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GROWTH, GAS EXCHANGE, AND HARVEST INDEX OF FIELD-GROWN CASSAVA IN A SUBTROPICAL SHORT-SEASON ENVIRONMENT

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ABSTRACT

Cassava (*Manihot esculenta* Crantz L.) is an important food and industrial crop in the tropics and holds potential in the subtropics. Cassava productivity is similar to C_4 crop plants but its single-leaf net photosynthetic rate (Pn) is lower than C_4 plants. This field investigation was conducted from 1982 to 1984 with seven cassava genotypes to study growth and gas exchange in a short-season environment. The Pn was determined on fully mature and attached leaves in an open system and canopy photosynthesis (CPn) was determined in a closed system between 1100 and 1500 hr using a portable plexiglass chamber. Leaf area index (LAI) of all cassava genotypes was similar except for Aug 1983 sampling and ranged from 2.40 to 6.16. The stomatal density was about ten times higher on the abaxial than the adaxial surface of cassava leaves. The abaxial stomatal conductance of water ranged from 0.23 cm s^{-1} to 1.94 cm s^{-1}. Canopy photosynthesis differed significantly only during 1983 and varied from 1.31 to 1.97 mg CO_2 m^{-2} s^{-1}. The Pn ranged from 0.48 to 1.21 mg CO_2 m^{-2} s^{-1}. 'Senorita' and 'M Ven 218', the two semi-forking genotypes, had generally higher HI than the forking genotypes. The HI was significantly correlated with CPn ($r = 0.76^{*}$) and storage root yield ($r = 0.92^{**}$) during 1984. Cassava HI in a short-season environment in the subtropics is similar to that in tropics. The relatively high productivity of cassava may be attributed to its high HI.

***Key Words*: *Manihot esculenta*, photosynthesis, respiration, stomatal conductance**

RÉSUMÉ

Le manioc (*Manihot esculenta* Crantz L.) est une plante importante tant sur le plan alimentaire que sur le plan industriel en régions tropicales et potentiellement prometteuse en régions subtropicales, la productivité du manioc est similaire à celle des plantes du groupe C_4 mais son taux de photosynthèse (Pn) qui est du type feuille-simple est inferieur a celui des plantes du groupe C_4. Une investigation sur terrain a été menée entre 1982 et 1984 pour étudier la croissance et l'échange gazeux dans un environnement de courte-saison. Le Pn a été déterminé en système fermé sur des feuilles mûres sur tige tandis que le taux de photosynthèse en canopée (CPn) a été déterminé en système clos entre 1100 et 1500 hr en utilisant une chambre en plexiglas portative. L' indice de surface foliaire (LAI) qui était compris entre 2,40 et 6,16, était similaire pour tous les génotypes à part l'échantillon d'Août 1983. La densite des stomates sur les feuilles était dix fois plus élevée sur la surface abaxiale que sur la surface adaxiale. La conductance pour l'eau de stomates en zone abaxiale variait de 0,23 cms $^{-1}$ à 1,94 cm s^{-1}. Le taux de photosynthèse en canopée qui accusait une différence significative seulement pour l'année 1983 variait de 1, 31 à 1, 97 mg CO_2 m^{-2} s^{-1}. Le Pn variait de 0,48 à 1, 21 CO_2 $m^{-2}1$ CO_2 m^{-2} s^{-1}. "Senorita" et "MVen 218, deux génotypes semi-divergents avaient généralement un HI supérieur á celui des génotypes divergents. Il y avait une corrélation significative entre HI et CPm ($r = 0,76^{*}$) ainsi qu' entre HI et

le rendement en tubercules (r=0,92) durant l'anee 1984. Le HI du manioc dans un envirnnemnet de courte-saison en régions subtropicales est similaire à celui des régions tropiocales. La haute productivité relative du manioc peut être attribuée à son HI élevé.**

