ADAPTABILITY OF FOUR CASSAVA (*MANIHOT ESCULENTA* CRANTZ) CULTIVARS IN SWAMPY INLAND VALLEY ECOLOGY

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ABSTRACT
Cassava is a popular dry season crop grown to utilize residual soil moisture in inland valleys. Trials to evaluate growth rates of four cultivars (TMS 4(2) 1425, TMS 91/02324, TMS 91/02327 and Isunikankiyan) were conducted along the toposequence in a 4 x 4 Latin square design. Effects of toposequence position, site, year and their interactions as well as of cultivar were significant for Leaf area index (LAI), net assimilation rate (NAR), crop growth rate (CGR), tuberous root bulking rate (TRBR), relative growth rate (RGR) and root yield. LAI, NAR, CGR, TRBR and RGR correlated positively with yield. TMS 91/02324 and TMS 91/02327 with the highest growth indices produced the highest yields. The deep water table site at Alabata had the highest growth indices and yield in valley bottom and the lowest in the fringe, while the shallow water table site at Ibadan recorded higher yield and growth indices in the fringe than the other positions. The shallowest water table depths at Ibadan and Alabata were 0.15-0.45 m and 0.45-0.58 m below mound surface in valley bottom and fringe, respectively. Valley fringe at Ibadan and valley bottom at Alabata had similar water table depth and they produced the highest growth indices and yield. Shallow water table of 0.15-0.4 m below mound surface reduced LAI, TRBR, CGR, RGR and yield, but increased NAR. Drought stress and high radiation, temperature and evaporation reduced yield and growth indices, while well distributed rainfall increased them. Cassava cultivars with high root yields in swampy inland valley are early maturing and maintain high LAI, TRBR, CGR, RGR and NAR under excess soil moisture and drought stress.

KEY WORDS: Growth indices, Cassava cultivars, Root yield, Groundwater table depth, Inland valley ecology, Drought stress

INTRODUCTION
Cassava is an important food crop in the tropics and it is usually an upland crop. However, in West and Central Africa, it is a popular dry season crop grown in inland valleys to utilize the residual soil moisture after rice is harvested (Carsky *et al*., 1993). Inland Valleys have shallow water table and become partially inundated in the rainy season (Mohamoud, 1994). The total area of inland valley in tropical Africa is about 130 million hectares, while the area in West Africa ranges from 22 to 52 million hectares (Andriesse *et al*., 1994). Inland valleys have high production potential, because they retain water throughout the growing season (Ekanayake *et al.*, 1994). They could have high soil fertility due to high level of organic matter and deposited as sediments from the upland (Agboola, 1987).

Cassava growing in inland valley is exposed to excess moisture stress during early and late season growth stages. The water table rises above the soil surface at planting and harvesting periods. Drought stress occurs during the mid-season when water table recedes deep below the soil surface and during the peak of the dry season (Mohamoud, 1994). Therefore, the main problems in exploiting inland valley for cassava production are water management and lack of adapted cultivars (Wouamane, 1994). Nevertheless, high levels of water management are not economical for crop production in inland valley (Izac *et al*., 1991), suggesting that availability of improved and adapted cultivars will enhance the utilization of inland valleys for cassava production. However, little work has been done to assess physiological traits associated with adaptability of cassava to inland valley conditions. This information could be useful for breeding new cassava cultivars with wider adaptability to both inland valley and upland soils. This paper evaluated the adaptability of four cassava cultivars in inland valley and the relationships between growth indices with root yield, water table depth and selected weather variables.

MATERIALS AND METHODS

Site description

The trials were conducted at two inland valleys at the International Institute of Tropical Agriculture (IITA) research farm at Ibadan, Nigeria (7^0 30' N and 3^0 54' E, 243 m above sea level) and at Alabata (4^0 46' N and 2^0 34' E, 210 m above sea level). During the trial period mean minimum temperature in 2001 (19.8 ^{0}C) was higher than in 2002 (19.1 ^{0}C), while mean maximum temperature was (27.5 ^{0}C) in 2001 and (28.4 ^{0}C) in 2002. Total rainfall (mm) and mean relative humidity (%) were higher in 2001 (955.9 mm; 68%) than in 2002 (642.6 mm; 63%), but evaporation (mm) and solar radiation (MJ/m/day) were higher in 2002 (962.8 mm; 13.49 MJ/m/day) than in 2001 (891.1 mm; 13.09 MJ/m/day). The valley bottom soils classified as Tropaquents (Moormann *et. al*., 1975) were loamy sand at both sites. At Alabata, soil pH (H_2O) was 3.91, organic C (%) 0.99, N (%) 0.11, P (mg/kg) 7.43 and K (cmol/kg) 0.18 in 2001. In 2002, pH was 4.60, organic C (%) 0.46, N (%) 0.13, P (mg/kg) 6.80 and K (cmol/kg) 0.20. The corresponding values at Ibadan were 4.87, 1.66, 0.15, 3.75 and 0.08 in 2001 and 5.40, 0.53 C, 0.13, 2.78 P and 0.10 K in 2002.

