



Crop diversification with short-duration cassava (*Manihot esculenta*) in the humid tropics for agronomic and economic benefits

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ABSTRACT

Presently cassava (*Manihot esculenta* Crantz) cultivation has shifted from the uplands to the lowlands, sequentially after main crop of rice, banana or vegetables and short-duration varieties (6-7 months) hold great promise. A three-year field experiment was carried out during 2007 to 2010 at Central Tuber Crops Research Institute, Thiruvananthapuram to develop feasible short-duration cassava-legume system in lowland situation akin to rice fallow. Two short-duration cassava varieties, Vellayani Hraswa and Sree Vijaya were evaluated in two cropping systems (sequential cropping and intercropping) involving two types of cowpea (vegetable (var. Pusa Komal) and grain types (var. C 152)) under two fertility levels based on soil testing (full and reduced) in split plot design. Vellayani Hraswa (24.55 tonnes/ha) produced significantly higher yield over Sree Vijaya (21.46 tonnes/ha) in systems involving cowpea. But the tuber and total biomass, crop growth rate, tuber bulking rate, mean tuber bulking rate, relative growth rate and harvest index of the varieties was comparable. Sequential cropping proved superior to intercropping as indicated by the significantly higher fresh tuber yield of 26.07 tonnes/ha under sequential cropping over 19.94 tonnes/ha in intercropping) and dry matter production. Both vegetable cowpea and grain cowpea were equally compatible with short-duration cassava under both the systems. Entire P and half N for short-duration cassava (N: P₂O₅: K₂O @ 50:0:100 kg/ha) could be saved in both the systems involving cowpea by the third year. Sequential cropping of vegetable cowpea [*Vigna unguiculata* (L.) Walp.] followed by short-duration cassava (under full N) proved to be a profitable production system generating the highest net return (Rs. 97398/ha) and benefit: cost ratio (2.15).

Key words: B:C ratio, Crop intensification, Cowpea, Early maturing cassava, Growth dynamics, Yield

Cassava (*Manihot esculenta* Crantz) is currently the world's seventh most important food crop in terms of area planted, far behind wheat, maize, rice, barley, sorghum and millet (Howeler 2014). It is the primary staple food for more than 800 million people in the world, mostly in the poorest tropical countries (Lebot 2009). It is an important tropical tuber crop that plays a significant role in the food and nutritional security of the rural households. It is a very rustic crop, efficient in carbohydrate production, adapted to a wide range of environments, grows well under marginal conditions and degraded soils and tolerant to drought and acidic soil conditions (Ceballos *et al.* 2010).

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 intensification in agriculture, especially multiple cropping to increase productivity. This has necessitated the development of short-duration varieties that can be grown intensively in cropping systems. Though, there is a great demand for food production in South Asia, there are large

areas left fallow after rainfed rice, and even irrigated rice, when there is inadequate irrigation water for year round cropping. Hence, presently there is a preference for early-maturing lines of cassava (that can be harvested by 6-7 months) for cultivation as a sequential crop in lowlands after the first crop of rice.

Over the last two decades, cassava cultivation in uplands has declined, whilst it has caught up in lowlands sequentially after main crop of rice, banana or vegetables (Mohankumar *et al.* 1985). Short-duration cassava varieties harvestable by 6-7 months hold promise as these are ideal for the better utilization of resources by small farmers as well as diversification of on-farm enterprise and income (Suja *et al.* 2010a, Suja *et al.* 2011). Nutrient management for short-duration cassava has been developed (Pamila *et al.* 2006, Suja *et al.* 2010b). The practice of growing a grain- or forage-legume like cowpea [*Vigna unguiculata* (L.) Walp.], 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. Mco1 1684 (Howeler 2012). However, information on cropping systems involving short-duration cassava is not available. The

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present investigation was, therefore, taken up to develop feasible short-duration cassava-cowpea system in lowland situation akin to rice fallow and evaluate the growth dynamics, yield, economics and soil nutrient status of the cassava-cowpea system.

