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Impact of nutrient management based on soil test data on biomass production and partitioning and growth indices of short-duration cassava (*Manihot esculenta*)

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ABSTRACT

Field experiments were conducted during 2004–07 at Thiruvananthapuram, Kerala, in a lowland situation similar to rice fallow to standardize the nutrient management practices for short-duration cassava (*Manihot esculenta* Crantz). The phasic pattern of biomass production and partitioning and growth indices of 5 short-duration/early bulking cassava lines ('Vellayani Hraswa', 'Kalpaka', 'Sree Jaya', 'Sree Vijaya' and 'Triploid 2-18') was studied under four levels of fertility (full farmyard manure+ NPK, 75% farmyard manure + NPK, 50% farmyard manure + NPK and based on soil test data). 'Triploid 2-18' and 'Vellayani Hraswa' had appreciably higher total biomass (1371.5 and 1264.7 g/plant), tuber biomass (857.3 and 826.0 g/plant), crop growth rate (15.95 and 14.82 g/m^2/day), tuber bulking rate (10.111 and 9.365 g/day), mean tuber bulking rate (4.763 and 4.590 g/day) and harvest index (0.63 and 0.65). Nutrient management based on soil test data promoted biomass production and partitioning to tubers, crop growth rate, tuber bulking rate and harvest index at par with that of full farmyard manure + NPK, saving the entire quantity of P, 10% N and 15% K (farmyard manure 12.5 tonnes/ha and NPK 90:0:85 kg/ha) by the third year.

Key words: Biomass production, Growth analysis, Nutrient management, Short-duration cassava

Cassava (*Manihot esculenta* Crantz) is a highly nutrient exhausting crop. A crop of cassava yielding 30 tonnes/ha of fresh tubers in 10-month cycle removes 180–200 kg N, 15–22 kg P and 140–160 kg K/ha (CTCRI 1983). The nutrient recommendation for normal duration cassava is farmyard manure @12.5 tonnes/ha and NPK @100:50:100 kg/ha. However, when short-duration varieties are integrated into the existing cropping systems, utilization of residual moisture and nutrients will be possible by slight modification of the management practices. Hence, it is imperative to assess the possibility of saving expensive nutrient inputs by formulating suitable nutrient management practices for short-duration cassava in lowland. A comprehensive analysis of the basic pattern of growth and development of a crop is useful to elucidate the response of the crop to various inputs and helps in deciding the phasic scheduling of agronomic practices for obtaining higher yield. Though a few reports on the agronomy of short-duration casava are available (Pamila *et al*. 2006), information on the impact of nutrient management practices on growth analysis of short-duration cassava is lacking. Hence a study was conducted to have a comparison of the temporal pattern of biomass production and partitioning, phasic trend of various growth indices of five short-duration/early- bulking lines of cassava under four levels of fertility in a lowland situation.

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MATERIALS AND METHODS

Field experiments were conducted in a lowland situation akin to a rice fallow during November–May in 2004–05, 2005–06 and 2006–07 at Central Tuber Crops Research Institute (CTCRI), Sreekariyam, Thiruvananthapuram (8° 29'N, 76°57'E, 64 m altitude), Kerala, to study the phasic pattern of biomass production and partitioning and growth indices of five short-duration cassava lines under four levels of fertility. The soil was well drained acid Ultisol with *p*H 4.35. The organic C status was medium (0.62%), available N content was low (234 kg/ha), available P content was high (28.3 kg/ha) and available K content was low (142.3 kg/ha). The site experiences a typical humid tropical climate with mean annual rainfall of 1846 mm and mean maximum temperature of 31.33°C and minimum 25.08°C.

The experiment was laid out in split-plot design with three replications. Five short-duration/early-bulking lines of cassava, such as 'Kalpaka', 'Sree Jaya', 'Sree Vijaya', 'Triploid 2-18' and 'Vellayani Hraswa' were used. 'Sree Jaya' and 'Sree Vijaya' are the released short-duration varieties and 'Triploid 2-18' is a promising early bulking triploid line

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from CTCRI. 'Kalpaka' and 'Vellayani Hraswa' are the released varieties from Kerala Agricultural University. The varieties were assigned to the main plots and four levels of fertility (S_1: full farmyard manure + NPK, S_2: 75% farmyard manure + NPK, S_3: 50% farmyard manure + NPK and S_4: fertility level based on soil test data) to the sub plots. The gross plot size was 5.4 m×5.4 m (36 plants) accommodating 16 net plants. The quantity of farmyard manure and NPK applied in the various treatments are provided in Table 1.