***Mot Clés: Manihot esculenta*, photosynthèse, respiration, conductance des stomates.**

INTRODUCTION

Cassava is an important crop in tropical regions. Its growth cycle ranges from six months to more than a year. Although cassava is mainly used for food, it is also considered an important source of energy and animal feed (Kawano *et al.*, 1978; San Jose and Mayobre, 1982; Cock, 1984). Cassava produces similar amounts of dry matter per unit land area to maize (*Zea mays* L.) (Enyi, 1972; Cock *et al.*, 1979; Cock, 1984) and many other C_4 species (deVries *et al.*, 1967), but it has a lower single-leaf photosynthetic rate (Pn) than many C_4 species (Aslam *et al.*, 1977; Mahon *et al.*, 1976 ; 1977). In greenhouse experiments, Pn for cassava ranged from 0.42 to 0.81 mg CO_2 m^{-2} s^{-1} (Mahon *et al.*, 1976; 1977; Palta, 1983; El-Sharkawy *et al.*, 1984b) and in field-grown cassava from 0.56 to 0.72 (San Jose, 1983) and 0.88 to 1.28 mg CO_2 m^{-2} s^{-1} (Cock *et al.*, 1985). Simultaneous determinations of Pn and canopy photosynthesis (CPn) have been reported for field-grown maize (Pearson *et al.*, 1984) and wheat (*Triticum aestivum* L.) (Gent and Kiyomoto, 1985). For a maize hybrid, mean Pn and CPn, expressed on ground area basis, ranged from 2.20 to 3.04 and 2.20 to 2.86 mg CO_2 m^{-2} s^{-1}, respectively, between 50 and 70 days after planting (DAP) (Pearson *et al.*, 1984). Mean Pn and CPn for wheat ranged from 0.23 to 0.75 and 0.43 to 2.13 mg CO_2 m^{-2} s^{-1}, respectively, over the growing period (Gent and Kiyomoto, 1985). In another study, CPn for wheat ranged from 0.14 to 1.56 (Morgan, 1988). Information on CPn of cassava is lacking.

Williams (1971) speculated that cassava yield could be improved by developing cultivars with increased leaf conductivity which was lower in cassava than in other crops. However, other reports indicate that cassava leaf conductance is similar to that of other C_3 species and varies from 0.30 to 0.70 cm s^{-1} (Connor and Palta, 1981; Ike 1982; El-Sharkawy *et al.*, 1984b).

Partitioning of assimilate to economic products has a major impact on improvement of crop yield (Gifford *et al.*, 1984). Yield improvements in wheat and peanut (*Arachis hypogaea* L.) have been directly related to increases in harvest index (HI) (Gifford *et al.*, 1984; Gent and Kiyomoto, 1985). Yield differences among cassava genotypes are related to HI (Williams, 1972; Wholey and Cock, 1974; Cock, 1976; Kawano *et al.*, 1978), which ranged from 0.40 to 0.60 (Williams, 1972), 0.0 to 0.62 (Wholey and Cock, 1974) and 0.25 to 0.75 (Cock *et al.*, 1977). Single-shoot plants had greater HI and yield than multi-shoot plants (Enyi, 1972; Cock *et al.*, 1979; Tan and Cock, 1979). Also, the HI decreases with increasing plant population (Cock *et al.*, 1977) and with shading of the canopy (Fukai *et al.*, 1984).

With the development of short-cycle cultivars, cassava cultivation is likely to extend to subtropical regions (El-Sharkawy *et al.*, 1992). However, information about cassava physiology is limited, especially for a short-season subtropical environment. In this paper growth, gas exchange, and HI of selected field-grown cassava genotypes in a short-season environment in the subtropics are reported.

