GROWTH AND DEVELOPMENT OF CASSAVA (*Manihot esculenta* Crantz) GENOTYPES UNDER SHADE IN A COCONUT GARDEN[1] /

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Resumen

Se estudió el crecimiento y el desarrollo de doce genotipos de yuca creciendo bajo la sombra de una plantación de coco. Bajo estas condiciones las características morfológicas que más variaron fueron la elongación entre nudos, la cantidad de hojas delgadas y la ausencia de ramificación. Secciones transversales de las hojas creciendo bajo sombra mostraron una baja acumulación de almidones en la región vascular. La mayoría del material fotosintetizado bajo sombra se empleó en la elongación de primordios, afectando el desarrollo de las raíces significativamente. Los mejores cultivares bajo sombra fueron H 165 y CI 590. Un mayor espaciamiento de la yuca en plantaciones aumenta el rendimiento de raíces.

Introduction

Crop plants differ markedly in their adaptation to light intensities. Cassava (*Manihot esculenta* Crantz), an efficient convertor of solar energy, is mainly adapted to tropical climate, and its maximum yield potential could be realised only under bright sun light. Kerala is the major cassava growing State in India where the crop is grown either as sole crop or as intercrop with perennial vegetation, and the tubers form a major source of dietary carbohydrates. Inspite of the poor tuber yield under shade, large scale cultivation of cassava in coconut gardens is in vogue. With the introduction of mixed cropping systems in coconut gardens (8), developing shade tolerant varieties of cassava has received greater attention in breeding programmes. Growth and development of cassava plants grown under normal sunlight has been studied in detail (2, 4, 5, 6). However, little is known on the growth and tuberization of cassava grown in coconut gardens. Hence, attempts were made in the present study to evaluate the productivity of certain promising cultivars of cassava under shade in coconut gardens and also to identify suitable physiological parameters determining shade tolerance

Materials and methods

Field experiments were conducted under uniform shade in a coconut garden at the Coconut Research Sub-station, Balaramapuram, Kerala Agricultural University during 1978-79 cropping season. The age of the coconut plantation was 30 years. The mean diurnal variations in solar radiation at the experimental site (open and shade) and related weather data are given in Tables 1 and 2. The mean annual rainfall was 170 to 180 cm and the soil of Balaramapuram is of a red loamy type. LI-COR 1600 steady state porometer with a quantum sensor was used to measure to diurnal solar radiation or photosynthetically active radia-

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tion (PAR). The measurements were made during the bright days and the mean values are presented in Table 1

Experiment I. Screening varieties for shade tolerance

Twelve genotypes of cassava namely M 4, H 2304, H 1687, H 1423, H 1253, H 648, H 226, H 165, H 97, H 97/2, CI 590 and CI 167, comprising released and pre-released hybrids and selections from the Central Tuber Crops Research Institute, Trivandrum were evaluated for their yield potential under shade. Uniform stem cuttings of 20 cm length were planted 90 cm x 90 cm apart in the interspaces of coconut palms leaving two metres around the trees (Figure 1) Recommended dosage of manure and fertilizers for both main crop (coconut: N, P_2O_5, and K_2O at 0.5, 0.32 and 1.2 kg/palm respectively) and the intercrop (cassava: N, P_2O_5, K_2O each at 100 kg/ha) were applied. Planting of cassava was done during June 1978 and only two shoots per plant were allowed to grow and the crop was harvested by the 10th month after planting. The experiment was laid out in randomized black design with four replications, with a plot size of 5.4 m² accommodating 36 plants per plot. Observations on plant growth, dry matter distribution, leaf area index, stomatal number, specific leaf weight (SLW), crop growth rate (CGR) and net assimilation rate (NAR) were recorded at monthly intervals from the first to the tenth month. All the morphological and physiological characters observed under shade were compared with the values obtained from the experiments conducted simultaneously in open area. The experiment in open field (full sun) was conducted in the same manner as the shaded by coconut, using the same spacings of 90 x 90 cm with the fertilizer dosages of 100 kg each of N, P_2O_5 and K_2O per ha. There was no source of shade around the radius of 50 m from the experimental site of the open field.

Table 1. Mean diurnal variation in solar radiation (Photosynthetically Active Radiation μ Einstein/m^{1}/sec.) during bright days.