Experimental design, planting and groundwater table depth measurement

At each site, the toposequence was divided into three positions: valley fringe, valley intermediate and valley bottom. Each position had 16 flat-top mounds arranged in a 4 x 4 Latin square design. Each mound (2 m x 2 m and 0.6 m high, spaced 1 m apart) was a plot. Three 2.1 m-long PVC pipes 0.05 m in diameter, serving as modified piezometers were buried to a depth of 1.5 m in furrows between mounds in each position to monitor water table depth on weekly basis. Five stem cuttings (0.25 m long) were planted on each mound at a spacing of 1 m between rows and 0.75 m between plants. Three improved cultivars (TMS 4(2)1425, TMS 91/02324 and TMS 91/02327) and a landrace (Isunikankiyan) were used. Planting was done at Ibadan and Alabata on 12 February and 12 March 2001 in the first planting season and on 18 and 24 December 2001 in second season, respectively. Hand weeding was done as required but no fertilizer was applied. This was done to emulate the field conditions of farmers who do not normally apply chemical fertilizers to their cassava fields.

Growth and yield measurements

Leaf area (using leaf area meter LI-3000, Li-cor Inc., Lincoln, Nebraska) was monitored on four tagged plants on a two-weekly basis in each plot. Leaf area index **(**LAI**)** was calculated as leaf area (m^2) / ground area (m^2). The first and second year trials were terminated on 15 August 2001 and 23 July 2002 at Ibadan and on 13 September 2001 and 28 July 2002 at Alabata, respectively. At harvest the five plants in each plot (a total of 20 plants per cultivar per toposequence position) were used for destructive growth analysis and separated into leaves, stems, rootstocks, fibrous and storage roots and the fresh weights recorded. Sub-samples of fresh materials (500g) were dried in a ventilated oven at 70^{o}C for 48h. Fallen leaves were collected on a two-weekly basis in each plot from one month after planting until harvest; and were oven dried and weights added to the respective leaf dry weights at harvest. Crop growth rate (CGR), tuberous root bulking rate (TRBR), relative growth rate (RGR) and net assimilation rate (NAR) were estimated from dry weights of plant parts according to Hunt (1978).

Data analysis

Mixed model procedure of the statistical analysis system (SAS) for Microsoft Windows, Release 6.12, using the restricted maximum likelihood method (REML) for the estimation of random variance components was used for analysis of variances. Rows and columns were random effects and cultivars, toposequence position, site and year fixed effects. Standard errors were used to detect differences between treatment means. Relationships between growth indices with root yield, groundwater table depth and selected weather variables were examined by correlation procedure in SAS (SAS Institute, 1997).

RESULTS

Growth indices and root yield

There were significant differences among cultivars, toposequence positions, sites and years for root yield and growth indices. Generally, the improved cultivars had significantly higher yield, LAI, TRBR, CGR, RGR and NAR than the landrace. On average, TMS 91/02324 and TMS 91/02327 produced similar and significantly the highest growth indices and yields in each toposequence position, site and year (Tables 1 and 2).

Table 1: Leaf area index (LAI), dry tuberous root yield and tuberous root bulking rate (TRBR) of four cassava cultivars in various toposequence positions at two inland valley sites in 2001-2002 in Nigeria

