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CASSAVA GROWTH AND DEVELOPMENT IN TWO CONTRASTING ENVIRONMENTS OF IBADAN AND JOS

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ABSTRACT

Twelve cassava (improved and local) genotypes were grown at two locations in Nigeria (Ibadan and Jos). Leaf area development and dry matter partitioning were studied from 1994 to 1996. Destructive samplings for growth analyses were done at 3, 6, 9 and 12 months after planting (MAP). Genotype, environment and genotype x environment effects were significant for leaf area index (LAI), total dry matter and total dry tuberous root weight. At Ibadan, LAI was 3.6 and 2.1 at 6 and 12 MAP, respectively, while at Jos LAI values of 0.5 and 2.0 were recorded at 6 and 12 MAP, respectively, in the 1994/1995 planting season. Dry matter production and total dry tuberous root weight were significantly less at Jos than at Ibadan. This was attributed to the lower temperature regime and reduced solar radiation levels recorded at Jos plateau. Patterns of dry matter partitioning to the leaves, shoots and roots were similar in both locations. Dry matter partitioning to the roots was controlled by plant age and solar radiation while dry matter partitioning to the leaves was a function of plant age and temperature. These results indicate that dry matter partitioning of cassava to the roots and leaves are dependent upon solar radiation and temperature in higher altitudes. The data may be useful for validation of models of cassava growth being designed for higher altitudes.

Key words: Cassava; temperature; solar radiation; partitioning; altitude

INTRODUCTION

Cassava is grown in the area between latitudes 30°N and 30°S (Cock, 1985; Nweke, 1994). Cassava tolerates cooler climates, but a critical point exist between a daily average temperature of 18°C and 20°C, below which the cassava plants do not grow normally and the root yields are less (Irikura, Cock & Kawano, 1979; Cock, 1985). Reviews on cassava physiology (Hunt, Wholey & Cock, 1977; Cock, 1985; Ekanayake, Osiru & Porto, 1997) highlighted information available on the effects of environment, mainly climatic variables, on cassava growth and development. Most work on cassava responses to environment has been conducted at lower altitudes of the tropics (Hunt *et al.*, 1977; Cock, 1985; Manrique, 1990; CIAT, 1993). There is a considerable interest in the expansion of the crop into the higher altitudes but little information is available on cassava responses to such environments.

Leaf area development of cassava is

influenced by several environmental factors such as daylength, temperature, rainfall, relative humidity and solar radiation (Hunt *et al.*, 1977; Keating, Evenson & Fukai, 1982a, b; Cock, 1985; Manrique, 1990). The effects of each of these factors on cassava growth and root yield have been studied extensively at lower altitudes (<800 m) both in the tropics and the sub-tropics (Keating *et al.*, 1982a, b; Fukai & Hammer, 1987).

However, little information is available on the effects of low temperature and low solar radiation on leaf area development, dry matter production and dry matter partitioning of various cassava clones. This paper covers the aspect of dry matter distribution and leaf area production as influenced by solar radiation and temperature in Nigeria, taking advantage of different temperature and solar radiation regimes that result from altitudinal differences between Ibadan and Jos plateau.

MATERIALS AND METHODS

Field experiments were conducted at Jos plateau (mid-altitude zone) and Ibadan (forest-savanna transition zone). Two experiments were conducted during 1994/95 and 1995/96 crop seasons at International Institute of Tropical Agriculture (IITA), Ibadan, and at the National Root Crop Research Institute field stations (Vom and Heipang) on the Jos plateau. In 1994/1995 crop season, cassava stem cuttings were planted on May 5, 1994 and May 13, 1994 at Ibadan and Jos plateau, respectively, while in 1995/1996 crop season, cassava stem cuttings were planted on May 10, 1995 and May 20,1995 respectively, at Ibadan and Jos plateau. The Jos plateau and Ibadan represent contrasting agroecological zones: Ibadan at 210 metres above sea level (masl) (4°46'N, 2°34'E) in the lowland humid-forest moist-savanna transition zone has mean annual minimum and mean temperatures of 22°C and 27°C, respectively, and mean annual solar radiation of 16 MJ-^{1} m-^{2}day-^{1}) and Jos plateau the mid-altitude woodland savanna zone. On the Jos plateau, Vom at 1280 masl (9°55'N, 9° 53'E) has mean annual minimum and mean temperatures of 16°C and 20°C, respectively, and mean annual solar radiation of 15 MJ-^{1} m-^{2}day-^{1}, while Heipang at 1290 masl (9°38'N, 8°9'E) has mean annual minimum and mean annual temperatures of 15.6°C and 20°C respectively, and mean annual solar radiation of 7.4 MJ-^{1} m-^{2}day-^{1}. Characteristics of different sites are presented in Table 1. The soil at Ibadan is classified as Oxic paleuestalf, Alagba soil series (Greenland, 1981) while in Jos plateau the soil is Ferruginous tropical soils (Kowal & Knabe, 1972).