MATERIALS AND METHODS

Crop management. From 1982 to 1984, field experiments were conducted with seven cassava selections at the Agricultural Research Station, Fort Valley State College, Fort Valley, Georgia, 32.3°LN and 83.8°LW. The soil type is Norfolk sandy loam (fine-loamy, siliceous, thermic Typic Paleudult). Before land preparation for planting, fertilizer was applied at a rate of 50 kg N, 44 kg P, and 123 kg K ha^{-1}.

Stem cuttings (0.30 m), were obtained from the Homestead Substation of the University of Florida, in mid-February 1982 and planted one per 5 l pot in a greenhouse. On 31 March 1982, after the cuttings had rooted and produced four to six leaves, they were field-planted 1.5 m apart in single rows in 1.2 x 6.0 m beds. In subsequent years, 0.3 m stem cuttings were taken at final harvest and maintained four per 9.5 l pot in the greenhouse during winter. Stems were transplanted on 6 April 1983 and 20 April 1984 in three-row experimental plots, with 1.5 m spacing between plants and 1.2 m between rows which

were 12 m long. Each year, the experimental design was a Randomized Complete Block Design with four replications. Generally, the 6 to 10 leaves produced in the greenhouse senesced before the start of new growth in the field. During 1984, a few days after transplanting, the stems were pruned to about 0.5 m height. Weeds were manually controlled. No insecticide was applied. Sprinkle irrigation was applied as needed. Water was also applied one day before photosynthesis measurements.

Plant samples. For growth analysis, samples of one plant per genotype from the middle row in each replicate were taken 25 to 27 July and 27 to 29 August 1983 and 17 and 18 July, and 27 to 30 August 1984. Plants were partitioned into leaves, branches, petioles, and storage roots and dried at 60°C to constant weight. Storage roots and woody stems were chopped to facilitate drying. Final harvest (four plants per experimental plot) was on 14 November 1984, but storage root yields were not recorded in 1983. Leaf area on five plants was determined with a leaf-area meter (Model LI-3100, LI-COR Instruments Corp., Lincoln, NE). HI was calculated by dividing total storage root dry weight by whole plant dry weight. Weight of senesced leaves and fibrous roots was not recorded.

Stomatal density and stomatal conductance. To determine stomatal density, leaf impressions of adaxial and abaxial surfaces were made 20 September 1982 by dipping attached leaves (four plants per replication and one leaf per plant) in Rhoplex, grade-AC-33 (Rohm and Haas Co., Charlotte, NC). Leaf impressions from both surfaces were peeled off after six hr drying in the sun and stored individually in petri dishes. Stomata were counted at five locations on each leaf impression under a microscope, as previously described (Bhagsari and Harmon, 1982).

The leaves for determining stomatal conductance were tagged at emergence to know approximate leaf age. Stomatal conductance was determined on fully expanded, attached 15 to 20 day-old leaves in full sunlight (above 1500 μmol $m^{-2}s^{-1}$) from 1100 to 1500 hr. Stomatal conductance was determined on four leaves per plant on 28 August, 17 and 27 September 1983, and 1 September, and 11 October 1984 with a steady-state porometer (Model LI-1600, LI-COR Instruments Corp., Lincoln, NE).

Single-leaf net photosynthesis. Single-leaf net photosynthesis was determined in an open system with an infrared analyzer (Model 215B, Beckman Instruments, Fullerton, Calif.) on 15 to 25 September 1982 and 8 and 9 July, and 20 to 26 September 1984 between 1100 and 1500 hr at or above PAR of 1500 μmol m^{-2} s^{-1}. Fully expanded, attached 15 to 20 day-old leaves at the top of the canopy were enclosed in an acrylic plastic chamber consisting of two halves with hinges on one side and latches on the other. The dimensions of the lower and upper sections were 24.5 x 25.0 x 6.5 cm and 24.5 x 25.0 x 2.5 cm, respectively. Chamber temperature was maintained at 30 ± 2°C by circulating water, first entering through copper tubing installed in the lower chamber and then passing through the entire upper chamber before re-entry into the water bath. Leaf temperature was monitored with a thermocouple touching the abaxial surface of the leaf. A small fan installed in the lower chamber provided turbulence. Tygon tubing was used to conduct reference and sample air to an infrared gas analyzer installed in a trailer. Humidified compressed air, containing 330 μl CO_2 l^{-1} was passed over the leaf at a rate of 9.0 l min^{-1}. Both, the reference and sample air were passed through drierite ($CaSO_4$) before entering the analyzer. Other Pn measurement information has been reported previously (Bhagsari and Harmon, 1982).