		2001				2002			
		Toposequence (Topo)				Toposequence (Topo)			
Site	Cultivar	Fringe	Inter-mediate	Bottom	Cultivar Mean	Fringe	Inter-mediate	Bottom	Cultivar mean
					(a) Leaf area index				
Alabata	TMS4(2)1425	6.60	5.00	5.40	5.70	3.10	2.60	1.80	2.50
	TMS91/02324	4.60	4.70	4.90	4.70	3.20	2.00	2.30	2.50
	TMS91/02327	4.20	3.30	3.50	3.70	2.40	1.70	1.40	1.80
	Isunikankiyan	5.10	4.50	3.50	4.40	2.10	1.80	1.30	1.70
	s. e ±	0.50	0.50	0.50	0.20	0.50	0.50	0.50	0.20
	Topo mean (s. e ± 0.10)	5.10	4.40	4.40		2.70	2.00	1.70	
	Year mean (s. e ± 0.10)	4.60				2.10			
	Site mean (s. e ± 0.10)	3.40							
Ibadan	TMS4(2)1425	6.90	3.90	2.70	4.50	3.00	0.90	1.00	1.60
	TMS91/02324	6.70	1.30	1.70	3.20	3.20	0.80	1.10	1.70
	TMS91/02327	5.80	1.40	1.50	2.90	3.30	0.50	1.20	1.70
	Isunikankiyan	3.00	1.70	1.60	2.10	1.70	1.00	0.70	1.10
	s. e ±	0.50	0.50	0.50	0.20	0.50	0.50	0.50	0.20
	Topo mean (s. e ± 0.10)	5.60	2.10	1.90		2.80	0.80	1.90	
	Year mean (s. e ± 0.10)	3.20				1.50			
	Site mean (s. e ± 0.10)	2.40							
					(b) Dry Tuberous root yield (t ha^{-1})				
Alabata	TMS4(2)1425	5.04	6.16	16.94	9.38	3.28	2.24	3.01	2.84
	TMS91/02324	4.68	4.71	17.24	8.88	4.12	4.01	4.66	4.26
	TMS91/02327	5.31	5.50	17.21	9.34	5.15	3.60	3.12	3.96
	Isunikankiyan	4.17	4.98	15.23	8.13	1.86	1.97	0.95	1.59
	s. e ±	0.64	0.64	0.64	0.32	0.64	0.64	0.64	0.32
	Topo mean (s. e ± 0.32)	4.80	5.34	16.66		3.60	2.96	2.94	
	Year mean (s. e ± 0.17)	8.93				3.17			
	Site mean (s. e ± 0.13)	6.05							
Ibadan	TMS4(2)1425	4.56	4.22	3.23	4.00	3.18	2.30	1.67	2.38
	TMS91/02324	7.77	4.13	5.04	5.65	5.48	2.52	2.62	3.54
	TMS91/02327	6.12	4.51	4.41	5.01	5.14	2.38	2.04	3.19
	Isunikankiyan	3.83	2.99	3.15	3.32	2.58	1.35	1.56	1.83
	s. e ±	0.64	0.64	0.64	0.32	0.64	0.64	0.64	0.32
	Topo mean (s. e ± 0.32)	5.50	3.96	3.96		4.10	2.14	1.97	

Table 2: Crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) of four cassava cultivars in various toposequence positions at two inland valley sites in 2001-2002 in Nigeria