MATERIALS AND METHODS

Field experiments were conducted for three consecutive years (2007-2008, 2008-2009, 2009-2010) during August-May at Central Tuber Crops Research Institute (CTCRI), Thiruvananthapuram, Kerala, India, in lowland situation similar to a rice fallow. The experimental site is located at 8° 29'N, 76°57'E and 64 m above sea level and represents humid tropical climate. The mean annual rainfall was 1204.11 mm and the annual means of maximum and minimum daily temperatures were 31.65°C and 25.02°C respectively. The soil type is well drained acid Ultisol. At the start of the experiment, the soil had pH of 4.35, low available N (251.98 kg/ha), high available P (28.13 kg/ha), medium available K (150.82 kg/ha) and organic C (0.747 %) contents.

Two short-duration cassava varieties, Vellayani Hraswa and Sree Vijaya, were evaluated in two cropping systems (sequential cropping (SC) and intercropping (IC)) involving two types of cowpea (vegetable (var. Pusa Komal) (VC) and grain types (var. C 152) (GC)) under two fertility levels (full recommended dose (RD) of NPK (based on soil testing), half RD N + full RD P + full RD K) in split plot design for studying the growth dynamics, biomass production characteristics, yield, economics, nutrient uptake and soil nutrient status. Varieties were assigned to main plots and combination of cropping systems and fertility levels to sub plots. Sole crop of cassava was also maintained for comparison. The gross plot size was 5.4 m × 5.4 m (36 plants) accommodating 16 net plants. A brief description of the test varieties is given in Table 1.

Planting and the other agronomic practices were done in accordance to the package of practices recommendations for cassava and cowpea (KAU 2002). The seed rates for sequential crop of vegetable cowpea and grain cowpea were 20-25 and 50-60 kg/ha respectively. The spacing adopted was 30 × 15 cm and cowpea was sown during August every year. Farmyard manure (FYM) @ 20 tonnes/ha and N, P₂O₅, and K₂O @ 20:30:10 kg/ha was applied to

sequential crop of cowpea. Full dose of FYM, P₂O₅, and K₂O and half N were applied basally at final ploughing and the remaining N was applied 15-20 days after sowing (DAS).

Mound method of planting was followed for cassava. FYM @ 12.5 tonnes/ha was applied at the time of planting every year. Based on soil test data, urea, Mussoorie rock phosphate and muriate of potash to supply N, P₂O₅ and K₂O @ 100:12.5:100 kg/ha was applied during the first two years under the full recommended dose. By the third year, the entire quantity of P could be saved for cassava and N, P₂O₅, and K₂O @ 100:0:100 kg/ha was used in this treatment. Hence, obviously under the reduced fertility level (half N, full P, full K), N, P₂O₅ and K₂O @ 50:12.5:100 kg/ha for the first two years and thereafter N, P₂O₅, and K₂O @ 50:0:100 were applied. The whole of P₂O₅ and half the doses of N and K₂O were applied immediately after sprouting of the setts. After one month the remaining quantities of N and K₂O were applied along with weeding and 'earthing up'. The crop was planted during November in each year, mainly rainfed and harvested after six months.

Both grain cowpea and vegetable cowpea were intercropped in additive series with cassava. Two rows of grain cowpea were intercropped in between two rows of cassava at a spacing of 30 × 15 cm and seed rate of 20 kg/ha. One row of vegetable cowpea was intercropped in between two rows of cassava at a spacing of 90 × 20 cm adopting a seed rate of 8 kg/ha. FYM and the whole of P₂O₅ and half the doses of N and K recommended for cassava were applied to both the crops as basal. One month after sowing cowpea, N, P₂O₅, and K₂O @ 10:15:10 kg/ha was applied to cowpea. Grain cowpea was harvested at 90-100 days and vegetable cowpea by 65-70 days. After the harvest of cowpea, the haulms were incorporated and the remaining quantities of N and K₂O were applied to cassava along with weeding and 'earthing up'.