Plant material and experimental design

Twelve cassava genotypes including six improved IITA genotypes (TMS 30001, TMS 91934, TMS 4(2)1425, TMS 30572, TMS 50395, TMS 30555); four landraces commonly grown in southwestern Nigeria (TME1, TME2, Isunikankiyan and Oko-Iyawo), and two landraces grown in mid-altitudes (Danduala and Danwaru) were used. Cassava stem cuttings of 0.20 m length were obtained from 12-month old mother plants, at the middle part of the stem, and were immersed in 0.05% of Benlate fungicide (a.i. = methyl 1-(butyl carbatomyl)-2-benzimidazole carbamate) solution.

The experiments were set up in each location in a completely randomized block design with three replications. Each plot had 6 rows, 10 m long and spacing of stakes planted singly was 1 m between rows and 0.8 m within row. Each plot contained 72 plants. Plants were grown rainfed under native soil fertility conditions. The fields were kept free of weed by regular hand-weeding.

Data collection and analyses

Harvesting was done sequentially at 3, 6, 9 and 12 months after planting (MAP). At each sampling, four plants were carefully removed from the centre rows in each plot. The plants were separated into fibrous roots (FR), tuberous roots (TR), stems (ST), leaves including the dead ones (LV), petioles (PT) and rootstock (mother stake) (RS). The fresh weight of the samples were taken and the samples were then oven-dried for 48 h at 80°C prior to dry weight determinations. Leaf area was measured on a subsample of green leaves using a leaf area meter (L1-3100, L1-COR, Lincoln, Nebraska, USA). Dry matter partitioning ratios were calculated as LV/ TOTDWT, (ST+FR+TR+ST+LV+PT+RS)/ TOTDWT, TR/TOTDWT (ST+LV+PT+RS) / TOTDWT where TOTDWT = total dry weight. Data for leaf area, dry weights, and partitioning ratios at each sampling were analysed as a separate experiment for each location. Analysis of variance was done using Statistical Analytical System (SAS, 1996) programme and while mean differences were detected using the least significant difference test procedure. Seasonal effects on dry matter partitioning were quantified using average values of mean monthly air temperature and mean monthly solar radiation, respectively. Variation in dry matter partitioning at a given time of the growing season was assumed to be controlled by both the plant age and by the environment prevailing at that time. The procedure STEPWISE Regression using Statistical Analytical System (SAS, 1996) programme was used for model analysis to relate dry matter partitioning ratios with plant age, temperature and solar radiation.

RESULTS

Result of weather data monitored during the crop growth periods revealed that both air temperature and solar radiation differed between the two locations (Table 1). Genotype, environment and genotype x environment effects were significant for leaf area index (LAI), total dry matter and total dry tuberous root weight (Table 2). In all the samplings, there were no significant differences ($P<0.05$) between the 1994/1995 and 1995/1996 planting seasons for LAI (Fig. 1). Although, LAI produced in 1994/1995 season was larger when compared to 1995/1996 planting season at both locations and years. There were significant differences among the four environments tested (Ibadan, 1994 and 1995, Jos, 1994 and 1995) for LAI. Ibadan 1994/ 1995 season had the highest overall value of 3.6 for LAI at 6 months after planting whereas in Jos plateau, the highest value of 2.0 LAI was recorded during the 1995/96 planting season at 12 MAP (Fig. 1). The patterns of LAI showed that maximum LAI was obtained at 6 MAP in the high-temperature site (Ibadan) thereafter a decline was observed upto 9 MAP and later increased upto 12 MAP. At the lower-temperature regime of Jos plateau, LAI continuously increased with plant age until 12 MAP (Fig. 1). Genotypic differences were observed for both within and across locations for leaf area index (Table 2).