Site	Cultivar	2001				2002			
		Toposequence (Topo)				Toposequence (Topo)			
		Fringe	Inter-mediate	Bottom	Cultivar Mean	Fringe	Inter-mediate	Bottom	Cultivar mean
		(a) Crop growth rate (g m^{-2} day^{-1})							
Alabata	TMS4(2)1425	9.10	7.68	19.11	11.96	5.60	3.43	4.63	4.55
	TMS91/02324	7.63	6.35	18.98	10.99	6.67	5.68	7.05	6.47
	TMS91/02327	7.93	6.84	17.78	10.85	8.24	5.18	4.33	5.92
	Isunikankiyan	9.35	7.71	17.86	11.64	4.34	3.57	1.98	3.30
	s. e ±	0.87	0.87	0.87	0.46	0.87	0.87	0.87	0.46
	Topo mean (s. e ± 0.45)	8.50	7.15	18.43		6.21	4.47	4.50	
	Year mean (s. e ± 0.26)	11.36				5.06			
	Site mean (s. e ± 0.22)	8.21							
Ibadan	TMS4(2)1425	8.14	5.44	3.49	5.69	4.36	2.70	2.38	3.15
	TMS91/02324	12.92	4.63	5.15	7.57	6.02	2.58	3.21	3.94
	TMS91/02327	10.29	4.73	4.47	6.50	6.55	2.56	2.69	3.93
	Isunikankiyan	7.50	4.57	3.57	5.21	4.32	1.97	2.77	3.02
	s. e ±	0.87	0.87	0.87	0.46	0.87	0.87	0.87	0.46
	Topo mean (s. e ± 0.45)	9.71	4.84	4.17		5.31	2.45	2.76	
	Year mean (s. e ± 0.26)	6.24				3.51			
	Site mean (s. e ± 0.22)	4.88							
		(b) Relative growth rate (g m^{-2} day^{-1})							
Alabata	TMS4(2)1425	0.053	0.051	0.058	0.054	0.044	0.040	0.042	0.042
	TMS91/02324	0.049	0.049	0.058	0.052	0.045	0.043	0.045	0.044
	TMS91/02327	0.051	0.051	0.058	0.053	0.046	0.043	0.041	0.043
	Isunikankiyan	0.051	0.051	0.058	0.053	0.041	0.040	0.037	0.039
	s. e ±	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
	Topo mean (s. e±0.001)	0.052	0.051	0.058		0.044	0.042	0.041	
	Year mean (s. e± 0.003)	0.054				0.042			
	Site mean (s. e ± 0.002)	0.048							
Ibadan	TMS4(2)1425	0.052	0.049	0.046	0.049	0.041	0.038	0.038	0.039
	TMS91/02324	0.055	0.048	0.048	0.050	0.044	0.038	0.039	0.040
	TMS91/02327	0.053	0.048	0.047	0.049	0.044	0.038	0.039	0.040
	Isunikankiyan	0.051	0.047	0.046	0.048	0.041	0.036	0.038	0.038
	s. e ±	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
	Topo mean (s. e±0.001)	0.053	0.044	0.047		0.043	0.038	0.039	

LAI was highest in cultivar, TMS 4(2)1425 followed by TMS 91/02324, TMS 91/02327, and lowest in Isunikankiyan (landrace) across toposequences in both years (Table 1) At Alabata, TMS 91/02327 had lower LAI than the landrace but at Ibadan, the landrace produced lower LAI than TMS 91/02327. Also, in 2001 TMS 4(2)1425 had larger LAI than TMS 91/02324, but in 2002 TMS 4(2)1425 gave lower LAI than TMS 91/02324. Also, plants in the valley fringe produced higher LAI than those in the other positions at both sites in each year. LAI was about 55% at Alabata and 65% at Ibadan higher in 2001 than in 2002. It was also 41% larger at Alabata than Ibadan. There were cultivar by site and cultivar by year interactions.

In general yield, TRBR, CGR, RGR and NAR were significantly higher in valley bottom than the other positions, with intermediate valley having the lowest CGR, TRBR, RGR and yield, while the fringe had the lowest NAR. This general trend was however only true for Alabata in 2001 as toposequence position by site, toposequence position by year, site by year and toposequence position by site by year interactions were significant for root yield and growth indices. These interactions were generally due to the fact that in 2001 at

Alabata, the highest yield and growth indices were produced in valley bottom and the lowest in valley fringe, while in 2002 at Alabata and in both years at Ibadan root yield, TRBR, CGR and RGR were higher in the fringe than the other positions. However, the interactions for NAR were not directional as toposequence positions changed their rankings only slightly over site and year (Tables 1 and 2).

Root yield was about 65% and 39% higher, while TRBR was 75% and 53% higher in 2001 than in 2002 at Alabata and Ibadan, respectively. Likewise, CGR was 64% and 42% higher, while RGR was 24% and 20% higher in 2001 than in 2002 at Alabata and Ibadan, respectively. NAR was about 43% higher at Alabata but 17% lower at Ibadan in 2001 than in 2002. Also, root yield, TRBR, CGR and RGR were about 40%, 50% 53% and 10% higher, while NAR was 13% lower at Alabata than Ibadan, respectively (Tables 1 and 2).

Relationships between growth indices with yield, water table depth and weather

LAI, TRBR, CGR, RGR and NAR correlated positively with root yield at Alabata, deep water table site. Similar results were obtained at Ibadan, shallow water table site for LAI, TRBR, CGR and RGR, but NAR had no significant correlation with yield (Table 3). CGR correlated positively with LAI at both Alabata ($r = 0.61$, $p < 0.0002$) and Ibadan ($r = 0.88$, $p<0.0001$). There was a marked negative correlation between LAI and NAR at Ibadan ($r = -0.69$, $p<0.0001$), but correlation at Alabata was not significant. A strong positive correlation also existed between NAR and CGR at Alabata ($r = 0.86$, $p< 0.0001$), but at Ibadan it was negative ($r = -0.38$, $p< 0.0333$). At Alabata, TRBR and NAR had negative correlation with water table depth, while at Ibadan LAI, TRBR, CGR and RGR correlated negatively, but NAR had positive correlation with water table depth. LAI, TRBR, CGR and RGR correlated positively with rainfall, minimum temperature and relative humidity, but negatively with evaporation rate, solar radiation and maximum temperature (Table 3).