Biomass measurements were done at 2, 4 and 6 months after planting (MAP) by uprooting three cassava plants at random per plot at each stage during the first two years (2007-2008 and 2008-2009). 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

Table 1 Brief description of the short-duration cassava varieties

Variety	Pedigree	Special traits	Duration (months)	Average yield (tonnes/ha)
Sree Vijaya	Selection from indigenous germplasm released from CTCRI	Early maturing, suitable for rotation in rice based cropping systems in lowlands, tuber contains 38-40% dry matter, 27-30% starch and low content of cyanogens (40-60 ppm), adapted to a wide range of agro-climatic conditions, southern, eastern and NE India	6-7 months	25- 28
Vellayani Hraswa	Selection released from Kerala Agricultural University	Short stature, highly branching, high yielding, tubers contain 27-28% starch and have good cooking quality	5-6 months	40- 45

and total biomass production of cassava at harvest were also calculated and expressed as tonnes/ha. From the values of dry weight, crop growth rate (CGR), relative growth rate (RGR), tuber bulking rate (TBR), mean tuber bulking rate, and harvest index (HI) were computed using the growth analysis techniques of Hunt (1982). CGR, TBR and HI computations correspond to three distinct phases of crop growth, viz. 0-2 MAP (Phase 1), 2-4 MAP (Phase 2) and 4-6 MAP (Phase 3). RGR of phase 2 and phase 3 were computed. At harvest the fresh tuber yield of cassava was computed in tonnes/ha based on the data taken from the net plants. The yield of vegetable cowpea and grain cowpea were also recorded and expressed in kg/ha. The N, P and K contents in the various plant parts was estimated (Piper 1970). The plant uptake of N, P and K was calculated by adding the products of the nutrient contents in the various plant parts and respective dry weights of plant parts and expressed as kg/ha. Organic C, available N, P and K status of the soil were estimated by standard analytical procedures (Page *et al.* 1982). Net income and benefit:cost ratio was computed. The analysis of variance of data was done using SAS 9.3 (2010) using PROC MIXED for the

analysis of split plot design and PROC GLM for pooled analysis of yield data of three years, which was followed by the mean comparison using Least Significant Difference (LSD) test.

RESULTS AND DISCUSSION

Biomass production and partitioning

Experimental years imparted significant effect ($P < 0.0001$) on biomass production and partitioning with higher values during the second year. During the first year, the dry matter production and its partitioning to leaf, stem and tuber was not influenced by the varieties, cropping systems, cowpea types or fertility levels at the early and mid growth phases (Fig 1). By 6 MAP, the tuber biomass production was significantly higher under sequential cropping than intercropping due to absence of competition. Moreover at this stage, the tuber and whole plant biomass of cassava was significantly higher in the cropping system (both sequential and intercropping) involving vegetable cowpea than grain cowpea due to the comparatively shorter period of competition for cassava with vegetable cowpea. However, there was no possibility to reduce the fertilizer

