Physiological basis of genotype-temperature interactions in cassava

Cassava (*Manihot esculenta* Crantz) is one of the most important calorie-producing crops in the tropics. This crop is successfully grown in zones between the latitudes 30° N and S, at altitudes from sea level up to about 2,000 m in equatorial regions, with annual precipitations ranging from 500 mm to 6,000—8,000 mm and soil pH between 3.8 and 8. It tolerates practically any hot climate, but a critical point seems to exist somewhere between 18 and 20°C of daily average temperature, below which the plants do not grow normally and the yields decrease markedly.[1,2,4,5,6]

In this paper an attempt is made to define how temperature effects the growth and yield of cassava and in consequence to determine if specific genotypes exist which are more suitable for different temperature conditions.

Four varieties of low, medium, high and very high vigor (M Col 22, M Col 113, M Mex 59 and Popayan, respectively) were planted in three sites at Colombia; Km 27, CIAT and Caribia with mean temperature of 20°, 24° and 28°C, respectively. All plots recived 200: 200: 300 kg/ha of N: P_2O_5: K_2O so as to give a high fertility level in all sites. Twenty-centimeter cuttings were planted obliquely on ridges at 1×1 m spacing. Each variety was planted in 5×12 m plots in a randomised block design with three replicates. Fungicidal applications were made to control *Phoma* leaf spot at Km 27 and superelongation disease at Caribia. Harvests were taken at 8, 12 and 16 months after planting.

As shown in Table 1, Popayan was the highest yielder at 20°C at both 12 and 16 months but was always the lowest yielder at 28°C among the all varieties tested. M Col 22 was the lowest yielder at all harvests at 20°C but was the highest yielder at 28°C at 8 and 12 months although it showed a slightly lower yield than the highest yielder (M Mex 59) at 16 months. These results clearly indicate that there is a genotype with temperature interaction for yield ability and effect of natural selection is highly significant on the varietal adaptation.

The rate of root bulking during a period between 8 and 16 months was closely related to differences in mean LAI (Fig. 1) with a marked optimum LAI for root production at LAI 3. Previous work has shown that cassava has an optimum LAI of 3–3.5 under CIAT conditions (24°C).[3,7] The data presented here show that this optimum LAI exists over a wide range of temperatures.

The components of LAI were analysed so as to determine the manner in which temperature

Table 1. Root yields of cassava varieties showing contrasting responses to different mean temperatures of 3 sites where they were grown

Months after planting	20°C			24°C			28°C		
	8	12	16	8	12	16	8	12	16
Fresh yield (t/ha)									
M Col 22	2.7	9.3	13.3	22.1	27.7	48.3	23.9	39.4	53.1
M Mex 59	9.2	22.8	32.8	25.3	38.8	57.0	21.3	30.4	60.3
M Col 113	14.2	24.2	28.6	16.4	26.1	51.3	20.2	23.9	55.0
Popayan	10.7	28.9	39.7	6.3	15.7	13.3	4.6	9.4	13.2
Dry yield (t/ha)									
M Col 22	0.9	3.3	5.6	8.4	11.5	18.0	8.8	14.2	18.4
M Mex 59	3.0	8.2	12.9	8.2	14.2	18.1	7.5	10.1	19.7
M Col 113	4.5	8.4	15.6	5.4	10.0	19.1	6.2	7.5	17.0
Popayan	3.1	10.7	16.2	1.9	5.1	2.6	1.1	2.2	3.0

For fresh and dry root yields effects of temperature and temperature × variety interaction were significant at 1% and 0.1% levels respectively.

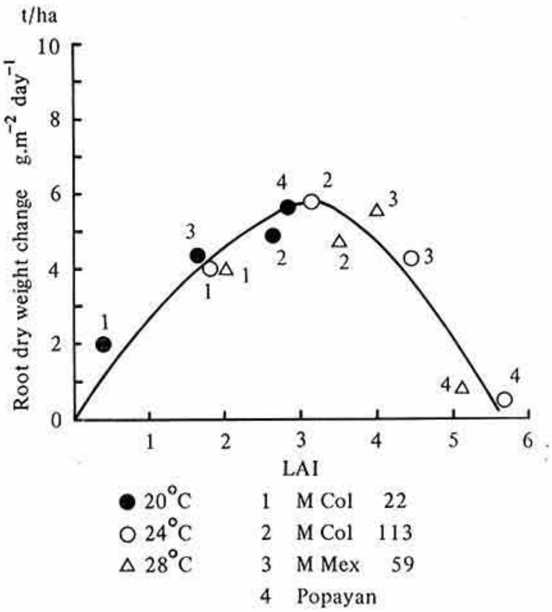

Fig. 1. Root dry weight increase as related to mean LAI during a period from 8 to 16 months after planting.