Table 3: Correlations between selected growth parameters of cassava and root yield (n = 32), groundwater table depth (n = 32) and weather variables (n= 64) in inland valley

	Tuberous root yield (t ha^{-1})				Groundwater table depth (m)				Weather variable											
	Alabata		Ibadan		Alabata		Ibadan		Rainfall (mm)		Evaporation rate (mm)		Solar radiation (MJ/m/day)		Minimum temperature (^{0}C)		Maximum temperature (^{0}C)		Mean relative humidity (%)	
Growth parameter	r	P	R	P	r	P	R	p	R	p	r	P	R	P	R	P	r	p	r	p
Leaf area index (LAI)	0.54	0.0015	0.72	0.0001	0.21	0.2587	-0.64	0.0001	0.60	0.0001	-0.60	0.0001	-0.60	0.0001	0.60	0.0001	-0.60	0.0001	0.60	0.0001
TRBR (g m^{-2} day^{-1})*	0.99	0.0001	0.98	0.0001	-0.36	0.0408	-0.74	0.0001	0.56	0.0001	-0.56	0.0001	-0.56	0.0001	0.56	0.0001	-0.56	0.0001	0.56	0.0001
CGR (g m^{-2} day^{-1})*	0.99	0.0001	0.87	0.0001	-0.29	0.1091	-0.66	0.0001	0.54	0.0001	-0.54	0.0001	-0.54	0.0001	0.54	0.0001	-0.54	0.0001	0.54	0.0001
RGR (g m^{-2} day^{-1})*	0.89	0.0001	0.86	0.0001	-0.11	0.5608	-0.75	0.0001	0.83	0.0001	-0.83	0.0001	-0.83	0.0001	0.83	0.0001	-0.83	0.0001	0.83	0.0001
NAR (g m^{-2} day^{-1})*	0.92	0.0001	-0.19	0.3021	-0.47	0.0067	0.46	0.0076	0.19	0.1357	-0.19	0.1357	-0.19	0.1357	0.19	0.1357	-0.19	0.1357	0.19	0.1357

* TRBR = tuberous root bulking rate; CGR = crop growth rate; RGR = relative growth rate; NAR = net assimilation rate

DISCUSSION

The improved cultivars with high LAI and photosynthetic efficiency estimated as NAR produced high CGR, TRBR, RGR and root yield, confirming their higher photosynthetic capacity than the landrace. Strong positive correlations existed among LAI, NAR, TRBR, CGR, RGR and root yield particularly at the deep water table site, suggesting that high root yield resulting from high LAI and NAR was partly due to increased TRBR, CGR and RGR. Similar relationships were obtained by Pellet and El-Sharkawy (1993) and Lahai *et al*. (1999). Enyi (1973) established that in cassava, final root yield is determined by rate and duration of bulking, while Cock (1984) stated that the main opportunity to increase root yield, other than changes in morphology, is to increase CGR per unit LAI. Lahai *et al*. (1999) also reported that high LAI, TRBR, RGR and CGR were accompanied by high root yield, while Hu *et al*. (2004) noted that high yielding cultivars were superior to low yielding ones for NAR and CGR. These findings are consistent with results of the present study. However, TMS 4(2)1425 with the highest mean LAI had lower CGR, TRBR, RGR, NAR and yield than the other improved cultivars. This suggests that other parameters of canopy function such as leaf carbon fixation and assimilate partitioning could interact significantly in root yield formation. TMS 4(2)1425 had lower photosynthetic efficiency and partitioned lower dry matter into storage root but higher dry matter into leaf and stem than the other improved cultivars, which partly contributed to its low yield. Cassava is harvested at 5-6 months after planting in inland valley because storage roots start to rot after this period due to waterlogging. In our study, the storage roots were harvested at 6-7 months after planting immediately after the start of flooding in the valley bottom. Root rot was therefore minimal. Thus cultivars that mature early are best for inland valley. Ntawuruhunga *et al*. (1998) showed that TRBR is a good indicator for selection for early maturity. Therefore TMS 91/02324 and TMS 91/02327 with the highest TRBR, CGR, RGR, NAR and root yield are early maturing and better adapted to inland valley conditions.