Analyses of the data revealed significant differences ($P<0.05$) in total dry matter production among the four environments throughout the sampling periods (Fig. 1). Dry biomass accumulation at Jos plateau was reduced when compared to Ibadan at all ages (3, 6, 9 and 12 MAP). The dry biomass production followed a similar trend in the four environments (Ibadan, 1994 and 1995, Jos, 1994 and 1995). There were continuous increases in dry biomass with plant age as expected in all the environments tested (Fig. 1).

There were significant differences in dry tuberous root weight per hectare among the four environments throughout the plant growth period (Fig. 1). At 3 MAP, Ibadan, 1994 had the highest overall tuberous root dry weight of 0.7 Mg ha^{-1}. There were continuous increase in the total dry tuberous root weight with plant age in all the environments tested (Fig. 1).

Genotypic differences were observed for both within and across locations for leaf area index, total dry tuberous root weight and total dry matter (Table 3). TMS 30572, TME1 and TMS 91934 performed better than the other genotypes across the test locations.

Table 1. Characteristics of The Different Sites and Seasons Used in Study

Location	Ibadan		Jos plateau	
Site	IITA a	IITA a	Vom b	Heipang b
Period	1994/1995	1995/1996	1994/1995	1995/1996
Max. temp. (? C)	31.8	31.5	22.9	23.9
Min temp.(? C)	21.2	22.3	16.2	16.6
Mean temp. (? C)	26.5	26.9	19.6	20.2
Mean rainfall (mm)	127.2	115.7	102.1	102.9
Mean solar radiation (MJ/m2/day)	15.5	15.0	15.1	7.4
Latitude	4? 46 N	4? 46 N	9? 55 N	9? 38 N
Longitude	2? 34 E	2? 34 E	9? 53 E	8? 51 E
Soil texture	sandy loam	loamy sand	clay loam	sandy clay loam
Soil pH	6.0	5.6	5.1	5.0
N (g/kg)	0.17	0.13	0.14	0.17
P (g/kg)	0.6	5.0	0.8	7.0
K (g/kg)	0.6	0.5	0.3	0.5
Organic matter (g/kg)	2.0	1.1	2.0	1.99
Exchange Ca (cmol/kg)	7.8	2.5	5.9	6.5
Exchange Mg (cmol/kg)	0.6	0.5	1.8	13.5
Exchange K (cmol/kg)	0.7	0.3	0.5	0.5
Sand (%)	73	82	35	56
Silt (%)	10	10	25	14
Clay (%)	17	9	40	30

a= weather data from IITA meteorological unit b= weather data from Nigeria meterological unit at Federal Secretariat, Jos.

Table 2. Means squares for total dry tuberous root weight, total dry biomass, leaf area index and harvest index of 12 cassava clones grown at two locations from 1994 to 1996.

Source of variation	d.f.	Dry tuberous root weight (Mg ha-^{1})	Total dry matter (Mg ha-^{1})	Leaf area index
Year (yr)	1	718**	2824**	26**
Location (loc)	1	2748**	10814**	78**
Loc x yr	1	0.7 $^{n.s}$	39 $^{n.s}$	51**
Rep (loc x yr)	12	18 $^{n.s}$	61**	2$^{n.s}$
Clone	11	137**	388**	2525**
Clone x loc.	11	47**	131**	5**
Clone x loc x yr	11	81**	250**	13**
Environment (Env)	3	1154**	4559**	52**
Rep (Env.)	12	17**	61**	2 $^{n.s}$
Clone x Env.	33	54**	162**	9**
Error	516	8	22	9
C.V.(%)		36	45	35

* = significantly different at P<0.05, * * = significantly different at P<0.01, n.s = not significantly different at P<0.05.