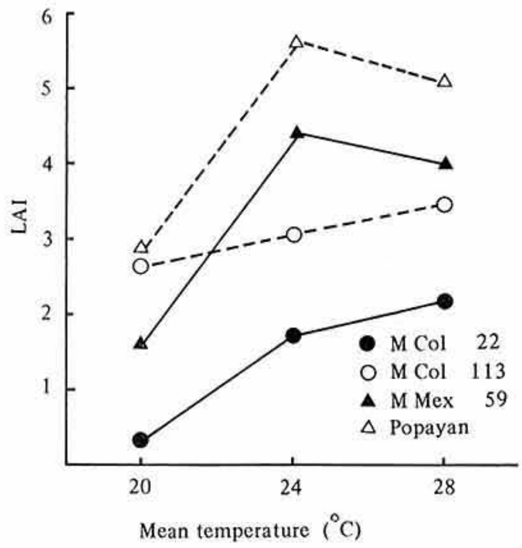

Fig. 2. Mean LAI (leaf area index) at 8—16 months after planting of four varieties at three temperatures.

affects LAI. The LAI is determined by the following parameters: (1) number of active apices, (2) rate of leaf formation per apex, (3) leaf size, and (4) leaf life.

As temperature increased from 20° to 24°C, leaf size increased and reached its maximum size earlier. Leaf life decreased as temperature increased and leaf formation rate increased over the range of 20°–28°C; the changes in leaf life, and leaf formation rate with temperature were more marked with the temperature change from 20° to 24° than from 24° to 28°C; some varieties produced more branches than others at each temperature. However, with all the varieties the branching occurred earlier as temperature increased to 24°C and then was delayed as temperature increased to 28°C.

Combination of these changes in LAI components in relation to temperature resulted in the increased LAI with the temperature increase from 20° to 24°C due to earlier branching, increased leaf formation and leaf size. As temperature increased further, the reductions in branch number and in leaf life caused a decrease in LAI in Popayan and M Mex 59 (Fig. 2).

LAI was actually measured by destructive sampling only at 8, 12 and 16 months because of the limited experimental area. However, light interception, which is closely related to LAI, was measured throughout the growth cycle. At 28°C 80% or more of the incoming light was intercepted by all varieties during the period from 4 to 16 months. At 24°C light interception was more than 90% from 4 to 6 months, causing the rapid leaf fall with leaves formed in 2–4 months, but afterwards it decreased especially in M Col 22 and M Mex 59. At 20°C light interception by M Col 22 was never greater than 50%, and the only variety that maintained interception value more than 80% for most of the growth cycle was Popayan.

The maximum yields obtained at 16 months at 20°, 24°, and 28°C were 40, 57 and 60 t/ha (16, 19 and 20 t/ha in dry matter) respectively. It shows that high yield can be obtained at each temperature by selecting varieties to be used. At 20°C LAI and light interception are generally lower than those at the other sites, and the insufficient LAI was the main factor limiting yield. In the least vigorous variety M Col 22 maximum light interception was less than 50% and yield was extremely low.

At 24° and 28°C the extremely vigorous variety Popayan showed excessive LAI and extremely low yields whilst M Col 22, M Col 113 and M Mex 59 maintained LAI near the optimum and produced high yields. It suggests that although LAI is the main factor limiting yield at 20°C, the balance between top and root growth is the most important factor at 24° and 28°C. This balance is optimized when LAI is maintained at about 3.

The existence of different yield abilities of varieties at different temperatures shows that the special genotypes are needed for temperature lower than 24°C. However, the existence of phenotypes which are suitable to all temperatures from 20—28°C is suggested.

Recent simulation data[3,7] suggest that increased leaf life is associated with high yield ability. At lower temperatures leaf life is longer, and, therefore, if LAI could be increased by some means, the productivity even higher than in the hotter areas could be expected.

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