Unlike Alabata where a positive correlation existed between NAR and yield, at Ibadan with shallow water table, NAR correlated negatively with yield. This was because at Alabata yield was higher in valley bottom with high NAR than in the fringe with low NAR, while at Ibadan yield was lower in valley bottom with high NAR than in the fringe with low NAR. LAI may correlate negatively with NAR, particularly at high LAI (Enyi, 1973). LAI in the fringe with deep water table was higher than in valley bottom with shallow water table. This indicated that under shallow water table, LAI was reduced, thereby reducing mutual shading of leaves, which may have increased NAR, as opposed to deep water table under which high LAI was maintained. The results are in line with George *et al*. (1998) who observed a dramatic increase in NAR due to drastic reduction in LAI at the onset of dry season. However, the increase in NAR at shallow water table did not lead to increased yield. Sink limitation occurs when storage roots are less than nine per plant (Pellet and El-Shakawy, 1993). At Ibadan, mean storage roots were 8.1 in the fringe and 5.6 per plant in valley bottom (data not shown), indicating that the low yield in valley bottom with high NAR was partly due to sink-limitation as shallow water table reduced number of storage roots.

Water table depth correlated negatively with LAI, TRBR, RGR and CGR at both sites, with the correlation at the shallow water table site at Ibadan stronger than at the deep water table site at Alabata, a pattern also similar to root yield. Also, there was a negative correlation between water table depth and NAR at the deep water table site, but a positive correlation existed between them at shallow water table site. The shallowest water table depth at Ibadan was 0.15-0.40 m and 0.35-0.45 m below mound top in 2001 and 2002 respectively, which was within the range (0.20-0.40 m) when water table depth is stressful to cassava (Carsky *et al*., 1993), while the shallowest depth at Alabata (0.45-0.50 m in 2001 and 0.51-0.58 m in 2002 below mound top) was above this range. Thus the high LAI and subsequently high CGR, TRBR, RGR and root yield in the fringe as well as at Alabata site compared to other toposequence positions and Ibadan site was partly due to deep water table. This suggested that shallow water table reduced LAI, TRBR, CGR and RGR resulting in low root yield. High LAI at the deep water table site reduced NAR, while low LAI at the shallow water site increased NAR, as was confirmed by the negative and positive correlations between NAR and water table depth at deep and shallow water table sites, respectively. The results are in line with Lahai et al. (1999) who also noted drastic reduction in LAI, TRBR, CGR, RGR and root yield, but an increase in NAR as water table depth decreased in inland valley.

However, at Alabata (deep water table site), the highest TRBR, CGR, RGR, NAR and root yield were obtained in valley bottom and the lowest in the fringe, while at Ibadan (shallow water table site), yield and growth indices were significantly higher in the fringe than in the other positions. The deeper water table in the fringe at Ibadan, likely improved soil aeration and plants in this position were able to maintain higher LAI, TRBR, CGR, RGR and hence higher root yield than those in the other positions. The water table at Alabata was much deeper than at Ibadan and coupled with high mound height higher TRBR, CGR, RGR, NAR and yield occurred in valley bottom with relatively better supply of soil moisture, particularly during the peak of dry season than the other positions. Infact valley fringe at Ibadan and valley bottom at Alabata had similar water table depth and they produced the highest growth indices and yield at these sites. These results showed that LAI, TRBR, CGR, RGR, NAR and root yield in an inland valley toposequence position largely depend on water table depth in that position. The results are in line with Jalloh (1998) who showed that the primary factor influencing productivity of cassava in inland valley is water table depth. Our results also agree with Izac *et al*. (1991) who noted that inland valleys are complex and heterogeneous because physical, morphological and socio-economic conditions change between and within them.

