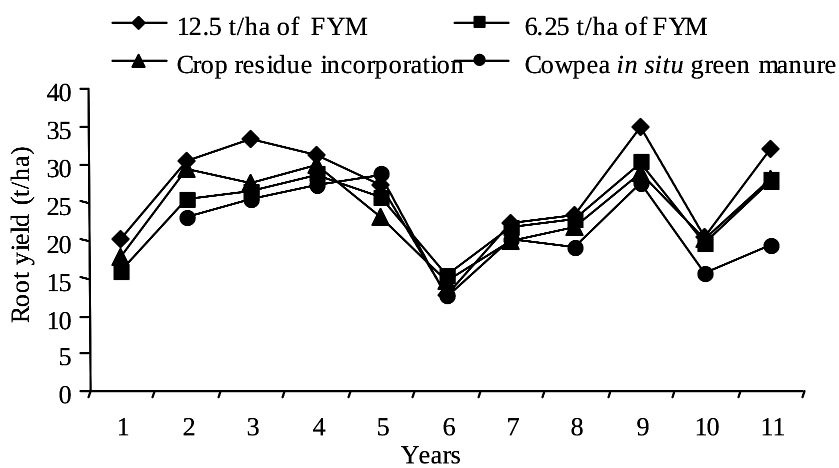

Figure 5. Influence of various organic manures on cassava root yields during 11 years of continuous cropping. All plots received 100 kg N, 50 P_2O_5 and 100 K_2O/ha as chemical fertilizers.
***Source:** Susan John, 2002. (unpublished)*

Table 4. Long-term effect of green manuring *in situ* with cowpea on soil pH and organic carbon.

Treatments[1)]	pH			Organic carbon (%)		
	Initial	5^{th} year	11^{th} year	Initial	5^{th} year	11^{th} year
12.5 t/ha FYM	4.75	4.94	4.61	0.80	0.78	1.14
6.25 t/ha FYM	4.78	5.03	4.72	0.64	0.71	1.17
crop residues incorporated	4.75	5.35	4.73	0.71	0.80	1.06
green manuring *in situ* with cowpea	4.45	4.80	4.78	0.67	0.77	1.02
CD (0.05)	NS	NS	NS	NS	NS	NS

[1)] All plots received annual application of 100 kg N, 50 P_2O_5 and 100 K_2O/ha
Source: *Adapted from CTCRI Annual Reports 1991, 1996 and 2001.*

T_1: FYM 12.5 kg/ha T_3: Crop residues incorporated
T_2: FYM 6.25 kg/ha T_4: Green manuring *in situ* with cowpea

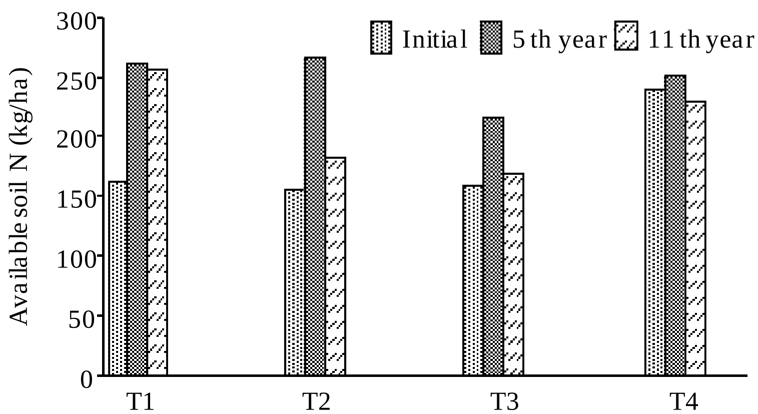

Figure 6. Influence of sources of organic manures on available soil N. All treatments received 100 kg N+50 P_2O_5+100 K_2O/ha.
Source: *Adapted from CTCRI 1991, 1996, 2001.*

2.2 Use of locally available composted organic manures

The advantages of composting organic wastes and using these as soil amendments are well-known. Organic wastes, such as coirpith, press mud (sugar factory waste), mushroom spent compost, paddy straw and sawdust, are available and marketed in the cassava producing areas of southern India, While composting, small amounts of urea and fungal cultures (*Pleurotus* + *Trichoderma* + *Penicillium*) are used as starter (Rajendran, 1991). Certain compost preparations are also fortified with micronutrients. Most of these have NPK contents comparable to those of FYM, the most widely used organic manure in cassava farming (**Table 5**).