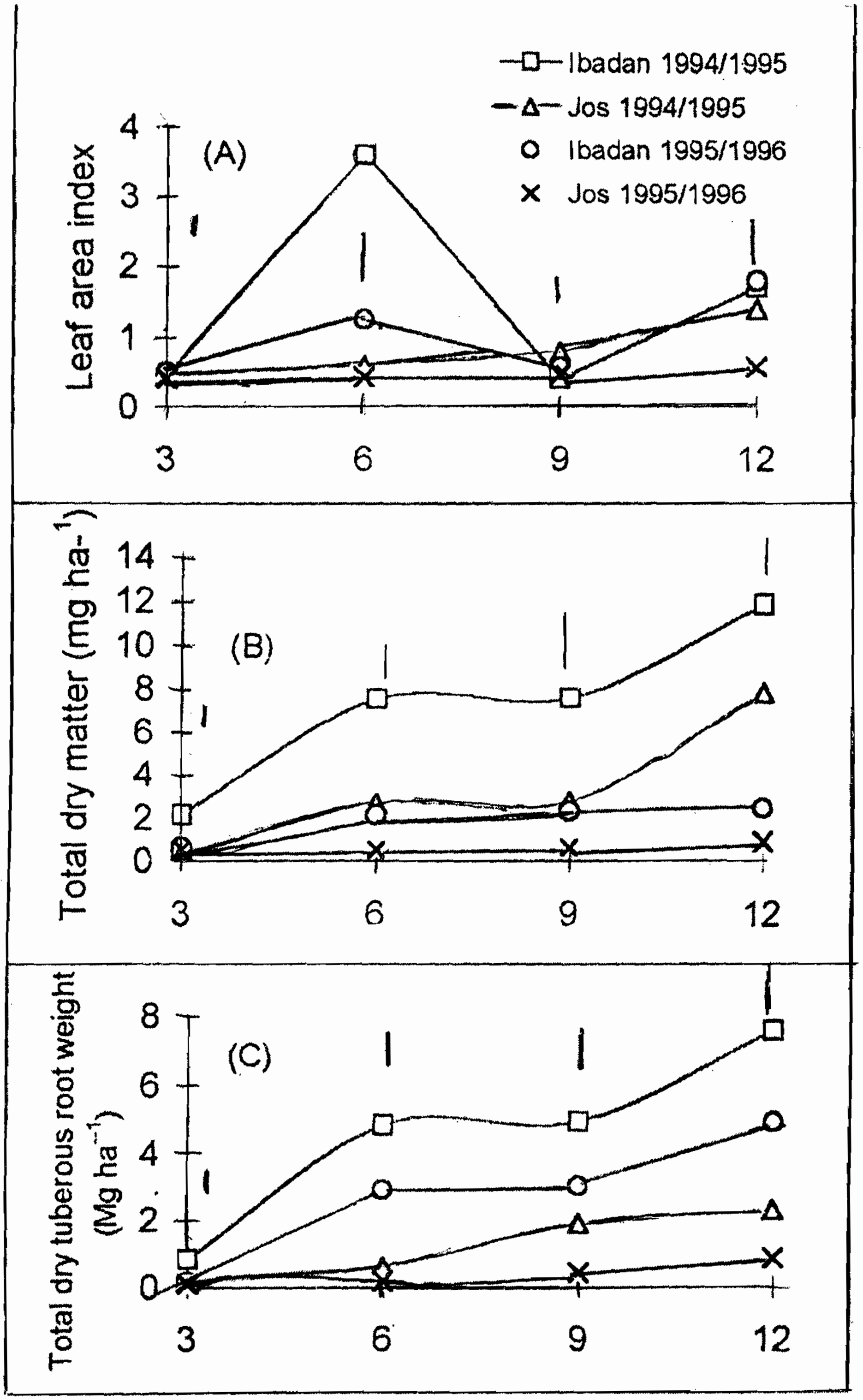

Fig. 1. Leaf area index, total dry matter and dry tuberous root weight as affected by (A) planting season, (B) environment at different plant age in two agroecological zones of Nigeria (Jos plateau and Ibadan) from 1994 to 1996

The proportion of total dry matter found in leaves decreased and later increased whereas the proportion in tuberous roots increased continuously with plant age (Fig. 2). This

Table 3: Stepwise Regression Equations Expressing The Effects Of Plant Age And Environment On Dry Matter Partitioning To Leaves (Lv/Totdwt) And Tuberous Roots (Tr/Totdwt).