LAI, TRBR, CGR, RGR and yield correlated positively with rainfall, minimum temperature and relative humidity, but negatively with evaporation rate, solar radiation and maximum temperature. This indicated that increase or decrease in yield due to weather was as a result of similar effects on LAI, TRBR, CGR and RGR. Cassava is planted in inland valleys in the dry season to utilize residual soil moisture (Ekanayake *et al.*, 1994). However, plants growing in the tropics are subjected to high radiation load for most of the day in the dry season. Ranney and Ruter (1997) showed that growth inhibition under supra-optimal temperatures could result from thermal effects on physiological processes, particularly photosynthesis. LAI increases with increasing temperature from 20-24^{o}C due to early branching and increased leaf formation and size, but increase above 24^{o}C reduce branch number and leaf life (Irikura *et al*., 1979). The mean minimum and maximum temperatures were 19.8^{o}C and 27.5^{o}C in 2001 and 19.1^{o}C and 28.4^{o}C in 2002, respectively. The minimum temperatures (19.1-19.8^{o}C) were within the minimum range that promotes LAI, while the maximum temperatures (27.1-28.4^{o}C) were above the maximum that favours high LAI, supporting the positive and negative correlations of LAI with minimum and maximum temperatures, respectively. However, the minimum and maximum temperatures in 2001 were closer to the optimum temperature range that increases LAI than in 2002, which partly explains the higher LAI in 2001. Thus the high radiation load in the dry season and the consequent increase in temperature and evaporation, especially in the afternoons were likely detrimental to the photosynthetic process, resulting in reduction in LAI, TRBR, CGR, RGR and subsequently in root yield. The positive correlation between LAI, TRBR, CGR, RGR and minimum temperature suggests that the cultivars have low temperature optimum. However, the high TRBR, CGR, RGR and yield of TMS 91/02324 and TMS 91/02327 in 2002 with high maximum temperature, indicates that these cultivars are more tolerant to high temperatures than the others, which partly resulted in their high root yields.

The positive correlation between growth indices and rainfall was due to higher LAI, TRBR, CGR and RGR in 2001 with higher rainfall than in 2002. This agreed with Kramer (1980) who reported that losses in production due to lack of water exceed that of all other factors. However, in inland valleys high rainfall is expected to decrease growth indices and yield due to decrease in water table depth as rainfall increases causing waterlogging (Lahai *et al*., 1999). In 2001, rainfall was recorded in all the months the crop was in the field, which likely caused rapid increase in LAI, TRBR, CGR and RGR, while in 2002 there was no rain in the first three months of growth. El-Shakawy and Cadavid (2002) observed that early (2 MAP) and mid-season (4 MAP) water stress reduced LAI and shoot and root biomass of cassava. Thus the lack of rain from planting to about mid-season, coupled with high evaporation and high mound likely subjected the plants to drought stress, resulting in low LAI, TRBR, CGR and RGR in all cultivars in 2002. On the other hand NAR was 48% higher but 17% lower in 2001 than in 2002 at Alabata and Ibadan, respectively. Water table was deeper at both sites in

2002 with less rainfall than in 2001. This indicated that at the site with deep water table, further increase in water table depth decreased NAR, partly due to soil moisture stress, while at the site with shallow water table increasing depth increased NAR, due likely to increased aeration in the root zone resulting in better water and nutrient uptake. TMS 91/02324 and TMS 91/02327 gave higher LAI, TRBR, CGR, RGR, NAR and root yield during this stress period, indicating that they were more drought tolerant than the others. The results agree with Lal (1981) who noted that soil moisture stress reduced shoot and root growth, but the levels of reduction varied with cassava cultivar. This suggests that adaptability of cassava cultivars to inland valleys is partly associated with drought tolerance as drought stress occurring during the peak of the dry season reduces LAI, TRBR, CGR and RGR, resulting in low yield.

High root yield resulting from high LAI and NAR was partly due to increased TRBR, CGR and RGR. Shallow water table of 0.15-0.40 m below mound surface reduced LAI, TRBR, CGR, RGR and yield, but increased NAR. Drought stress and high radiation, temperature and evaporation reduced yield and growth indices, while well distributed rainfall increased them. Cassava growth and yield performance in an inland valley toposequence position largely depends on water table depth in that position. TMS 91/02324 and TMS 91/02327, which appear to be better adapted to inland valleys are early maturing and maintain high growth indices and root yields under both excess moisture and drought stress conditions.

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Wouamane M (1994). Cassava (*Manihot esculenta* Crantz) selection for adaptation to inland valleys. MSc. Thesis, University of Ibadan, Nigeria. 115pp.Table 1: Leaf area index (LAI), dry tuberous root yield and tuberous root bulking rate (TRBR) of four cassava cultivars in various toposequence positions at two inland valley sites in 2001-2002 in Nigeria