T_1: FYM 12.5 kg/ha T_3: Crop residues incorporated
T_2: FYM 6.25 kg/ha T_4: Green manuring in situ with cowpea

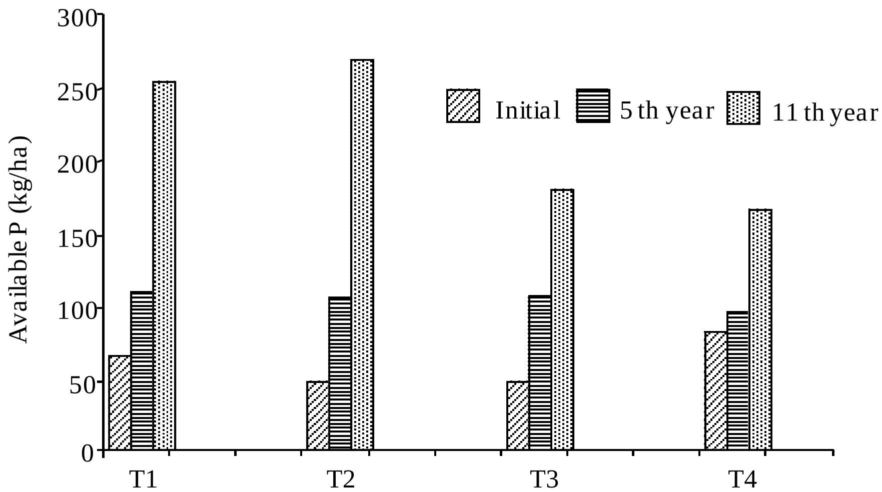

Figure 7. Influence of sources of organic manures on available soil P.
All treatments received 100 kg N + 50 P_2O_5 + 100 K_2O/ha.
Source: *CTCRI, 1991, 1996, 2001.*

T_1: FYM 12.5 kg/ha T_3: Crop residues incorporated
T_2: FYM 6.25 kg/ha T_4: Green manuring *in situ* with cowpea

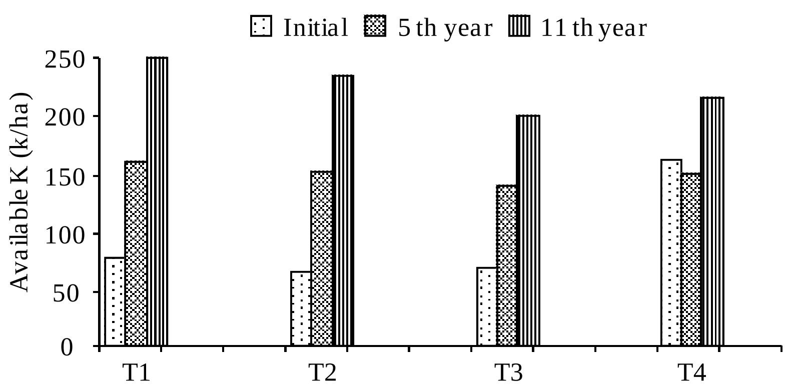

Figure 8. Influence of sources of organic manures on available soil K.
All treatment received 100 kg N + 50 P_2O_5 + 100 K_2O/ha.
Source: *CTCRI, 1991, 1996, 2001.*

Table 5. Nutrient contents of various organic manures.

Organic manures	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Fe (ppm)	Zn (ppm)	Mn (ppm)	Cu (ppm)
FYM	0.80	0.30	1.00	-	-	-	91	1.64	46.4	-
Press mud compost	1.30	2.20	0.50	3.50	2.50	0.25	3,000	500	300	65
Mushroom spent compost	1.84	0.69	1.19	-	5.10	0.38	2,200	225	1,260	-
Coir pith compost	1.08	0.06	1.20	0.50	0.50	0.48	1,800	125	212	6
Sawdust compost	1.00	0.50	0.50	-	-	-	-	-	-	-

Source: *Rajendran et al., 1991.*

During 1996-1998 the efficacy of mushroom spent compost (MSC), sawdust compost (SDC), coirpith compost (CPC) and press mud compost (PMC) were compared to FYM as organic manure (on equal nutrient basis) at CTCRI using three cassava varieties, i.e. Mankuzhanthan, Sree Prakash (SP) and Sree Visakham (SV) . The effect of these organic manures on the fresh root yield of cassava is shown in **Figure 9**. There were no significant differences in yield of all three varieties due to the source of organic manure. Further, these composted manures had no significant effect on the available N, P and K status of the soil (**Figure 10**). These results suggest that any of the above organic manures can be used as substitute to FYM, depending on their cost and availability. Coirpith compost is available at cheaper prices throughout the coastal regions of Kerala, and press mud is available in large quantities in the cassava producing zones of Tamil Nadu and Andhra Pradesh. Hence, coirpith compost and press mud compost are recommended as substitutes for FYM in cassava production. (Nayar and Potty, 1998).