Environment	Time				
	8 hr	10 hr	12 hr	14 hr	16 hr
Open area	148	1 242	1 322	1 665	386
Under the coconut trees (shade)	15	148	198	249	46

Experiment II. Spacing cum topping studies in cassava under shade

The variety H 2304, released from the Central Tuber Crops Research Institute, Trivandrum was chosen for this study. Uniform stem cuttings were planted at three spacings namely 60 cm x 60 cm (S1); 90 cm x 90 cm (S2) and 120 x 120 cm (S3) under similar conditions as in Experiment I. Two shoots per plant were allowed to grow and the apical portion (15 cm) in each shoot was removed during the fourth month (T1), the fifth month (T2) and the sixt month

Table 2. Weather data of the experimental site during the period of investigation.

Period	Temperature °C		Rainfall (mm)	Number of rainy days	Relative humidity (%)	Hours of bright sun light
	Maximum	Minimum				
1978:						
June	29.6	23.1	191.9	13	82.5	105.1
July	29.0	22.8	175.5	12	84.5	137.7
August	28.8	22.8	161.1	16	86.5	127.1
September	30.1	23.0	67.1	9	80.5	200.3
October	30.3	23.4	89.7	7	84.5	163.9
November	30.3	22.5	722.0	10	80.0	221.3
December	31.3	23.2	52.1	4	76.0	207.7
1979:						
January	32.0	22.7	3.1	1	70.5	300.3
February	32.1	23.5	73.3	7	75.0	252.0
March	32.7	24.3	40.5	3	72.5	255.7
April	33.5	25.4	43.8	5	73.0	248.9

Fig. 1. Growth of intercropped cassava in coconut garden at the experimental site

(T3) stages of the crop. The experimental design was a randomized black design with three replications. Light transmission ratio (LTR) at canopy level was calculated at weekly intervals using the formula $LTR = I/I_0 \times 100$ where, I = light intensity at ground level and I_0 = light intensity at the top of the canopy. The light intensity at the top and bottom of cassava canopy in the coconut garden was measured with a lux meter. Growth characters were recorded at the time of harvest.

Results

Effect of shade on growth and tuberization

Establishment and sprouting of buds under shade were normal in all the cultivars. The root formation was very fast and more number of root initials around the callus tissue were noticed under shade when compared to those cuttings planted in the open. The plant height continued to increase in all the cultivars under shade. The shoot length of the short statured type CI 590 was almost doubled under shade when compared to the open growth (Table 3). The increase in plant height under shade was mainly due to internodal elongation. However, significant varietal difference for internodal length was noticed. The genotypes H 1423 and CI 167 did not branch under shade in contrast to their profuse branching habit observed at normal light intensity. Tuber initiation in cassava is normally noticed from the third week after planting. Under shade, the process of tuberization was delayed significantly. Microscopic observation of the roots of cassava grown under shade revealed that the intensity of starch deposition was very poor in all the cultivars even after six weeks of growth. The time taken for tuber initiation under open and shade conditions was observed for the 12 cultivars with a considerable delay of tuber initiation under shade (Table 4) when compared to the open conditions.

The mean leaf are index (LAI) of the cultivars grown under shade varied from 1.90 to 2.95 and the hybrids H 165, H 2304 and H 1687 recorded significantly higher LAI over the other cultivars (Table 3). The specific leaf weight under shade ranged from 2.0 to 3.6 mg dry wt/cm^2 showing significant variations among the cultivars. The leaf area index showed positive relationship with specific leaf weight. The hybrids H 165 and H 2304, which are broad leaf type, recorded higher values of LAI and SLW. Photosynthetic efficiency of the cultivars under shade was

Table 3. Variations in morphological and physiological characters among cassava genotypes grown under shade.

Cultivars	Plant height cm	Internodal length cm	SLW mg/cm^2	LAI	NAR mg/dm^2/day	Dry matter distribution			Tuber number per plant
						Shoot	Tuber	Shoot: tuber	
M 4	273 (201)	3.4	2.8	2.14	16.76	242.0	60.0	1:0.25	2
H 2304	233 (196)	2.4	3.6	2.94	22.10	398.4	238.4	1:0.60	5
H 1687	245 (190)	2.9	3.1	2.83	34.70	346.4	182.0	1:0.53	5
H 1423	265 (136)	4.2	2.4	2.19	12.00	306.4	138.0	1:0.45	3
H 1253	215 (160)	3.6	3.2	2.64	9.35	254.4	76.0	1:0.30	3
H 648	240 (190)	3.6	3.4	2.00	13.35	256.0	116.0	1:0.45	4
H 226	280 (230)	4.3	3.0	2.41	15.65	271.1	112.0	1:0.41	4
H 165	240 (195)	3.8	3.4	2.95	35.05	339.2	240.0	1:0.71	6
H 97	270 (215)	4.7	2.2	1.96	27.63	155.6	75.0	1:0.48	3
H 97/2	280 (220)	3.2	3.2	2.51	23.85	419.0	260.0	1:0.62	4
CI 590	285 (145)	3.8	3.4	2.34	28.80	379.6	230.0	1:0.61	6
CI 167	223 (141)	2.6	2.0	1.90	13.55	176.0	78.0	1:0.44	4
CD 5%	38.6	0.96	0.66	0.39	4.44	75.9	65.7	-	1.8