Pooled (N = 16)

LV/TOTDWT = 0.218 - 0.013 MAP ** (57%) $R^2(\%) = 57$

TR/TOTDWT = -0.129 + 0.034 MAP ** (62%) + 0.014 SAR (12%) $R^2(\%) = 74$

Jos plateau (N = 8)

LV/TOTDWT Y= -0.140 - 0.009 MAP ** (57%) + 0.017 MAT * (29%) $R^2(\%) = 86$

TR/TOTDWT = -0.129 + 0.035 MAP ** (62%) + 0.0145 SAR* (12%) $R^2(\%) = 74$

Ibadan (N=8)

LV/TOTDWT = 0.236 - 0.015 MAP * (59%) $R^2(\%) = 59$

* = denotes significance at the P = 0.05 confidence levels, ** = denotes significance at the P = 0.01 confidence levels, MAP = Months after planting,, SAR = Solar radiation, MAT = Mean air temperature, TR = Total dry tuberous root weight, LV = Total dry leaves weight, TOTDWT = Total dry biomass.

pattern of dry matter partitioning was observed in both locations irrespective of differences in altitude. Significant differences (P<0.05) were also observed between Jos plateau and Ibadan for the partitioning ratios to tuberous roots and shoots. The cassava grown at Ibadan were more efficient in allocating dry matter to roots when compared to Jos plateau (Fig. 2).

Regression models of dry matter partitioning to leaves, shoots and tuberous roots were carried out in an attempt to quantify the effects of solar radiation and temperature and plant age on assimilate distribution (Table 3). Only those model components that significantly (P<0.05) improved the description of distribution ratio were considered here. When the data were pooled over locations, relatively poor relationships were obtained among dry matter partitioning ratios and environmental factors suggesting environment-specific patterns of allocation. A large amount of the observed variation in tuberous roots and leaves could be accounted (57% to 63%) for by plant age while only 12% was due to solar radiation. The data within locations give a better description of the effects of environment on dry matter distribution. At Ibadan, plant age accounted for 59% of the variation in dry matter distribution to leaves. At Jos plateau, dry matter distribution to leaves was modeled as a function of plant age and temperature whereas for partitioning to tuberous roots, 62% of the variation was accounted for by plant age and 12% was by solar radiation (Table 3).

DISCUSSION

There were significant genotype, environment and genotype x environment for leaf area index, total dry matter and total dry tuberous root weight. Thus, selection among the genotypes for leaf area index, total dry matter and total dry tuberous root weight should be conducted over more than one season in order to ensure some stability to seasonal influences.