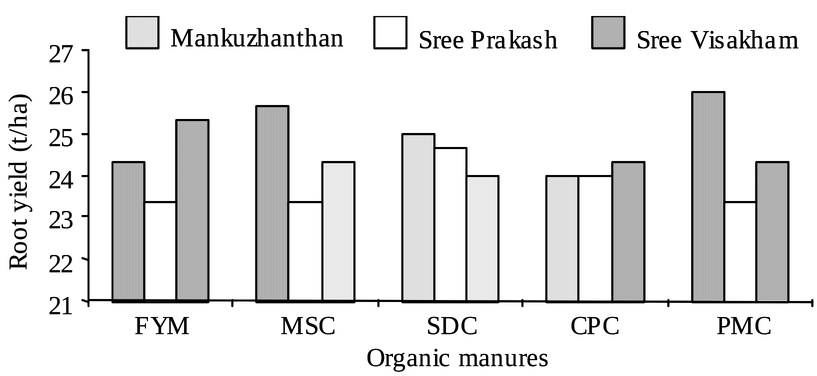

Figure 9. Effect of organic manures on the root yields of three cassava varieties grown at CTCRI.
Source: *Nayar and Potty, 1998.*

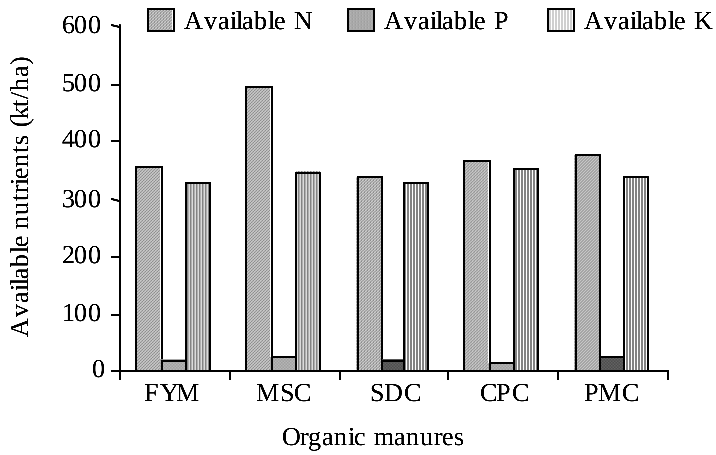

Figure 10. Effect of organic manures on the available NPK contents of the soil
Source: *Nayar, 1998. (unpublished)*

2.3 Use of neem cake-coated urea as a slow-release N fertilizer

Earlier studies conducted under the All-India Coordinated Research Project on Tuber Crops have shown that the use of neem cake coated urea is beneficial to enhance the fertilizer's efficiency. To confirm this and to demonstrate the same to farmers, on- farm trials (OFT) were conducted at five locations in Tamil Nadu (TNAU, 2002). The results show that by using neem cake-coated urea, a 27% increase in cassava yield was obtained (**Figure 11**).

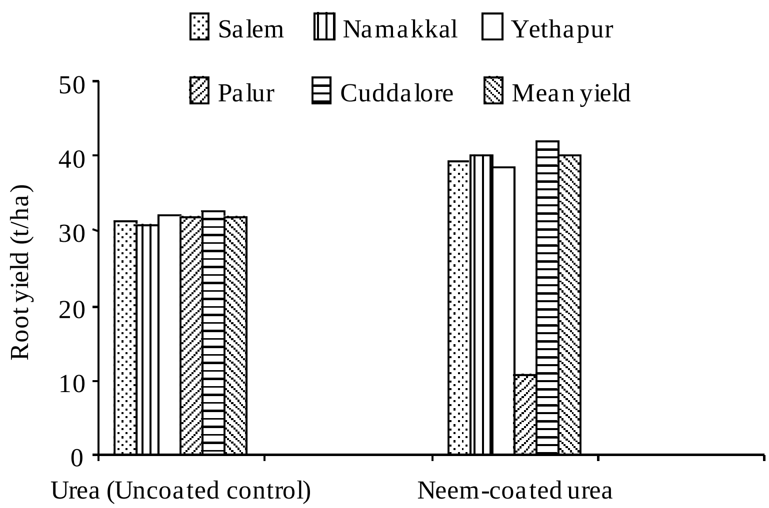

Figure 11. Influence of the use of neem-coated urea as a slow-release nitrogenous fertilizer on the root yield of cassava, cv. Co-2 in on-farm trials conducted in five locations in Tamil Nadu.
Source: *Adapted from TNAU, 2002.*

2.4 Indigenous rock phosphate as P source

In India the necessity to utilize indigenous rock phosphate to supply P to crops arises mainly due to economic and soil property considerations. The direct application of indigenous rock phosphate saves foreign exchange needed to import high-grade rock phosphate as well as the cost of acidulation in the manufacture of superphosphate. Investigations conducted in many parts of the country have shown that indigenous rock phosphate is agronomically as efficient as single superphosphate in soils with pH less than 6.8. The long-term effect of application of Mussorie rock phosphate (MRP) in comparison to single superphosphate (SSP) for cassava was studied at CTCRI. Results of the past 11 years show that MRP was equally effective as SSP (**Figure 12**). The chemical properties, such as soil pH, organic carbon, available N, P and K of the soil, were also not significantly affected by the sources of P (**Table 6 and Figure 13**).