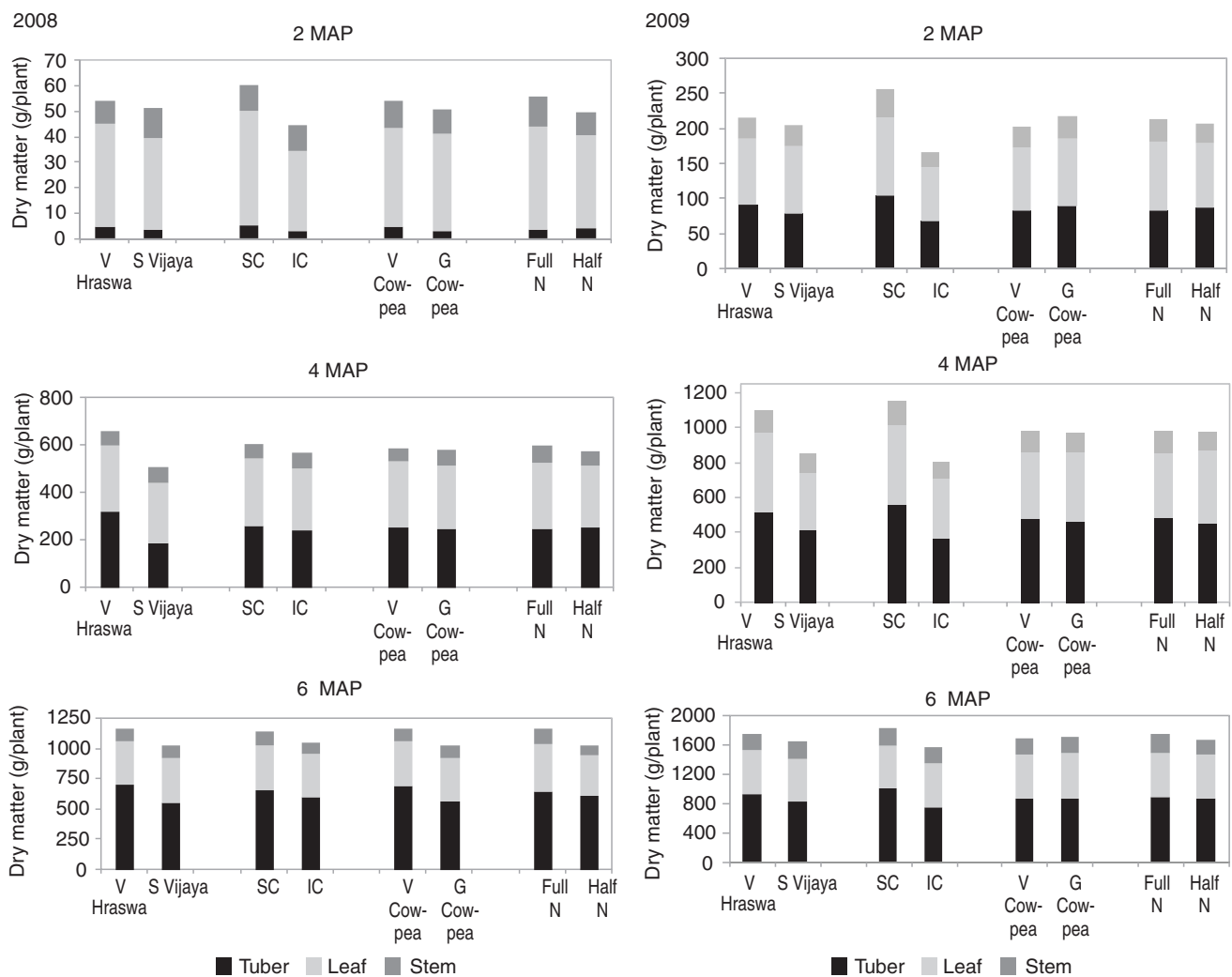


Fig 1 Biomass production and partitioning in short-duration cassava as influenced by cropping systems involving cowpea and fertility levels

dosage to short-duration cassava in either of the systems involving cowpea as revealed by the significantly higher total biomass under full recommended dose.

In the subsequent year, the total biomass production and its partitioning to leaf, stem and tuber was significantly higher under sequential cropping than intercropping during 2 and 4 MAP (Fig.1). At 6 MAP, total and tuber biomass production was significantly higher under sequential cropping than intercropping. By the second year of study, there was a possibility to reduce the fertilizer dosage (N by half) to short-duration cassava in both the systems involving cowpea as indicated by the almost similar pattern of biomass production and partitioning at various stages under the two fertility levels.

Growth indices

As observed in the case of biomass production and partitioning, the CGR, TBR and HI were not significantly influenced by the varieties, cropping systems, cowpea types or fertility levels at most growth phases during the first year of study (Fig 2). By 6 MAP, the CGR and TBR of cassava were significantly higher in the cropping system

(both sequential and intercropping) involving vegetable cowpea than grain cowpea. This was also reflected in the mean TBR, which was significantly higher for sequential cropping than intercropping and vegetable cowpea than grain cowpea (Table 2). However, the RGR of cassava was significantly higher for intercropping than sequential cropping during phase II. By the last phase, RGR was almost the same under sequential and intercropping systems (Table 2). This indicates there is scope for intercropping in short-duration cassava.