Canopy photosynthesis. The chamber for canopy photosynthesis consisted of three parts: (i) a 1.26 x 1.12 m base made of 3.7 cm angle iron. The steel frame had a 3.5 cm groove on top to hold water and a side lip entering the soil to make the system air-tight at soil level; (ii) a 1.2 m high acrylic plastic middle chamber with dimensions similar to the steel frame and open at top and bottom. The top of the middle frame had a 3.0 cm wide groove on the top four sides to hold water; (iii) an acrylic plastic top section, dimensions 1.26 x 1.12 x 0.68 m, open at the bottom. Three squirrel-cage fans, two in the top section and one in the lower part of the middle section, provided air turbulence during CPn measurements. Air temperature in the top section was monitored with a thermocouple. The rise in air temperature in the chamber during CPn measurement was about 2°C. Three plants of each cultivar were monitored.

TABLE 1. Mean monthly minimum (Min) and maximum (Max) temperatures (°C) during cassava growing seasons of 1982–1984[a]

	1982		1983		1984	
Month	Min	Max	Min	Max	Min	Max
April	10.2	22.2	8.3	21.7	10.0	23.4
May	15.2	29.2	13.9	28.4	13.9	27.8
June	19.1	31.6	17.8	30.0	18.9	32.3
July	21.0	31.4	21.1	33.9	20.0	30.6
Aug.	20.2	31.4	21.1	34.5	20.0	31.1
Sept.	16.4	29.3	16.7	28.9	15.0	29.5
Oct.	10.8	25.5	11.7	25.0	13.4	29.5
Nov.	7.3	20.1	5.0	19.5	3.9	19.5

During CPn measurements, the rectangular steel frame was placed around the second plant from the border in the middle row and pushed into the soil to secure a good seal. The middle section was placed over the groove of the iron base followed by the top section. At each CPn measurement, water was poured into the grooves of the iron base and middle acrylic plastic section to make the system airtight. Air was continuously drawn from the enclosed system and passed through the infrared analyzer to determine CO_2 uptake for two minutes at each measurement. Canopy photosynthesis was determined from 27 to 29 August 1983 and 27 to 30 August 1984, using techniques previously described (Bhagsari, 1988).

After the photosynthesis measurements, plants were harvested and partitioned into leaves, petioles, branches, stems, and storage roots. Plant material was dried at 60°C to constant weight.

Temperature data. Mean monthly minimum and maximum temperatures for the three experimental years ranged from 3.9 to 21.1°C and 19.5 to 34.5°C, respectively (Table 1).

Data analysis. Data were subjected to analysis of variance. Treatment means were compared using the Least Significant Difference at 0.05 probability level. Simple correlation coefficients were determined within years using mean values of each parameter and seasonal means for LAI, Pn, and stomatal conductance.

RESULTS AND DISCUSSION

Morphology and growth. Among the seven genotypes examined, Senorita and MVen 218 had semi-forking branching and others had forking type (Table 2). At the first sampling in 1983 and 1984 July, the LAIs were similar among genotypes (data not presented). At the 27 to 29 August 1983 sampling, LAI among genotypes ranged from 2.40 for 'Senorita' to 6.16 for 'MCol 1684' (Table 2). During August 1984, LAI was similar for all genotypes with a maximum of 3.47 for MVen 218. Mean LAI was about 42% higher in 1983 than in 1984. The low LAIs during 1984 were probably the result of pruning after planting. Number of storage roots per plant varied significantly among genotypes in 1984, but not in 1983 (Table 2). The mean number of storage roots per plant was also higher in 1984.