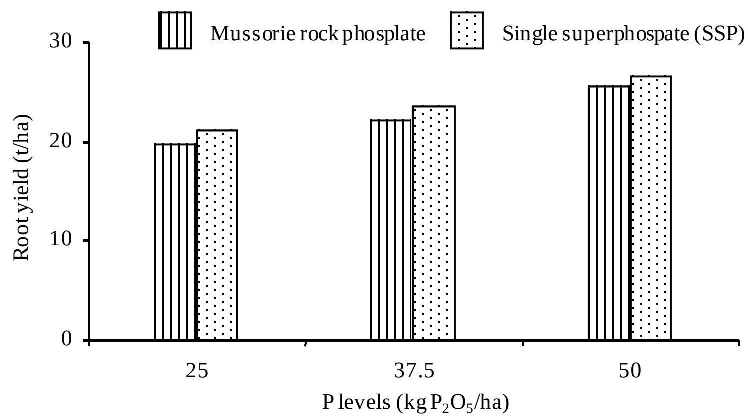

Figure 12. Influence of levels and sources of P on root yield of cassava (mean of 11 years).
***Source:** Susan John, 2002. (unpublished)*

Table 6. Influence of three levels and two sources of applied P on soil pH and organic carbon content.

P level (kg P_2O_5/ha)	P source[1)]	pH			Organic carbon (%)		
		Initial	5th year	11th year	Initial	5th year	11th year
25	MRP	4.58	5.18	4.90	0.63	0.63	1.05
37.5	MRP	4.80	5.05	4.68	0.66	0.73	1.04
50	MRP	4.58	4.93	4.68	0.80	0.67	1.09
25	SSP	4.56	5.03	4.85	0.77	0.91	1.37
37.5	SSP	4.53	4.98	4.93	0.68	0.78	1.21
50	SSP	4.88	4.95	4.53	0.79	0.90	1.19
CD (0.05)		NS	0.55	NS	NS	NS	NS

[1)] MRP = Mussorie rock phosphate; SSP = single super phosphate
***Source:** CTCRI, 1991, 1996, 2001.*