The values given in the parentheses are the height of the plants grown under full sunlight (open).

Table 4. **Time taken for tuber initiation in cassava grown under shade and open area.**

Cultivar	Time taken for tuber initiation in days after planting	
	Open	Shade
M 4	28	50
H 2304	28	54
H 1687	28	51
H 1423	30	50
H 1253	27	50
H 648	29	51
H 226	27	50
H 165	26	48
H 97	28	50
H 97/2	26	45
CI 590	29	52
CI 167	28	48

evaluated based on the net assimilation rate and crop growth rate Significant differences were noticed among the cultivars with respect to these two parameters (Tables 3 and 5) Total biomass production and partitioning of the dry matter between shoot and tuber also showed significant differences among the cultivars tested (Table 3) The cultivars H 97/2, H 165, CI 590 and H 2304 accumulated more dry matter in tuber when compared to other cultivars at low light The sink capacity under shade, was poor for all the cultivars when compared to open condition The yield reduction of the varieties due to shade effect ranged from 65 to 94 per cent Among the cultivars tested, the tuber yield in H 165 (Figure 2) was maximum, which is about 1/3 of its normal yield. The ratio of dry matter accumulated in ruber to that of shoot was also high in H 165 under shade when compared to ther cultivars (Table 3), showing its tendency for adaptation to shaded area. The mean values of the twelve cultivars on various growth characters under shade were compared with the values obtained from the parallel experiment conducted in the open (Table 6).

Effect of spacing cum topping on yield of cassava in a coconut garden

The plants were taller under wider spacing The girth of the stem was also longer (6 7 cm) under wider spacing than that of closer spacing (5 7 cm), indicating more dry matter production and accumulation under shade when the plant density was reduced Leaf area index was significantly higher in closer spacing However, higher LAI caused mutual shading as evident from lower light transmission ratio and dry matter production The light transmission ratio for canopy photosynthesis was 49 per cent at closer spacing and 54 to 68 per cent at wider spacings. Under shade, removal of apical shoots did not cause any significant effect on yield, while the spacing of 120 cm x 120 cm increased the tuber yield significantly (Table 7).

Discussion

Experimental evidences showed that the plants grown at high light intensity have a different leaf morphology than those grown at low light intensity. By evaluating the sun and shade adapted species of higher plants, Björkman (1) and Noble (9) concluded that shade plants in their native habitat often have

Table 5. **Crop growth rate and yield of cassava genotypes grown under shade and open condition.**

Cultivar	Crop growth rate g/m^2/day (dry wt.)		Tuber yield g/plant (fresh wt.)		Yield reduction %
	Open	Shade	Open	Shade	
M 4	5.06	1.11	2 000	160	92
H 2304	6.40	2.61	2 500	506	79
H 1687	5.62	2.17	2 410	483	80
H 1423	4.81	1.83	2 060	206	90
H 1253	5.30	1.49	1 930	366	81
H 648	5.29	1.12	2 300	283	88
H 226	5.17	1.58	2 450	393	84
H 165	6.02	2.38	2 500	800	68
H 97	6.49	1.07	2 600	170	94
H 97/2	4.73	2.79	2 170	500	77
CI 590	3.44	2.92	2 000	700	65
CI 167	5.00	1.04	1 840	184	90