Stomatal density for both adaxial and abaxial surfaces varied significantly among the genotypes

TABLE 2. Branching patterns, leaf area index, and number of storage roots of field grown cassava during 1983–1984[a]

		Leaf area index		Number of storage roots per plant	
		1983	1984	1983	1984
Genotype	Branching pattern	27–29 August	27–30 August	27–29 August	27–29 August
Senorita	semi-forking	2.40	2.50	17.0	21.0
MVen 218	semi-forking	4.37	3.47	14.5	24.3
CMC 40	forking	4.93	3.42	12.8	18.3
CMC 92	forking	5.12	3.44	12.0	11.3
HMC 2	forking	3.83	2.82	12.3	11.3
CMC 323–375	forking	3.66	2.90	9.3	19.0
MCol 1684	forking	6.16	2.87	9.3	13.8
CV (%)	–	29.8	24.0	32.9	21.1
L.S.D. (0.05)	–	1.93	N.S.	N.S.	N.S.

[a]Data are means of four observations.

(Table 3) ranging from 27.3 to 48.3 mm^{-2} and 166.8 to 446.8 mm^{-2} for adaxial and abaxial surfaces, respectively. Mean stomatal densities for eleven genotypes at Centro Internacional de Agricultura (CIAT) for the adaxial and abaxial leaf surfaces were 71.2 and 481.9 mm^{-2}, respectively (El-Sharkawy et *al.*, 1984a). In contrast to the random stomatal distribution on the adaxial surface in that study (El-Sharkawy *et al.*, 1984a), the adaxial stomata in the present study were mainly concentrated along the mid-rib for all the genotypes.

Gas exchange. Abaxial stomatal conductances varied among the genotypes except during September 1984 (Table 3). The significantly lower abaxial stomatal conductance on 27 September 1983 and 11 October 1984, compared to the three other dates, may have been caused by low night temperatures, which dropped below 17°C (Table 1). The adaxial stomatal conductance for all genotypes was less than 0.1 cm s^{-1}.

Up to mid-September, stomatal conductances were twice as high as reported earlier (Connor and Palta, 1981; El-Sharkawy *et al.*, 1984b). The low values of cassava stomatal conductances reported by Williams (1971) were attributed to the nature of the instruments and scarification of the upper epidermis. Contrary to a previous report (Williams, 1971), this study indicates that abaxial stomatal conductance for cassava is similar to that of many C_3 and C_4 plants.

Senorita generally had higher Pn than the other genotypes, except for CMC 323-375 during September 1982 and CMC 40 during July 1984 (Table 4). The 37 to 43% lower value of Pn during September 1984 was probably associated with low night temperatures (Table 1). The Pn rates during July 1984 were similar to those reported from other studies in the tropics (El-Sharkawy *et al.*, 1984b; Cock *et al.*, 1985). But recently higher Pn rates for field grown cassava have been reported in the tropics (El-Sharkawy and Cock 1990; El-Sharkawy *et al.*, 1992).

The CPn rates differed significantly among genotypes only in 1983 and ranged from 1.31 to 1.97 mg CO_2 m^{-2} s^{-1} (Table 4). These CPn rates are similar to those for wheat (Gent and Kiyomoto, 1985; Morgan, 1988) but lower than those for maize (Pearson *et al.*, 1984).

Harvest index and yield. Harvet index and phytomass varied significantly among the genotypes at all samplings in both years (Table 5). During August 1983, HI was higher for Senorita than for all other genotypes. During August and November 1984, HI for CMC 92, HMC 2, and MCol 1684 was lower than for the other four genotypes.