In the second year, the CGR and TBR of the cassava varieties were significantly higher under sequential cropping involving cowpea than intercropping during the active growth phases (Fig 2). By the final phase, CGR (14.00, 15.70 g/m²/day) and TBR (7.35, 6.47 g/day) were almost the same under both the systems, which indicate that short-duration cassava regained growth due to recovery from competition after the harvest of intercrop of cowpea. This is also clear from the significantly higher RGR of cassava under intercropping (11.31 mg/g/day) than sequential cropping (7.88 mg/g/day) during this phase. However, the mean TBR of cassava was significantly higher

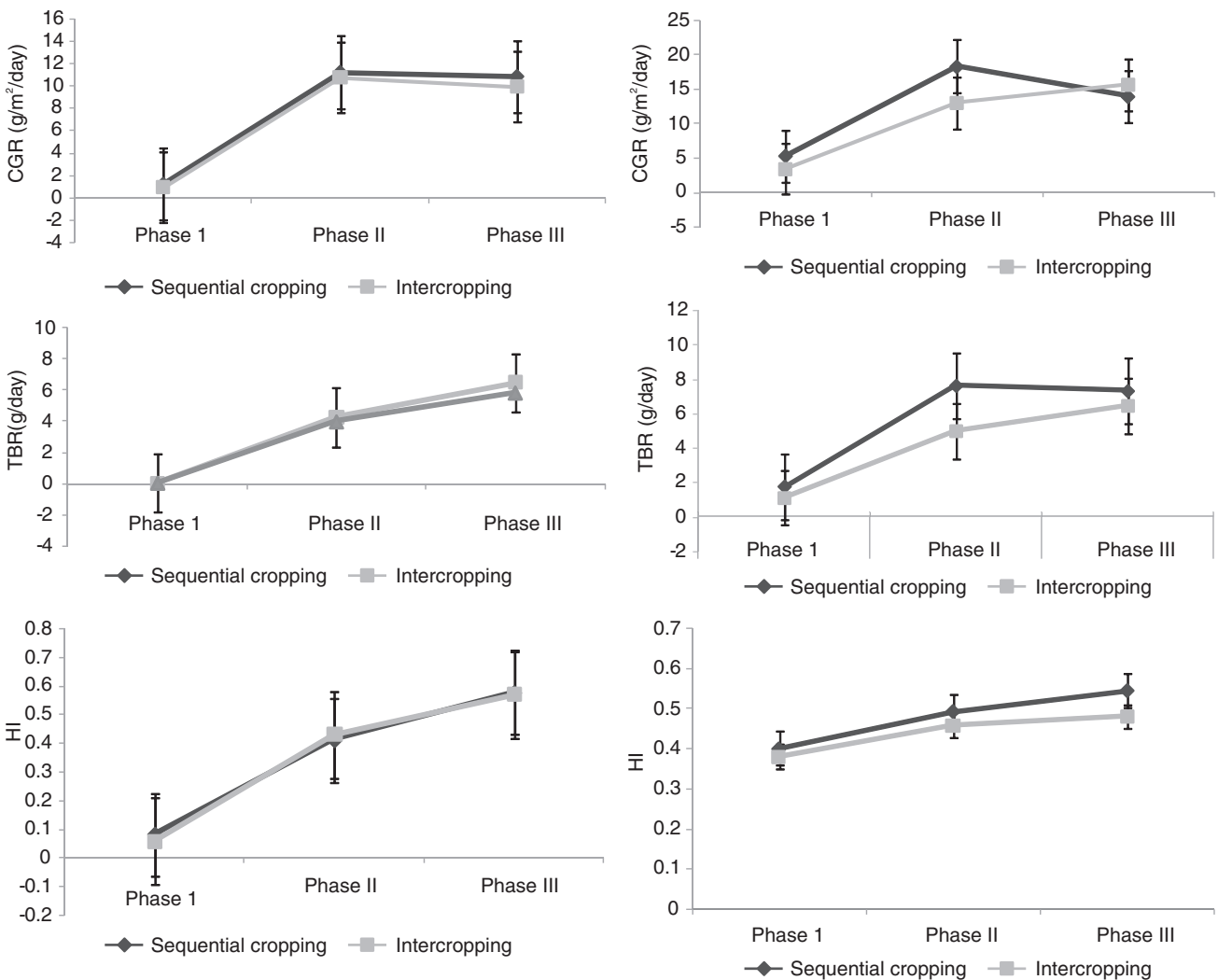


Fig 2 Growth indices of short-duration cassava under the two systems

Table 2 Mean tuber bulking rate and trend of relative growth rate as influenced by short- duration cassava varieties, systems involving cowpea and fertility levels