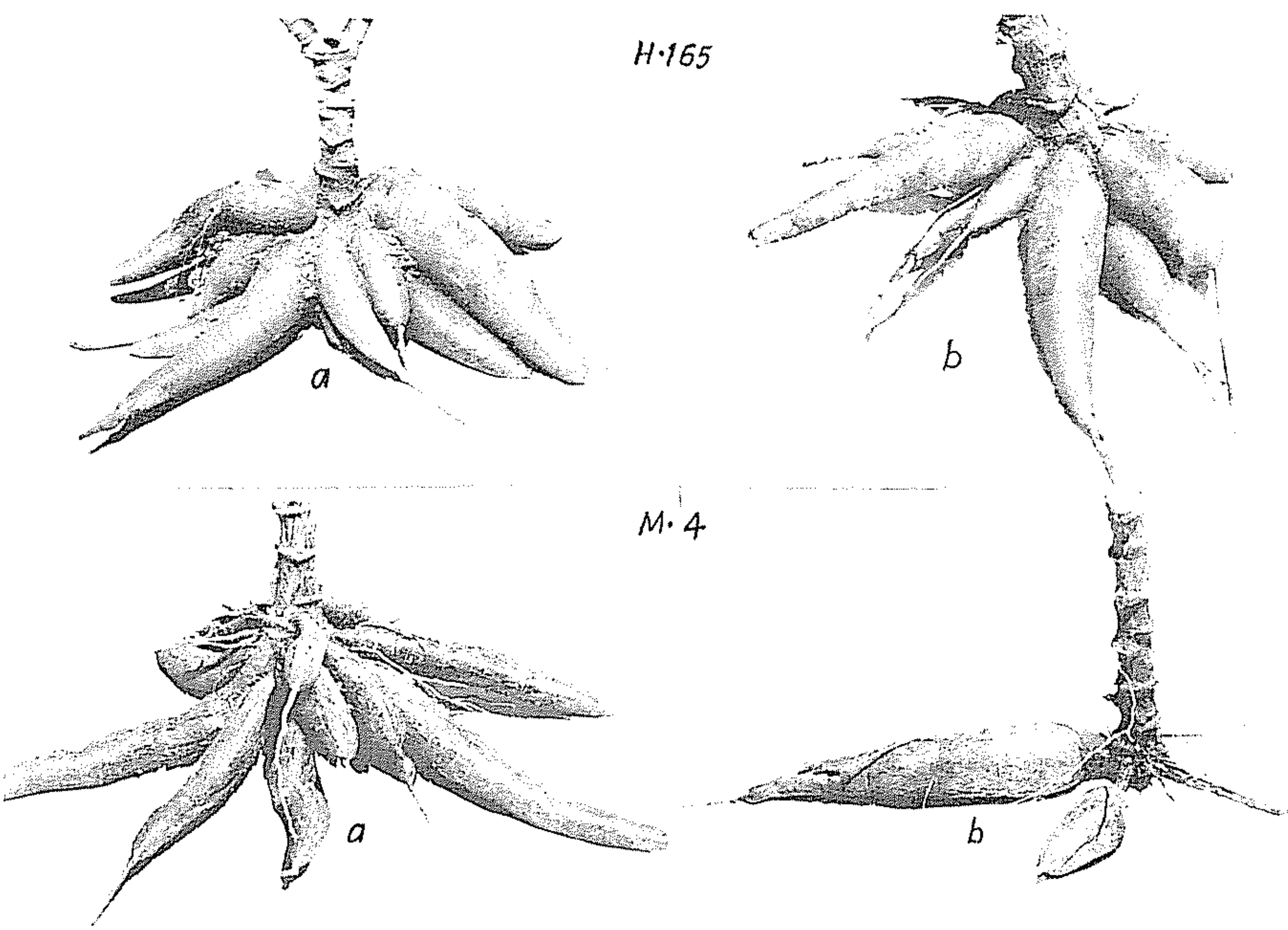

Fig. 2. Tuber growth of H-165 and M-4 in full sunlight (a) and under shade in coconut garden (b) showing varietal differences for adaptation to shade

Table 6. Comparison of growth parameters of cassava grown under shade and open area (mean of 12 cultivars).

Characters	Open	Shade
Plant height (cm)	185	254
Internodal length (cm)	1 6	3 5
Leaf area index	2 19	2 40
Specific leaf weight (mg/cm^2/dry wt.)	5 6	3 0
Net assimilation rate (mg/dm^2/day dry wt.)	48 8	21 1
Crop growth rate (g/m^2/day dry wt.)	5 3	1 8
Stomatal count (450 X)	17 1	10 2

thin leaves with higher chlorophyll content per unit leaf weight than do sun species Further investigation by Crooskston *et al* (3) suggested that high light causes stronger development of palisade and spongy mesophyll tissues resulting in thicker leaves. These reports supported the present observations that cassava leaves grown under shade were thinner and their specific leaf weights were significantly reduced as the light intensity available at canopy level was very low when compared to open area (Table 1)

Under shade, the internodal length increased significantly due to cell elongation as the plants have to compete with coconut palms for light energy Branching in cassava was mainly considered as a genetical factor Absence of branching as observed in the present study under low light is a clear evidence to prove that branching is also influenced by environmental factors and that the hormonal balance is altered under low light Tuberization of cassava in coconut garden was poor, as seem from less number of tubers per plant (Table 3), although varietal differences existed Tuber differentiation is mainly under hormonal and genetical control Occurence of micro-organisms production indole acetic acid and gibberellin like substances in the rhizosphere of coconut

Table 7. Effect of spacing cum tropping on plant height, leaf area index and tuber yield of H 2304 under shade in coconut garden.