The differences among cassava genotypes in HI were consistent across the years. The higher HI for Senorita and MVen 218 as compared to HMC 2, CMC 92, and MCol 1684 may be associated with their semi-forking branching habit, implying fewer stems.

Variations in phytomass accumulation existed among genotypes (Table 5). At the August 1983 sampling, phytomass of MVen 218 and CMC 40

TABLE 3. Stomatal density and stomatal conductance of field-grown cassava during 1982–1984

			Abaxial stomatal conductance[b]				
	1982		1983			1984	
	Stomatal density[a]		28	17	27	1	11
Genotype	adaxial	abaxial	August	Sept.	Sept.	Sept.	Oct.
	mm^{-2}		cm s^{-1}				
Senorita	48.3	435.5	1.69	1.76	0.47	1.28	0.67
MVen 218	48.3	401.0	1.55	1.94	0.41	1.23	0.62
CMC 40	43.8	166.8	1.61	1.86	0.45	1.24	0.74
CMC 92	35.3	391.5	1.18	1.57	0.24	1.15	0.57
HMC 2	35.0	362.0	1.35	1.53	0.36	1.14	0.52
CMC 323–375	33.3	331.5	1.33	1.67	0.37	1.09	0.54
MCol 1684	27.3	446.8	1.30	1.45	0.23	1.24	0.48
CV (%)	25.2	15.9	15.20	8.76	26.19	11.88	15.47
L.S.D. (0.05)	14.5	85.4	0.32	0.22	0.14	N.S.	0.14

[a]Determined 20 September 1982.
[b]Stomatal conductance values based on 16 determinations.

was significantly higher than that of CMC 323-375, HMC 2, and MCol 1684. Up to the end of August 1984, phytomass accumulation in HMC 2 was similar to that in other genotypes except MVen 218 but at final harvest phytomass accumulation was significantly higher for HMC 2 than for CMC 92, MCol 1684, and CMC 323-375. Phytomass was significantly higher in 1983 than in 1984, but the genotypes x year interaction was not significant.

Leaf area index was negatively correlated with mean stomatal conductance ($r = -0.88^{**}$), HI ($r = -0.78^{*}$), and number of storage roots per plant ($r = -0.85^{*}$) in 1983. Harvest index was positively correlated with number of storage roots per plant ($r = 0.93^{***}$) in both years and storage root yield at final harvest ($r = 0.92^{**}$) in 1984. CPn showed significant correlations with HI ($r = 0.76^{*}$), final harvest storage root yield ($r = 0.76^{*}$), and number of storage roots per plant ($r = 0.86^{**}$) in 1984. Number of storage roots per plant was correlated with yield ($r = 0.78^{*}$) and phytomass ($r = 0.84^{*}$) in 1984. These correlations indicate that higher LAIs in 1983 occurred at the expense of storage roots biomass.

TABLE 4. Single leaf and canopy photosynthesis of selected field-grown cassava genotypes from 1982–1984

	Single leaf net photosynthesis[a]			Canopy photosynthesis[b] Ground area basis	
	September	July	September	August	
Genotype	1982	1984	1984	1983	1984
	mg CO_2 $m^{-2}s^{-1}$				
Senorita	0.71	1.21	0.58	1.86	1.47
MVen 218	0.64	0.95	0.70	1.44	1.39
CMC 40	0.60	0.93	0.61	1.31	1.22
CMC 92	0.60	0.99	0.59	1.61	1.67
HMC 2	0.53	0.95	0.72	1.97	1.28
CMC 323–375	0.49	0.98	0.71	1.67	1.36
MCol 1684	0.48	1.16	0.57	1.47	1.61
CV (%)	10.79	9.12	21.27	17.02	21.65
L.S.D. (0.05)	0.09	0.13	N.S.	0.42	N.S.

[a]Pn = Single leaf net photosynthesis, mg CO_2 $m^{-2}s^{-1}$, determined from 15 to 25 September 1982, 8 and 9 July 1984 and 20 to 26 September 1984.