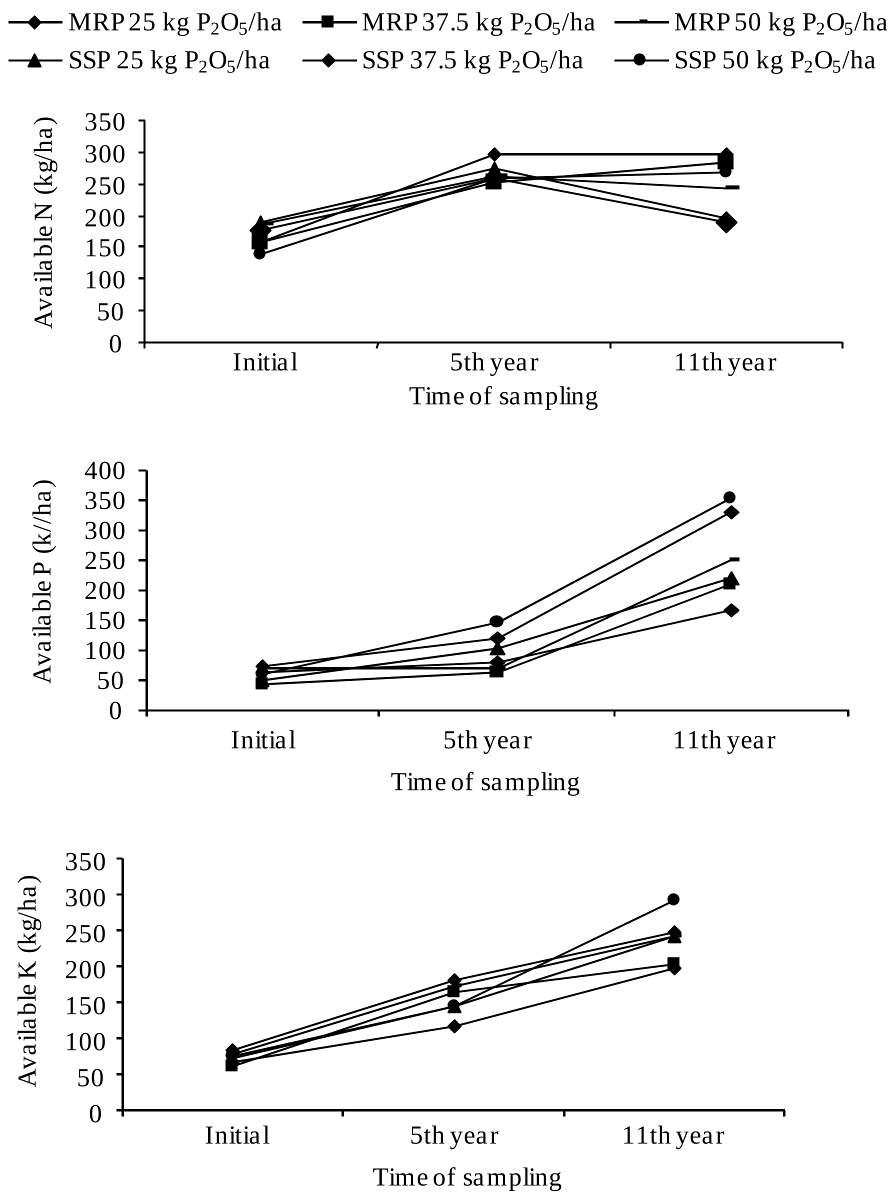

Figure 13. Effect of levels and sources of applied P on available soil-N (top), soil-P (middle) and soil-K (bottom).
Source: *CTCRI, 1991, 1996, 2001.*

2.5 Utilization of biofertilizers

Experiments were conducted to determine the best integrated nutrient management practice for cassava in laterite soils (Geetha *et al.*, 2000). The treatments consisted of factorial combinations of four biofertilizers and three levels of chemical fertilizers. The organic inputs were *Azospirillum* and *Phosphobacterium*, *Azospirillum* and VAM, and vermicompost at 20 t/ha. The levels of chemical fertilizer were 100, 75 and 50 per cent of the recommended dose for the crop (50:50:50 kg N: P_2O_5: K_2O/ha). The results show that neither the biofertilizers nor the chemical fertilizer levels influenced the yield significantly. Their interaction effect was also not significant. The results indicate that chemical fertilizer application could be reduced to 50% when biofertilizers were used in an integrated manner. A higher dose of biofertilizers did not increase root yields. Preliminary experiments conducted at CTCRI have shown similar results (**Table 7**).

Table 7. Effect of integrated use of organic manures, chemical fertilizers and biofertilizers on cassava production yield parameters at CTCRI.

Treatments	No. of roots per plant	Mean root weight (g)	Root yield (t/ha)
FRD[1]: FYM at 12.5 t/ha and N-P_2O_5-K_2O at 100:50:100 kg/ha	5.33	371	24.28
FYM+P+K+75% N+*Azospirillum*	5.93	300	21.85
FYM+P+K+50% N+*Azospirillum*	5.78	282	20.20
FYM+N+K+75% P+*Phosphobacterium*	6.11	296	21.89
FYM+N+K+50% P+*Phosphobacterium*	5.04	312	23.58
FYM+K+75% N and P+*Azospirillum* + *Phosphobacterium*	5.58	321	22.22
FRD[1]+FYM+K+50% N and P+*Azospirillum*+ *Phosphobacterium*	5.33	321	21.19
FRD[1] +Azospirillum + *Phosphobacterium*	5.39	375	24.93
Half recommended dose + *Azospirillum*+ *Phosphobacterium*	5.70	304	21.48
Absolute control	5.51	291	19.66
CD	NS	NS	NS

[1] FRD = full recommended dose
Source: *Nayar et al., 2002.*

2.6 *Fertilizer recommendation for targeted yield*

Targeted yield models have been developed for achieving specific yields through balanced fertilizer recommendations mainly based on soil test values. In this approach the soil nutrient status and the crop requirements are taken into consideration.

Swadija and Sreedharan (1998) developed fertilizer recommendation equations for specific yield targets of cassava, var. M4, grown on laterite soils for the following two scenarios:

a) Without FYM

$$F\ N = 12.10\ T - 0.74\ SN$$
$$F\ P_2O_5 = 5.04\ T - 2.02\ SP$$
$$F\ K_2O = 11.93\ T - 1.10\ SK$$

b) With FYM

$F\ N = 12.10\ T - 0.74\ SN - 1.44\ ON$

$F\ P_2O_5 = 5.04\ T - 2.02\ SP - 2.79\ OP$

$F\ K_2O = 11.93\ T - 1.10\ SK - 1.58\ OK$

where F N, F P_2O_5, and F K_2O are fertilizer N, P_2O_5, and K_2O, respectively, in kg/ha, T is the target of root yield in t/ha; SN, SP and SK are soil available N,P and K in kg/ha, respectively, and ON, OP and OK are quantities of N, P and K supplied through organic manure in kg/ha.