Treatments	Mean tuber bulking rate (g/day)		Relative growth rate (mg/g/day)			
	2007-2008	2008-2009	2007-2008		2008-2009	
			Phase II	Phase III	Phase II	Phase III
<i>Short- duration varieties</i>						
Vellayani Hraswa	3.865	5.15	43.1	9.42	27.9	7.66
Sree Vijaya	3.050	4.64	39.4	11.91	23.8	11.53
LSD (P=0.05)	NS	NS	1.421	NS	NS	NS
<i>Systems</i>						
Sequential cropping	3.613	5.58	38.7	10.86	25.3	7.88
Intercropping	3.302	4.20	43.8	10.48	26.4	11.31
LSD (P=0.05)	0.2863	0.782	4.680	NS	NS	0.203
<i>Cowpea types</i>						
Vegetable cowpea	3.806	4.89	40.3	11.69	26.4	9.29
Grain cowpea	3.109	4.89	42.2	9.65	25.3	9.90
LSD (P=0.05)	0.2863	NS	NS	NS	NS	NS
<i>Fertility levels</i>						
Full N	3.555	4.94	40.4	11.24	26.0	9.81
Half N	3.360	4.84	42.1	10.10	25.7	9.38
LSD (P=0.05)	NS	NS	NS	NS	NS	NS
<i>Controls (Sole cassava)</i>						
Vellayani Hraswa	4.440	4.95	46.61	6.02	26.5	9.17
Sree Vijaya	4.113	3.35	39.20	2.56	26.7	7.00

under sequential cropping than intercropping (Table 2). The HI was unaffected, except at the last phase when it was significantly higher for sequential cropping (0.55) than intercropping (0.48) (Fig 2).

Tuber and total biomass production

There was significant seasonal variation ($P < 0.0001$) in tuber and total biomass production with higher values observed in the second year (Fig 3). Both the varieties had similar tuber and total biomass production, but Vellayani Hraswa produced slightly higher biomass. During the first year, as expected, sequential cropping (8.03 tonnes/ha) resulted in significantly higher tuber biomass production per ha over intercropping (7.34 tonnes/ha) due to absence of competition. Moreover, the tuber and total biomass production of cassava was significantly higher in the cropping system (both sequential and intercropping) involving vegetable cowpea (8.46 and 14.33 tonnes/ha) than grain cowpea (6.91 and 12.58 tonnes/ha) due to the comparatively shorter duration of competition for cassava with vegetable cowpea than grain cowpea. The full recommended dose of N produced significantly higher total biomass (14.25 tonnes/ha).

Similarly during the second year also, total and tuber biomass production was significantly higher under

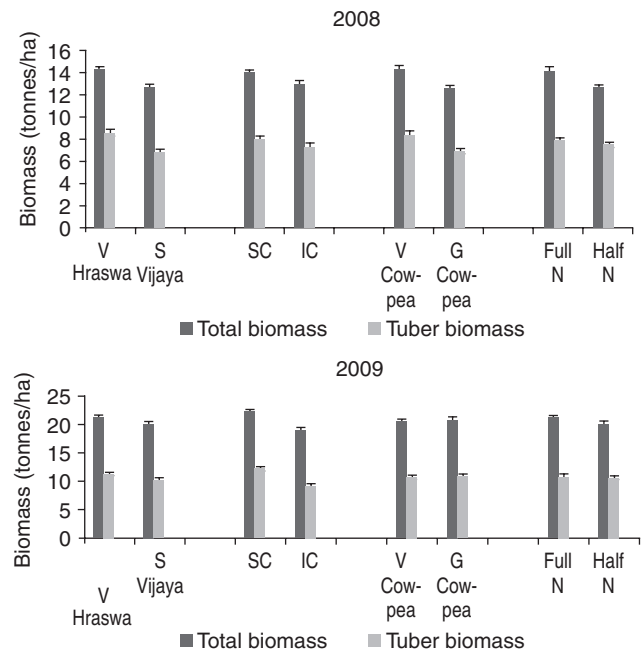


Fig 3 Effect of short-duration cassava varieties, systems, cowpea types and fertility levels on tuber and total biomass production

sequential cropping (22.60 and 12.40 tonnes/ha) than intercropping (19.28 and 9.34 tonnes/ha). The tuber and total biomass production were almost same under the two fertility levels, indicating the scope to reduce the quantity of N by half (Fig 3).