[b]CPn = Canopy photosynthesis, mg CO_2 $m^{-2}s^{-1}$ ground area, detrmined from 27 to 29 August 1983 and 27 to 30 August 1984[a].

TABLE 5. Harvest index, total phytomass, and storage root yield of selected field-grown cassava genotypes during 1983 and 1984[a]

	Harvest index			Total phytomass			Yield[b]
	1983	1984		1983	1984		1984
Genotype	27–29 August	27–30 August	14 Nov.	27–30 August	27–30 August	14 Nov.	14 Nov.
	HI			Kg $plant^{-1}$			
Senorita	0.50‡	0.41	0.62	1.44	1.22	2.78	5.47
MVen 218	0.36	0.41	0.59	2.04	1.69	2.95	5.21
CMC 40	0.28	0.37	0.53	1.97	1.46	3.47	6.74
HMC 2	0.19	0.24	0.40	1.18	1.06	3.32	5.40
CMC 92	0.14	0.19	0.29	1.74	1.09	1.58	1.95
MCol 1684	0.14	0.25	0.39	1.27	0.84	1.19	2.74
CMC 323–375	0.25	0.35	0.53	1.14	1.24	2.44	4.39
CV (%)	27.0	17.2	13.0	28.9	24.1	19.5	27.81
L.S.D. (0.05)	0.11	0.08	0.09	0.66	0.44	0.76	1.88

[a]Value for each parameter for each genotype is based on four measurements.

[b]Fresh storage root yield at final harvest.

Previous reports have indicated that manual manipulation of number of shoots per plant increased yield from 20.0% (Cock *et al.*, 1979) to 75.0% (Tan and Cock, 1979). Yield increase was associated with increased HI (Enyi, 1972; Cock *et al.*, 1979; Tan and Cock, 1979) and lower LAI (Cock *et al.*, 1979; Tan and Cock, 1979). The results of this study also indicate that HI for the semi-forking type Senorita was generally higher than for other genotypes, while its LAI was similar or lower. More research is needed to identify semi-forking genotypes and their role in cassava yield improvement.

For various physiological traits examined, no single cassava genotype was superior to all others. Senorita, though not significantly different from all the other genotypes, had relatively high stomatal density and stomatal conductance. The improved stomatal functioning of Senorita was reflected in its higher Pn rates which contributed to its higher canopy photosynthesis. Further, CPn expressed on leaf area and leaf dry weight basis (data not presented), was significantly higher for Senorita than all other genotypes for 1983, indicating its superior photosynthetic efficiency. LAI of Senorita is about half that of the optimum LAI needed for interception of maximum radiation and storage root yield (Cock *et al.*, 1979). Thus, it is possible that production efficiency of Senorita and other similar genotypes could be improved through management practices designed to maintain optimum LAI and over a longer crop duration than that of the test plants (8 months).

Analysis of photosynthetic profiles developed within canopies indicated that cassava produced excessive foliage which remained underutilized (Zamora *et al.*, 1984) probably due to mutual shading as for MCOL 1684 in the present study. Canopy photosynthesis for CMC 40 (expressed on leaf area basis), determined within 26 days of the previous measurement, was decreased 32.3% (Bhagsari, 1988). Since cassava Pn of individual leaves changes little with age upto 90 days (Cock, 1984; Bhagsari, 1988), the decrease in CPn may be attributed more to mutual shading. In this study, low LAI for Senorita, combined with its erect growth habit, facilitated light penetration into the canopy and thereby enabled this cultivar to achieve comparatively higher CPn.

This study indicates that Pn, CPn and stomatal conductance values for cassava are similar to those reported for other C_3 root/tuber crop species, but, HI seems to be higher in cassava. HI represents storage root sink capacity and integrated sink strength over the growth period. The higher HI in combination with the indeterminate growth habit partly explains the relatively high productivity of cassava.

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