Selvakumari *et al.* (2001) also used the soil test crop response (STCR) approach to develop fertilizer recommendations for the state of Tamil Nadu as fertilizer adjustment equations for targeted yield of cassava as follows:

$F\ N = 5.60\ T - 0.61\ SN - 0.81\ ON$

$F\ P_2O_5 = 3.53\ T - 1.80\ SP - 0.53\ OP$

$F\ K_2O = 9.42\ T - 0.67\ SK - 0.70\ OK$

Wherever FYM/composted coir waste/press mud is applied at 12.5 t ha, on an average 40 kg N, 22 kg P_2O_5 and 40 kg K_2O can be reduced from the recommended fertilizer rates. For the addition of A*zospirillum* and *Phosphobacterium* each at 2 kg/ha, 11.3 kg N and 10 kg $P_2O_{5,}$ respectively, can be reduced from the recommended fertilizer rate Using this approach, recommended rates of fertilizer at varying soil test values for a specific yield target in cassava are shown in **Table 8**.

Table 8. Fertilizer rates remommended at varying soil test values for specific yield targets in cassava.

Initial soil test value (kg/ha)			Nutrients needed (kg/ha) for a root yield target of 40 t/ha		
N	P	K	N	P_2O_5	K_2O
180	10	180	114	123	256
190	12	190	108	119	250
200	14	200	102	116	243
210	16	210	96	112	236
220	18	220	90	109	230
230	20	230	84	105	223
240	22	240	78	101	216
250	24	250	71	98	209
260	26	260	65	94	203
270	28	270	59	91	196
280	30	280	53	87	189

Source: *Selvakumari et al.,2001.*

3. CROPPING SYSTEMS RESEARCH

Sequential cropping involving short duration legumes and cassava is beneficial not only to generate higher net returns per unit area per unit time, but also for the improvement of soil fertility. Field experiments on crop rotations were conducted at Coimbatore and Peddapuram under the aegis of the All-India Coordinated Research Project on Tuber Crops. The results of the trial at Coimbatore, Tamil Nadu, indicate that FYM and P application to cassava could be reduced to 50% by using the vegetable cowpea-cassava sequential cropping system. This treatment also proved to be cost effective and generated net returns as high as Rs. 61,298/ha and a very high benefit cost ratio (BCR) (**Table 9**). Apart from a cassava root yield of 41.2 t/ha, about 5.75 t/ha of pods and 16.75 t/ha of crop residues of vegetable cowpea were also obtained (**Table 10**). At Peddapuram, Andhra Pradesh, vegetable cowpea-cassava sequential cropping generated the highest root yield of 17.62 t/ha when only 50% of FYM and no P were applied (**Table 11**).

Table 9. Economics of sequential cropping with cassava and vegetable cowpea at Coimbatore. Data are the means of two seasons.

Treatments[1]	Cassava root yield (t/ha)	Total cost of production (Rs/ha)	Gross income (Rs/ha)	Net returns (Rs/ha)	Cost/ Benefit ratio
Zero FYM + zero P_2O_5	26.9	16,041	56,235	40,193	1:3.5
Zero FYM + half P_2O_5	33.2	18,389	60,985	42,596	1:3.3
Zero FYM + full P_2O_5	35.9	19,430	65,302	45,872	1:3.4
Half FYM + zero P_2O_5	36.4	20,012	67,717	47,705	1:3.4
Half FYM + half P_2O_5	41.2	19,596	80,895	61,299	1:4.1
Half FYM + full P_2O_5	36.1	20,133	71,476	51,343	1:3.6
Full FYM + zero P_2O_5	31.3	22,797	64,417	41,620	1:2.8
Full FYM + half P_2O_5	35.2	23,184	70,877	47,693	1:3.1
Full FYM + full P_2O_5	40.9	24,944	80,732	55,788	1:3.2

[1] Half FYM: 12.5 t/ha; Full FYM: 25 t/ha
Half P_2O_5: 30 kg/ha; Full P_2O_5: 60 kg/ha
Source*: TNAU, 2002.*

Table 10. Yield of fresh vegetable cowpea pods and haulms from a vegetable cowpea-cassava sequential cropping system at Coimbatore, Tamil Nadu, when half the recommended rates of FYM and P were applied. Data are the mean of two seasons.