Prior to planting cassava, a crop of green manure *Vigna unguiculata* L. Walp cowpea was raised and incorporated at 45–60 days during all the years. Planting and the other agronomic practices were done in accordance to the package of practices recommendations (KAU 2002). The mound method of planting was followed. Farmyard manure at the required quantity was applied at planting in all the treatments. Urea, mussorie rock phosphate and muriate of potash to supply NPK at the various fertility levels were used. The nutrient status of the soil after two weeks of incorporation of green manure cowpea was analyzed. 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 following Aiyer and Nair (1985) (Table 1). The whole of P_2O_5 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, mainly rainfed and harvested after six months.

Biomass measurements were done at two, four and six months after planting (MAP) by sampling three plants at random/plot at each stage. The uprooted plants were separated into leaves, stems and tubers; air-dried and then oven-dried at 70°C to constant weight. The dry weights of leaves, stems and tubers were recorded and the total plant dry weights were computed and expressed in g/plant. 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. The analysis of variance of data was done using the package GenStat (GenStat Seventh Edition (DE3) 2007).

Table 1 Quantity of farmyard manure (FYM) and NPK applied in the various treatments

Notation	Treatment	Quantity applied			
		FYM (tonnes/ha)	N	P_2O_5 (kg/ha)	K_2O
S_1	Full FYM + NPK	12.5	100	50	100
S_2	75% FYM + NPK	9.5	75	37.5	75
S_3	50% FYM + NPK	6.25	50	25	50
S_4	*Based on soil test results*				

Year of soil sampling, testing and planting	Organic C (%)	Available nutrient status after green manure cowpea (kg/ha)			Quantity computed and applied (kg/ha)			
		N	P	K	FYM (tonnes/ha)	N	P_2O_5	K_2O
2004	0.670	236.55	14.23	112.15	12.5	95	40	105
2005	0.658	162.09	19.50	151.33	12.5	95	35	95
2006	0.759	133.09	66.35	171.36	12.5	90	0	85

RESULTS AND DISCUSSION

Biomass production and partitioning

In all the years, with progressing plant age the total biomass production showed a significantly increasing trend with age, in all the short-duration cassava lines. This is consistent with the report of Akparobi *et al*. (2002) in Nigeria in cassava clones of 10–12 months. During the first year, the phasic trend of biomass production and partitioning varied significantly among the varieties, the 'Triploid 2-18' produced significantly higher leaf, stem, tuber and whole plant biomass, particularly during the mid and final growth phases. In the second and third years, at most stages, the varieties followed almost similar patterns of total biomass production and distribution to tubers, leaves and stems. However, at two months after planting in the second year, 'Vellayani Hraswa' and 'Triploid 2-18' gave significantly higher tuber and total biomass. The efficiency of 'Triploid 2-18' for producing greater canopy size as well as higher tuber and total biomass was also observed earlier (Suja *et al*. 2010). During the first two years, full dose of farmyard manure and NPK promoted total biomass and tuber biomass production almost throughout the growth cycle, though comparable aerial biomass was also produced at lower nutrient levels (75% farmyard manure+ NPK and nutrient level based on soil test data). Higher dry root yield, aerial and total biomass under higher NPK levels is a common phenomenon in cassava (Pellet and Sharkawy 1993). By the third year, the different soil fertility levels exerted profound influence on biomass production and partitioning at various stages. The total biomass production as well as its diversion to leaf, stem and tuber was higher and at par under full dose of farmyard manure and NPK and fertility level based on soil test data at most stages, suggesting a possibility for saving fertilizer input for short-duration cassava production. A perusal of data in Table 1 will clearly indicate the reduction in the quantity of major nutrients that was possible (from second crop season onwards) in plots that received fertilizers based on soil test data. By the third year, the entire quantity of P, 10% N and 15% K could be saved as

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Table 2 Phasic pattern of crop growth rate and relative growth rate in short duration cassava varieties