Treatment	Control	T_1	T_2	T_3	Mean	SE	CD (5%)
Plant height (cm)							
S_1	198	208	243	211	215	7.42	NS
S_2	249	243	214	253	240	–	–
S_3	278	271	291	240	270	–	–
Mean	242	241	249	235	–	–	–
SE 6.42							
CD (5%) 18.85							
Leaf area index							
S_1	2.50	2.55	3.23	2.72	2.75	0.21	NS
S_2	1.83	1.48	1.45	1.73	1.62	–	–
S_3	1.29	1.18	1.19	1.20	1.20	–	–
Mean	1.87	1.74	1.96	1.88	–	–	–
SE 0.18							
CD (5%) 0.53							
Tuber yield g/plant							
S_1	118	128	87	154	122	22.50	NS
S_2	246	192	371	197	252	–	–
S_3	563	463	288	292	402	–	–
Mean	309	263	249	214	–	–	–
Se 19.49							
CD (5%) 57.16							

S_1, S_2 and S_3 are spacings of 60 cm x 60 cm; 90 cm x 90 cm and 120 cm x 120 cm respectively. T_1, T_2 and T_3 are tropping treatments given at 4th, 5th and 6th month respectively.

trees has been reported by Nair and Rao (7). As the tuberization of cassava in coconut garden was reduced significantly, further investigations for the isolation of inhibiting substances around the root zone of coconut trees and their effect on tuberization are worth contemplation.

Productivity of cassava is mainly controlled by optimum leaf area index and proper sink capacity to accept the photosynthesis. Leaf area index of a variety is largely associated with leaf life (longevity of individual leaf), size of individual leaf and rate of new leaf formation. Due to longer leaf life the number of leaves retained at any stage of the crop in all the cultivars under shade were significantly higher resulting higher LAI. However, the crop growth rate (Figure 3) and net assimilation rate of cassava grown under shade were reduced significantly when compared to those plants grown under normal light. The cross section of the leaves grown under shade showed poor starch deposition in the vascular region demonstrating lower rate of photosynthesis compared to those leaves grown in normal light (Figure 4). Accumulation of starch grain during day time in normaly lighted leaves is an indication for higher rate of photosynthesis. Reduction in stomatal count observed in the leaves of cassava grown under shade (Table 6) would also affect CO_2 uptake. Crookston *et al* (3) recorded 48 per cent increase in stomatal resistance to CO_2 diffusion in shaded bean leaves which showed lower stomatal frequency.

The dry matter accumulated in shoots of sun and shade grown cassava plants was on par with each other (Figure 5) while marked difference was noticed for dry matter accumulated in tuber. Most of the photosynthates of shade grown cassava plants were utilised for shoot growth affecting tuber growth significantly. Though the sink size under shade was poor when compared to normal light, varietal differ-

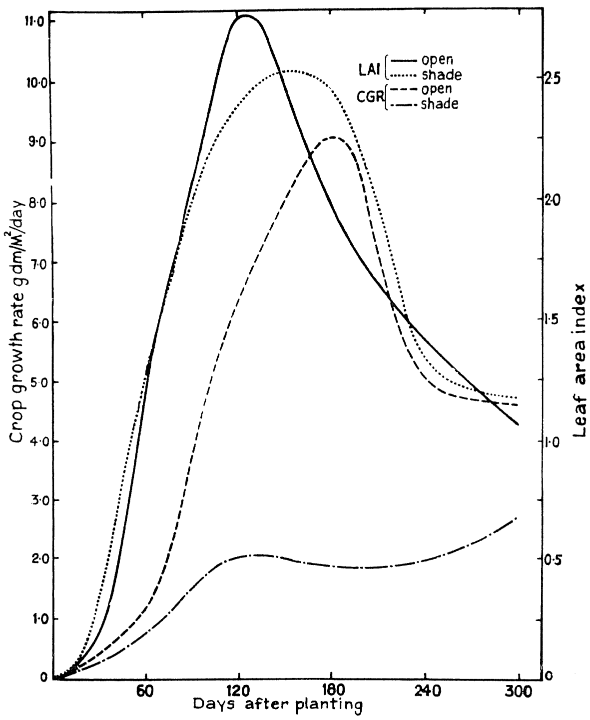

Fig. 3. Leaf area index and crop growth rate of cassava grown under shade in coconut garden and in open area (mean of 12 cultivars).