Haulm yield (t/ha)	Pod yield (t/ha)	Total biomass yield (t/ha)
16.75	5.75	22.50

Source: *TNAU, 2002.*

The feasibility and profitability of cassava + groundnut intercropping already has been reported under CTCRI conditions. In a cassava + groundnut intercropping system at Tamil Nadu, the application of NPK at 54:72:180 kg/ha, along with biofertilizers, i.e. *Azospirillum* for cassava and *Rhizobium* for groundnut, promoted crop growth, increased yield and generated higher profits from the system (Thanunathan *et al*., 2000).

Table 11. Performance of cassava in a vegetable cowpea-cassava sequential cropping system at Peddapuram.

	Treatments[1)]	Root yield (t/ha)		
		1997	1998	Mean
1.	Zero FYM + zero P_2O_5	20.56	9.89	15.21
2.	Zero FYM + half P_2O_5	15.39	10.79	13.09
3.	Zero FYM + full P_2O_5	19.47	13.89	16.68
4.	Half FYM + zero P_2O_5	23.19	12.05	17.62
5.	Half FYM + half P_2O_5	16.83	14.46	15.65
6.	Half FYM + full P_2O_5	18.14	11.91	15.05
7.	Full FYM + zero P_2O_5	18.97	11.14	15.06
8.	Full FYM + half P_2O_5	16.77	10.45	13.61
9.	Full FYM + full P_2O_5	19.69	11.82	15.76
10.	Control (No FYM or P_2O_5)	17.64	7.23	12.44

[1)] Half FYM: 12.5 t/ha; Full FYM: 25 t/ha
Half P_2O_5: 30 kg/ha; Full P_2O_5: 60 kg/ha
Source*: *ANGRAU,2002.

4. PRODUCTIVITY OF CASSAVA UNDER DROUGHT STRESS

In India a considerable area of cassava is in the states of Tamil Nadu and Andhra Pradesh where rainfall is low and is received for only a limited period of 3-4 months. Hence, the identification of drought tolerant genotypes would be very useful. With this objective, 59 cassava genotypes, including 49 exotic genotypes (CE) and 10 indigenous genotypes (CI) were planted under upland rainfed conditions at CTCRI in Thiruvananthapuram during two seasons. The crop was planted in August and harvested 8 months after planting. During the first season, the crop received 810 mm rain between August-December in 49 days during the initial 4-month period, and 94 mm rain between January-April in 11 days during the second 4-month period. During the second season the crop received 690 mm rain between August-December in 34 days during the initial 4-month period and 185 mm rain between January-April in 21 days during the second 4 month period. Thus, during both seasons, the crop faced four months drought, which coincided with its root-bulking period.

Out of 59 cassava genotypes evaluated, the root yield and extractable starch yield of some promising genotypes are listed in **Table 12.** The highest root yield was obtained with the genotype CE-534, while the highest extractable starch yields were obtained in genotypes CE-534 and CE- 273 (CTCRI, 2002).

5. STORAGE TECHNIQUE FOR CASSAVA STEMS IN NON-TRADITIONAL AREAS

In Andhra Pradesh, cassava is planted in June with the onset of the monsoon rains and is harvested in the next year during January at 7 months after planting. As a result, farmers have to store the cassava stems for the next planting for a period of 4 to 5 months, which are very hot (33-41^{0}C) and dry. Under such adverse weather conditions, farmers usually store the cassava stems horizontally under tree shade. In this method they lose about 60% of their planting material. Hence, a study was conducted during 2000 and 2001 to identify the best storage technique for cassava stems.

Table 12. Root yield and extractable starch yield of cassava genotypes grown under rainfed conditions.

	Fresh root yield (t/ha)			Extractable starch yield (t/ha)		
Genotype	1999/00	2001/02	Mean	1999/00	2001/02	Mean
CE - 77	22.7	16.4	19.6	4.9	2.7	3.8
CE –94	22.9	15.2	19.1	4.8	3.5	4.2
CE –123	30.1	9.1	19.6	6.0	2.9	4.5
CE –127	17.3	9.5	13.4	3.6	3.2	3.4
CE –152	22.6	8.7	15.7	4.1	2.2	3.2
CE –166	17.3	9.0	13.2	4.0	2.6	3.3
CE –273	28.0	11.1	19.6	6.9	3.1	5.0
CE –274	25.9	11.5	18.7	4.6	2.9	3.8
CE –326	16.9	12.3	14.6	4.0	2.2	3.1
CE -328	19.8	11.1	15.5	4.7	2.3	3.5
CE –440	22.2	7.4	14.8	6.0	2.0	4.0
CE- 534	34.1	18.9	26.5	10.6	6.0	8.3
CI-82	28.0	4.1	16.1	8.2	0.9	4.6
CD	NS	5.28		3.73	1.51	