Treatment	Crop growth rate ($g/m^2/day$)									Relative growth rate (mg/g/day)	
	2004–05			2005–06			2006–07			Mean of 3 years	
	2MAP	4MAP	6MAP	2MAP	4MAP	6MAP	2MAP	4MAP	6MAP	2-4 MAP	4-6 MAP
Varieties											
'Kalpaka'	0.76	11.44	12.59	1.66	9.13	7.28	1.46	13.25	15.47	39.04	10.94
'Sree Jaya'	0.74	9.76	17.75	1.29	7.51	9.74	0.96	11.50	12.79	39.82	13.49
'Sree Vijaya'	0.98	11.81	15.84	1.34	8.35	7.10	1.08	13.46	10.57	40.18	10.60
'Triploid 2-18'	0.84	14.49	20.58	1.80	8.20	9.91	0.74	10.75	17.35	41.41	13.60
'Vellayani Hraswa'	0.60	10.71	17.54	1.73	9.78	9.77	1.02	9.77	17.16	40.13	14.10
CD (*P*=0.05)	0.165	1.934	1.733	0.313	NS	NS	NS	NS	NS	NS	NS
Fertility levels											
Full FYM+NPK	0.92	13.13	16.91	1.95	9.80	9.51	1.42	13.50	16.76	38.64	11.84
75% FYM+NPK	0.80	11.23	16.98	1.55	8.86	8.45	0.97	10.91	13.31	39.82	12.44
50%FYM+NPK	0.61	10.37	16.54	1.22	8.00	7.24	0.68	8.94	12.50	42.24	12.92
Based on soil test data	0.82	11.84	17.01	1.53	7.71	9.84	1.14	13.64	16.10	39.76	12.97
CD (*P*=0.05)	0.194	0.898	NS	0.287	1.522	NS	0.253	1.340	NS	NS	NS

MAP, Months after planting

per the present study. However, the interaction between varieties and fertility levels was not significant at most stages during the period of study.

Growth indices

Crop growth rate: During the first year, crop growth rate of all the lines increased progressively with advancing age of the crop, attaining peak values at harvest. The phasic trend of crop growth rate varied considerably among the varieties tested (Table 2). In the first phase, 'Sree Vijaya' and 'Triploid 2-18' had significantly higher crop growth rate, while in the subsequent 2 phases, 'Ttriploid 2-18' gained rapid momentum resulting in significantly higher crop growth rate. The higher efficiency of these lines for higher biomass production might have led to higher crop growth rate (Suja *et al*. 2010). During second year, crop growth rate of 'Sree Jaya' and 'Triploid 2-18' followed a steady increase throughout the crop cycle and attained peak values at the last phase, whereas 'Vellayani Hraswa', 'Kalpaka' and 'Sree Vijaya' peaked at the mid growth phase and thereafter expressed slight decline. The early season advantage of crop growth rate in those varieties might explain their high-yielding nature and early maturity. Varietal variation of crop growth rate was less pronounced, except during the first phase, in which 'Triploid 2-18' had higher crop growth rate which was at par with 'Vellayani Hraswa' and 'Kalpaka'. During the third year, the crop growth rate of short-duration cassava varieties was almost the same at various phases. In all the years, the higher fertility levels influenced crop growth rate markedly during the first two phases and the full dose of farmyard manure and NPK or the fertility level based on soil test data proved superior. During the last growth phase, all the fertility levels had similar effects on crop growth rate.

Relative growth rate: Between the two phases observed, relative growth rate was significantly higher during phase 2 (2–4 MAP) than phase 3 (4–6 MAP), which indicates the declining trend of relative growth rate with crop age. A similar trend was observed in *Dioscorea* species as well (Suja *et al*. 2005). During the early phases significant additions in dry matter/unit of original dry matter occurred both due to canopy development and tuber growth. By this time the tuber development was sufficient and tubers represented as active sinks of the plants. Thereafter significant dry matter increments occurred solely due to tuber bulking with negligible contributions from the leaves, stems and roots and hence relative growth rate declined markedly towards harvest. On the whole relative growth rate was not significantly influenced by varieties or fertility levels or their interaction (Table 2).

Tuber bulking rate: In all the years, tuber bulking rate increased progressively with advancing age, attaining the highest values at harvest (Table 3). In the first year, tuber formation was not observed during the first phase. In the remaining phases, the tuber bulking rate of the varieties varied significantly, with 'Triploid 2-18', 'Sree Vijaya' and 'Vellayani Hraswa' showing higher tuber bulking rate in the mid growth phase and 'Triploid 2-18', 'Vellayani Hraswa' and 'Sree Jaya' showing higher tuber bulking rate at the final phase. In the second year, varietal effect on tuber bulking rate was pronounced during the first and last phases; 'Vellayani Hraswa' and 'Triploid 2-18' had almost similar, but significantly higher tuber bulking rate at these phases. During the last year, the varieties exhibited almost similar tuber bulking rate at the first and the last phase, while during the second phase, 'Sree Vijaya' and 'Kalpaka' proved superior. The soil fertility levels influenced tuber bulking rate in a similar pattern as that of crop growth rate. The application of nutrients based on soil test data resulted in

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Table 3 Pattern of tuber bulking rate and harvest index in short duration cassava varieties as affected by fertility levels