Tuber yield

In the first year, the varieties performed similarly in the different systems involving cowpea. Sequential cropping proved superior to intercropping and vegetable cowpea was better than grain cowpea. The full fertility level produced significantly higher tuber yield. In the subsequent years also, sequential cropping continued its superiority, but there was no significant difference between the varieties, cowpea types and fertility levels.

The average over the years indicated that Vellayani Hraswa produced significantly higher yield than Sree Vijaya in systems involving cowpea (24.55 and 21.46 tonnes/ha respectively) (Table 3). The yield reduction noticed in Vellayani Hraswa and Sree Vijaya in cropping systems, especially under intercropping, over sole cropping was negligible (1.88 and 14.37% respectively). Sequential cropping enhanced yield by 4%, whereas intercropping reduced yield by 20.36% over sole cropping. The superior performance of Vellayani Hraswa and Sree Vijaya has been reported earlier (Suja *et al.* 2010a. Suja *et al.* 2010b. Suja *et al.* 2011). Of the 2 systems, sequential cropping (26.07 tonnes/ha) proved superior to intercropping (19.94 tonnes/ha). Both vegetable cowpea (var. Pusa Komal) and grain cowpea (var. C 152) were found to be equally compatible with short-duration cassava under both the systems. Saving of full P and half N for short-duration cassava was possible

Table 3 Tuber yield (tonnes/ha) of short-duration cassava varieties as influenced by systems involving cowpea and fertility levels

Treatments	2007-2008	2008-2009	2009-2010	Mean
<i>Short- duration varieties</i>				
Vellayani Hraswa	21.61	28.87	23.17	24.55
Sree Vijaya	19.27	26.12	19.00	21.46
LSD ($P=0.05$)	NS	NS	NS	1.159
<i>Systems</i>				
Sequential cropping	21.14	33.17	23.90	26.07
Intercropping	19.74	21.83	18.27	19.94
LSD ($P=0.05$)	1.088	2.032	3.016	5.912
<i>Cowpea types</i>				
Vegetable cowpea	21.81	27.58	21.16	23.52
Grain cowpea	19.07	27.42	21.01	22.50
LSD ($P=0.05$)	1.088	NS	NS	NS
<i>Fertility levels</i>				
Full N	21.00	28.38	22.51	23.96
Half N	19.88	26.62	19.66	22.05
LSD ($P=0.05$)	1.088	NS	NS	NS
<i>Controls (Sole cassava)</i>				
Vellayani Hraswa	22.30	26.15	26.62	25.02
Sree Vijaya	22.20	26.82	26.15	25.06

in both sequential and intercropping systems with cowpea from the second year onwards.

As expected, sequential cropping produced higher yield than sole cropping (by 4%) and intercropping (by 30.74%) in short-duration cassava as the cassava crop benefitted from the residual nitrogen fixed by the cowpea as well as organic matter added by cowpea residues after its harvest as reported by Njoku and Muoneke (2008). Earlier studies indicated that intercropping legumes like cowpea, French beans and groundnut and vegetables like cucumber, okra and *Amaranthus* reduced the yield of a cassava of 10 months cycle (Prabhakar *et al.* 1983, Mohankumar and Ravindran 1990). However the objective of the present study was to find out the extent of yield reduction under intercropping in short-duration cassava in situation similar to rice fallow. The study indicated that there was scope for intercropping with extra-short-duration pulses or legumes in short-duration cassava as the cassava yield reduction was less (20.36%) and could be compensated by the additional yield and soil health benefits from the legume. The short-duration cassava variety, Vellayani Hraswa tolerated the competitive stress more and was more compatible than Sree Vijaya, as indicated by the 14.4% higher yield than Sree Vijaya. The compatibility of cassava and cowpea is well documented (Mason *et al.* 1986, Leihner 2002, Adeniyani *et al.* 2011) and development of a feasible rice based cropping system involving short-duration cassava and cowpea will help to diversify our food basket. This will also help to achieve self sufficiency in pulse production in a country like India, where pulses are still imported to meet our deficit demand.