Source: *CTCRI, 2002.*

In the above study, healthy and mature cassava stems of three short duration varieties, Sree Prakash, Sree Jaya and H-165, were stored for 5 months under 10 treatments. The stems stored vertically under tree shade retained high moisture content (68%), less spoilage due to drying (7%) and had high sprouting efficiency (88%). With the horizontal method, stems stored in zero-energy cool chambers (ZECC) showed less drying (31%) than stems stored under tree shade (70%). Stems stored vertically under tree shade or in the open with their bottom portion (2-3 cm) buried in sand bed and wetting the bed once every 10 days was identified as the best method of storage under hot dry weather conditions for five months. The cassava yields as influenced by the stem storage treatments are shown in **Table 13.** Treatments 1 and 2 (stems with or without shoot apex stored vertically under tree shade) gave the highest root yields (37 t/ha).

6. RESPONSE OF CASSAVA TO DRIP IRRIGATION

With the objective of economizing irrigation water through the use of a drip system, field studies were conducted for three years at the Agricultural Research Station, Bhavanisagar, Tamil Nadu, during 1996-2000 with the cassava variety MVD1 (Manickasundaram *et al.*, 2002). The experiment was laid out in split plot design with three replications. In the main plot, surface irrigation at 0.60 IW/CPE ratio to 5 cm depth was compared with drip irrigation once in two days at three levels, i.e. 100, 75 and 50% of surface irrigation. In the subplot, three levels of nitrogen at 40, 60 and 80 kg N/ha were applied through irrigation water in the drip treatments and as band placement in surface irrigation.

Table 13 . Cassava yield of three varieties as influenced by the stem storage treatments.

Treatments	Root yield (t/ha) Sree Prakash	Sree Jaya	H-165	Mean
1. Stems with shoot apex stored vertically under tree shade	32.2	37.2	41.1	36.8
2. Stems without shoot apex stored vertically under tree shade	34.7	33.8	41.8	36.8
3. Stems with shoot apex stored vertically on sand bed under tree shade	38.8	33.6	33.2	35.2
4. Stems without shoot apex stored vertically on sand bed under tree shade	33.3	34.1	34.2	33.9
5. Stems with shoot apex stored horizontally under tree shade	36.4	32.2	32.2	33.6
6. Stems without shoot apex stored horizontally under tree shade	26.8	34.0	34.1	31.6
7. Stems without shoot apex treated with cow dung and stored vertically under tree shade	29.9	31.3	31.7	31.0
8. Fresh stems (without storage)	35.0	34.6	37.9	35.8

Variety NS; Treatment NS

***Source**: Ravi, 2002. (unpublished)*

The results revealed that the fresh root yield was significantly influenced by the irrigation treatments and irrigation through drip at 100% of surface method of irrigation produced the highest mean yield of 58.7 t/ha (**Table 14**). However, the fresh root yields at 100% and 75% of surface irrigation through drip were not significantly different. The fresh root yield was the lowest at surface irrigation scheduled at 0.60 IW/CPE ratio and this was not significantly different from drip with irrigation at 50% of surface irrigation. Nitrogen levels had no significant effect on root yields.

Table 14. Effect of drip irrigation on root yield and water use efficiency of cassava (mean over three years).

Irrigation levels	Fresh root yield (t/ha)	Irrigation water applied (mm)	Irrigation water saving (%)	Total water used (mm)	Water use efficiency (kg/ha.mm)
Surface at 0.60 IW/CPE	51.37	915	-	1,255	41.0
Drip at 100% of surface	58.69	851	6.9	1,192	49.2
Drip at 75% of surface	56.32	652	28.7	993	56.7
Drip at 50% of surface	53.32	472	48.4	812	65.5

***Source**: Manickasundaram et al., 2002.*

Drip irrigation at 75% of surface irrigation consumed 933 mm of water for the whole period, equivalent to a water saving of 28.7% and this treatment had a water use efficiency of 56.7 kg/ha.mm. The percent saving in irrigation water under drip irrigation applied at 50% of surface irrigation was 48.4% compared to that of surface irrigation. The water use efficiency was 20 to 60% higher in drip irrigation treatments compared to that of surface irrigation.

FUTURE THRUST

Future research on cassava agronomy will focus on :

- Refinement of agro-techniques for cassava in non-traditional areas
- Resource management for short-duration cassava-based cropping systems
- Integrated nutrient management strategies for cassava
- Development of labor-saving and drudgery-reducing agro-techniques
- Rationalization of water and nutrients for cassava production in industrial areas
- Soil conservation practices for cassava in slopy and high-rainfall areas
- Tackling micronutrient deficiency problems

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