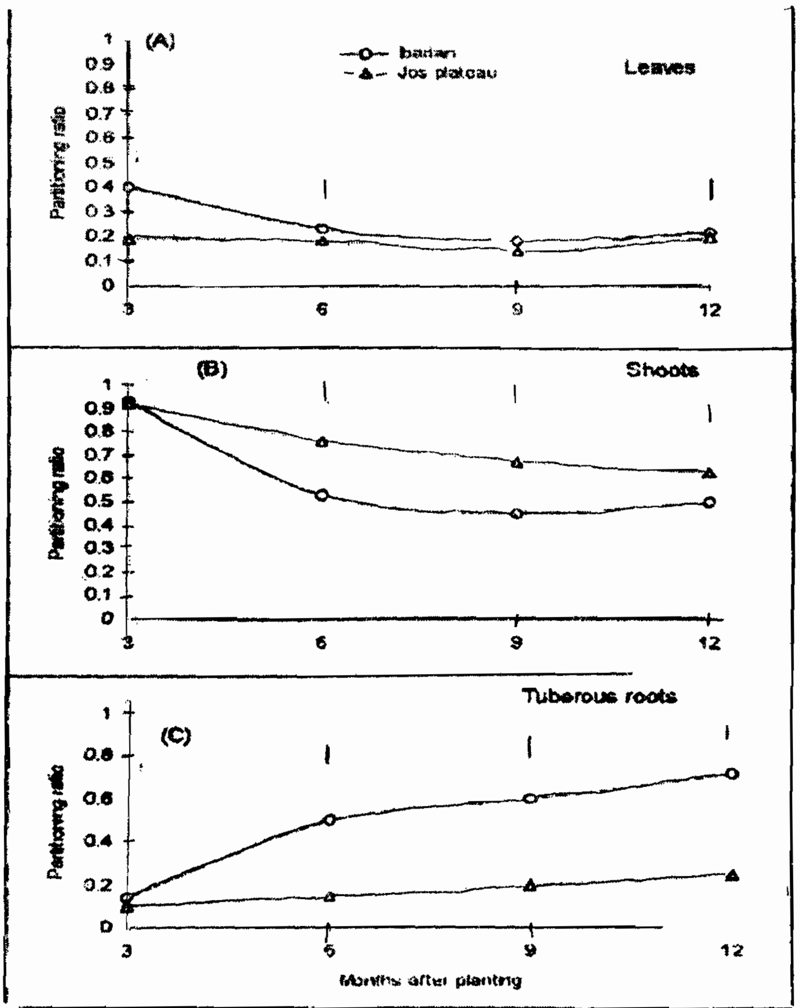

Fig. 2. **Patterns of dry matter partitioning to different plant parts: leaves, shoots and tuberous roots as affected by season and plant age. Bars indicate L.S.D. at 5% level of probability**

The result also implies that genotype performance will be enhanced by planting in certain locations in certain seasons.

The leaf area index (LAI) was significantly reduced at Jos plateau than Ibadan. The maximum LAI of 3.6 was obtained at 6 months after planting at high temperature regimes while a maximum of 2.0 was recorded at 12 months after planting at low the temperature regime. Previous work has also shown that cassava has an optimum LAI of 3.0 to 3.5 under a temperature regime of 24°C (Cock, Franklin, Sandoval & Juri, 1979). Studies conducted in Australia (sub-tropics) have also shown that cassava achieve maximum LAI greater than 7 (Fukai, Alcoy, Liamelo & Patterson, 1979). Although differences in LAI among cassava genotypes may be due to differences in branching patterns, the lower LAIs in tropical environments are probably due in part to very short life and small leaf size (Cock *et al.*, 1979). Results obtained in this study may be due to high temperatures experienced at Ibadan which promoted rapid initial leaf area development and by 6 months after planting, it reached its peak and thereafter declined. The reduction at 9 MAP may be due to dry season experienced at Ibadan The reduced LAI in Jos plateau can be attributed to the lower temperature, which resulted in slower a pace of leaf area development.

Patterns of dry matter partitioning to leaves, shoots and tuberous roots in both locations were similar. Partitioning to leaves and shoots decreased while tuberous roots increased with plant age, indicating a shift in sink capacities which is affected by both the plant age and environment (Howeler & Cadavid, 1983). The cassava grown at Ibadan (lowland) were more efficient in allocating dry matter to roots than those planted at Jos plateau (mid-altitude). This finding was consistent with other studies which have shown that cassava growth rate was reduced when grown under low light or temperature and therefore tuberous root formation also affected (Keating *et al.*, 1982a, b; Cock, 1985; Manrique, 1990).

The large amount of variation in dry matter partitioning to leaves and tuberous roots were accounted for by plant age and solar radiation. This result indicates that plant age was the main factor controlling dry matter partitioning in cassava. Similar results have been reported by Manrique (1990). The results from within locations enabled a reasonable description of the effects of solar radiation and temperature on dry matter partitioning of cassava. At Jos plateau, plant age accounted for variation in dry matter partitioning to leaves and tuberous roots while temperature and solar radiation accounted for variation in leaves and tuberous roots respectively. From these study, it is interesting to note that solar radiation instead of temperature controlled significantly the dry matter partitioning to tuberous roots while temperature affected the partitioning to leaves. These results appear to support the view that leaf growth was more sensitive to temperature than any other shoot component in cassava (Irikura *et al.*, 1979). These findings were also consistent with studies which have shown a decline in dry matter partitioning to roots with a reduction in solar radiation (Fukai *et al.*, 1984). Other studies indicate that low solar radiation delays root enlargement and reduces root cell size and number (Kasele, Hahn, Oputa & Vine, 1984).

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