Nutrient uptake and soil nutrient status

The uptake of N, P and K by short-duration cassava varieties was unaffected by cropping systems involving cowpea and fertility levels. Chemical properties of the soil, viz., pH, organic C, available N, P and K status of the soil at the end of 3 years of experimentation were also not significantly influenced by the treatments (Table 4). This indicates that both intercropping and sequential cropping, grain cowpea and vegetable cowpea were equally compatible with short-duration cassava. The uptake as well as the soil nutrient status was not profoundly influenced by the fertility levels, which indicates that there is a possibility for reducing the N dosage to half.

Economic analyses

Cost benefit analysis indicated that sequential cropping of vegetable cowpea followed by short-duration cassava under full N was the most profitable generating the highest net returns (₹ 97 398/ ha) and B: C ratio (2.15) due to the high yield and income from vegetable cowpea (Table 5). Sequential cropping of vegetable cowpea with short-duration cassava under half N (B:C ratio of 1.86) was the next best, followed by sequential cropping of grain cowpea with short-duration cassava under full N (1.72). Mohankumar and Nair (1990) also found that vegetable cowpea followed by cassava was profitable. Sole crop of cassava under full N proved to be significantly inferior to

Table 4 Nutrient status of the soil as influenced by systems involving cowpea and fertility levels at the end of experimentation

Treatment	Organic C (%)	pH	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
<i>Short- duration varieties</i>					
Vellayani Hraswa	0.666	4.295	134.6	33.2	207.5
Sree Vijaya	0.627	4.569	129.5	36.0	220.6
LSD ($P=0.05$)	NS	NS	NS	NS	NS
<i>Systems</i>					
Sequential cropping	0.648	4.450	134.3	36.7	204.7
Intercropping	0.644	4.414	129.9	32.6	223.4
LSD ($P=0.05$)	NS	NS	NS	NS	NS
<i>Cowpea types</i>					
Vegetable cowpea	0.656	4.440	132.8	37.2	217.1
Grain cowpea	0.637	4.424	131.4	32.0	211.0
LSD ($P=0.05$)	NS	NS	NS	NS	NS
<i>Fertility levels</i>					
Full N	0.645	4.463	136.7	36.5	217.4
Half N	0.648	4.401	127.5	32.7	210.7
LSD ($P=0.05$)	NS	NS	NS	NS	NS
<i>Controls (Sole cassava)</i>					
Vellayani Hraswa	0.658	4.287	130.0	36.2	191.5
Sree Vijaya	0.673	4.356	120.8	24.0	190.4

Table 5 Economic analysis of short-duration cassava and cowpea system (mean of 3 years)

Treatment	Mean tuber yield (tonnes/ha)	Cowpea yield (kg/ha)	Gross income (₹/ha)	Gross costs (₹/ha)	Net income (₹/ha)	B:C ratio
VC-Cassava + full N	27.318	2500	181954	84556	97398	2.15
VC-Cassava + half N	25.940	1918	154521	83156	71365	1.86
GC-Cassava + full N	26.325	815	127875	74256	53619	1.72
GC-Cassava + half N	24.693	750	119080	73656	45424	1.62
Cassava+VC + full N	21.506	1100	108517	70256	38261	1.54
Cassava+VC + half N	19.297	880	93090	69656	23434	1.34
Cassava+GC + full N	20.701	530	93904	66256	27648	1.42
Cassava+GC + half N	18.284	428	80503	65656	14847	1.23
Sole cassava + full N (Control)	25.040		75119	59256	15863	1.27
LSD (P =0.05)	1.158		11072.53		11071.62	0.160

VC refers to vegetable cowpea and GC to grain cowpea.

most of the cropping systems treatments.

The study indicates that including vegetable cowpea or grain cowpea either in sequence before short-duration cassava or as intercrops is a viable proposition than sole cassava. This is the first report in short-duration cassava. The study also underscores the importance of the development of a feasible rice based cropping system involving short-duration cassava and cowpea to diversify our food basket. This will also help to achieve self-sufficiency in pulse production in a country like India, where pulses are still imported to meet our deficit demand.

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