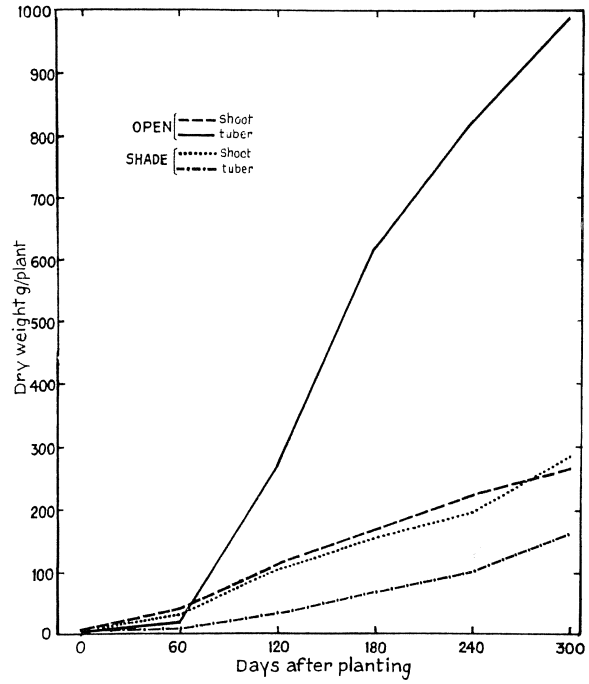

Fig. 5. Dry matter distribution between shoot and tubers of cassava plants grown under shade in coconut garden and in open area (mean of 12 cultivars).

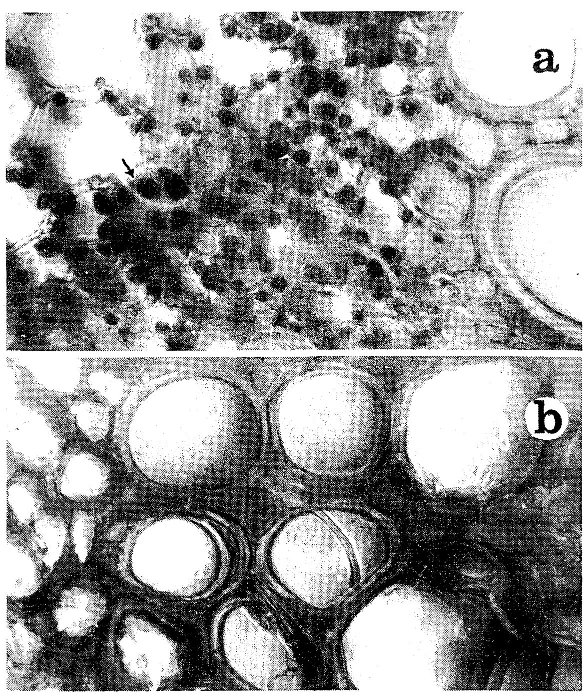

Fig. 4. Transverse section of leaf grown in full sunlight (a) and under the shade (b) showing presence and absence of starch grains in the vascular region (indicated by arrow) during the day time (Magnified 450 x).

ence for tuber yield under shade was noticed showing the tendency for adaptation to shade. The present work suggested that rate of photosynthesis and tuberization limit the productivity of cassava grown in coconut garden. It is concluded that specific leaf weight, stomatal number, diffusive resistance, crop growth rate and tuber bulking rate can be considered as suitable selection indices while screening varieties for shade tolerance.

Summary

The growth and development of twelve cassava genotypes were studied under the shade in a coconut garden. Internodal elongation, thin leaves and absence of branching were the most significant morphological changes noticed under shade. Cross section of leaves grown under shade showed poor starch deposition in vascular region. Most of the photosynthates of shade grown cassava were utilized for shoot growth affecting tuber development significantly. The cultivars H 165 and CI 590 recorded higher yield under shade when compared to other cultivars. Wider spacings of cassava in coconut garden resulted in higher tuber yield.

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Publicaciones

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