Treatment	Tuber bulking rate (g/day)									Mean tuber bulking rate (g/day)	Harvest index		
	2004–05			2005–06			2006–07			Mean			
	2MAP	4MAP	6MAP	2MAP	4MAP	6MAP	2MAP	4MAP	6MAP		2MAP	4MAP	6MAP
Varieties													
'Kalpaka'	0.0	3.445	8.005	0.312	4.018	3.573	0.120	6.529	9.291	3.921	0.101	0.469	0.590
'Sree Jaya'	0.0	3.130	10.860	0.165	2.920	5.754	0.080	4.518	6.758	3.798	0.083	0.419	0.586
'Sree Vijaya'	0.0	3.989	9.793	0.250	3.094	4.826	0.051	6.881	6.328	3.912	0.095	0.466	0.618
'Triploid 2-18'	0.0	4.591	12.141	0.392	3.454	6.088	0.001	4.095	12.105	4.763	0.092	0.428	0.627
'Vellayani Hraswa'	0.0	3.808	11.138	0.392	4.636	6.044	0.029	4.345	10.914	4.590	0.103	0.483	0.652
CD (*P*=0.05)	NS	0.784	1.640	0.093	NS	1.137	NS	0.722	NS	0.4536	0.028	0.028	0.028
Fertility levels													
Full FYM+NPK	0.000	4.278	10.149	0.408	4.451	5.523	0.096	6.128	10.141	4.576	0.111	0.465	0.603
75% FYM+NPK	0.000	3.600	10.639	0.322	3.523	5.336	0.019	4.868	8.299	4.068	0.091	0.439	0.618
50%FYM+NPK	0.000	3.377	10.635	0.211	3.222	4.585	0.007	4.049	8.389	3.830	0.077	0.452	0.637
Based on soil test data	0.000	3.915	10.126	0.269	3.301	5.583	0.103	6.049	9.487	4.314	0.100	0.456	0.599
CD (*P*=0.05)	NS	0.373	NS	0.053	0.930	NS	0.069	0.476	NS	0.4057	0.025	0.025	0.025

tuber bulking rate at par with full farmyard manure+NPK during the first and second phases in all the three crop cycles, while during the last phase, all the fertility levels exerted similar influence.

Mean tuber bulking rate did not vary appreciably among the varieties, except during the first year in which 'Triploid 2-18' had significantly higher mean tuber bulking rate (5.577 g/day) (Table 3). During the first and the last years of study the soil fertility levels imparted similar effects on mean tuber bulking rate, while during the second year, full dose of farmyard manure and NPK resulted in significantly higher mean tuber bulking rate. Considering the mean of 3 years, mean tuber bulking rate of 'Triploid 2-18' and 'Vellayani Hraswa' were higher and almost equal (4.763 and 4.590 g/day respectively). Further, application of nutrients based on soil test data (4.314 g/day) promoted mean tuber bulking rate as that under full dose of farmyard manure and NPK (4.576 g/day).

Harvest index: The mean trend of harvest index in the short-duration cassava varieties at various stages as influenced by soil fertility levels is given in Table 3. Harvest index showed an increasing trend with age attaining the highest values at harvest. Significant increment in harvest index with progressing stages was observed in *Dioscorea* species also (Suja *et al*. 2005). In general the harvest index of the short-duration cassava varieties remained almost the same at various stages, except during the last phase. In the last phase, the harvest index of 'Vellayani Hraswa' (0.652) and and 'Triploid 2-18' (0.627) was higher and almost equal.

During the first two stages the full recommended dose was at par with reduced doses of nutrients (75% or 50% farmyard manure + NPK) and fertility level based on soil test data. This suggests the possibility for reducing nutrients for greater and efficient translocation of assimilates for storage in the tuber, culminating in higher harvest index at these stages. During the last phase 50% farmyard manure+ NPK proved superior. Excessive shoot growth at the expense of tuber bulking might have reduced harvest index at higher nutrient levels at this stage as reported earlier (Suja 2005, Nayar 1986).

On the whole, short-duration cassava varieties hold great promise for crop diversification as sequential crops after rice or banana or vegetables. 'Triploid 2-18' and 'Vellayani Hraswa' had appreciably higher total biomass and tuber biomass, crop growth rate, tuber bulking rate, mean tuber bulking rate and harvest index. Nutrient management for short-duration cassava based on soil test data for organic C, available P and K status, which resulted in a saving of full P, 10% N and 15% K by the third year, favoured total biomass production and its efficient diversion to tubers, crop growth rate, tuber bulking rate and harvest index, thereby enabling higher cassava production.

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