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CIAT Centro Internacional de Agricultura Tropical

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Information and conclusions reported herein do not necessarily reflect the position of any of the aforementioned entities.

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INTRODUCTION

The Cassava Program had an extremely active year in 1986. The demand studies commisioned by the TAC are now nearing completion and the results have been published in a preliminary draft for discussion. These formed the basis for the new long term plan which is also available as a discussion document to be presented to the CIAT board and to the TAC after appropriate modifications.

While the demand studies have been underway, the Program has been active in developing its research and outreach activities. In Asia, the efforts on germplasm testing have been reinforced by posting a senior agronomist, with special project funding, to develop management practices suitable to the intensive Asian cropping systems that also allow sustained high levels of productivity.

In Africa, links with IITA have become closer with a greater spirit of cooperation to resolve the urgent needs of Africa. Of note here is the agreement to jointly carry out an in-depth study of the future demand for cassava on that continent, so as to better plan research and development programs in the future.

In Latin America, the changing economic circumstances have created tremendous dynamism in the cassava field. Cassava drying industries are already functioning in Mexico, Colombia and Ecuador. In Peru, Brazil and Cuba pilot plants are being established by either the private or the public sector. In the fresh cassava market the first commercial use of the new cassava conservation technology has begun with promising results.

All this has occurred when the Program is basically on hold awaiting the results of the demand studies ! The recent advances and the demand studies both indicate a bright future for cassava.

CASSAVA VARIETAL IMPROVEMENT IN ASIA

During the first 10 years of the Cassava Program (1973-1982), CIAT offered cassava germplasm and training/communication opportunities to Asian cassava researchers. Since the opening of the CIAT Cassava Program Regional Office in Bangkok, Thailand in 1983, cooperation with Asian national programs has been greatly strengthened. This has contributed to the establishment and improvement of national cassava research programs in many Asian countries. In 1973, cassava breeding work was non-existent in Kasetsart University, Thailand; Visayas State College of Agriculture (VISCA), Philippines and Brawijaya University, Indonesia; Malaysian Agricultural Research and Development Institute (MARDI), Malaysia. Breeding work was only just starting in the Department of Agriculture (DA), Thailand and was essentially dormant in the University of Philippines at los Banos (UPLB); Central Research Institute for Food Crops (CRIFC), Indonesia and South China Academy for Tropical Crops (SCATC), China. Now, Thailand (D.A.), Philippines (PRCRTC, VISCA) and Malaysia (MARDI) have fully functional cassava varietal improvement programs and the others are rapidly catching up (Table 1). The underlying strategy of CIAT's work is to generate socially relevant basic technology through the research activities of national programs.

One clone selected from CIAT clonal introduction (CM 323-52 by PRCRTC, Philippines, 1986) and two clones selected from CIAT seed introduction (CM 407-7 as Rayong 3, by D.A., Thailand, 1984 and CM 305-21 as Rayong 2 by D.A., Thailan- dia, 1985) were recently released officially by government institutions after clearing all the necessary steps of varietal evaluation. Hybridizations for these clones were made at the CIAT headquarters in Colombia during 1973 and 1974. Due to the long period required for cassava genotype evaluation and the slow multiplication rate of the crop, it is only now that it is possible to observe the positive outcome of CIAT's earliest work in the farmers' fields.

Varietal improvement objectives common to Asian national programs are:

1. Higher yielding capacity under limited and medium-input conditions.
2. Higher root dry matter content.
3. Early harvestability.
4. Disease and pest resistance and tolerance to adverse soil and climatic conditions.
5. Lower root cyanide content.

Increased production efficiency rendered by improved yielding ability, and higher processing efficiency by higher root dry matter content, will lead to greater competitiveness of cassava products. Higher yield per area may help cassava production retreat from erosion threatened sloping areas and early harvestability may lead to better land use efficiency. Far from the center of origin and diversification

of the species, cassava in Asia (except in India and Sri Lanka where the cassava is infected by African mosaic disease) is less troubled by disease and insects than cassava in tropical America, yet, diversification of cultivars with respect to resistance factors is much needed for the long term stability of cassava cultivation. The relative importance of cassava for fresh human consumption is less in Asia than in Latin America, yet, demand for improved low-cyanide cultivars continues to be significant. The CIAT germplasm materials supplied to national programs in the past tended to contain relatively limited numbers of low cyanide genotypes.

Germplasm distribution

Sexual seeds have been the major means of germplasm transfer, occasionally supplemented by meristem culture. During the past years, approximately 140,000 hybrid seeds from some 2,300 crosses have been distributed to cassava breeding programs in Asia (Table 1). The strategy evolved from sending any available Latin American germplasm to any interested program in the early years, to one of providing seed populations with well defined parents, directed to the specific needs and capacity of each national program. This effort particularly has been reinforced since 1982.

In many national programs, the seed populations are regarded as sources for immediate varietal selection, while programs in e.g Thailand and the Philippines have also selected cross-parents from the seed populations to be used in their hybridization programs. These materials are being processed through various evaluation steps in each national program.

Extra quantities of promising hybrid seeds from crosses between locally selected Thai and CIAT parents, have been produced by the cooperative program between D.A. and CIAT in Thailand for distribution to other Asian national programs.

Thailand

The cassava research program, with its headquarters at the Rayong Field Crop Research Center, Field Crop Research Institute, Department of Agriculture, has developed a highly comprehensive varietal improvement program, which has incorporated massive germplasm introductions from CIAT (Table 2) into its evaluation scheme (Table 3). From the first CIAT seed introduction of 1975, a clone selected from a CM 407 cross (M Mex 55 x M Ven 307, crossed at CIAT in 1974) and another from CM 305 (M Col 113 x M Col 22, crossed at CIAT in 1973) were released as Rayong 3, high starch cultivar and Rayong 2, cultivar for snack food, respectively. Several clones have been selected from the seed populations to be used as parents in hybridizations (Table 4) and the resulting hybrid seeds from Thai x locally selected CIAT clones, and locally selected CIAT x CIAT clones, now constitute the main stream of breeding materials.

Rayong 3 seems to be popular among starch factories and advanced farmers and is estimated to be planted in more than 500 ha. The limiting factor to further expansion of area is planting material.

Rayong 2, just released, attracted a few snack food companies and is planted by contract farmers.

Some clones which had shown promising results in evaluation trials and regional trials, have dropped out of the list of candidates for varietal release due to inconclusive results in on-farm trials. These included 27-77-10 (a selection from the CM 321-170 x M Col 1684 cross made at CIAT, Colombia in 1977 by Charn Tiraporn, Director of Rayong Field Crop Research Center (RFCRC), OMR 23-29-15 and CMR 23-128-141. (CMC 76 x V 43) 21-1, a clone with good yielding capacity with very high root starch content which is still extensively evaluated in on-farm trials, but whose occasionally unsatisfactory germination habit and poor plant type disappointed breeders. CMR 24-63-43, a selection from the M Col 1684 x Rayong 1 cross made at Rayong Center in 1980, continued showing good results and is considered to be a strong candidate for next varietal release. All of these clones have been incorpo- rate into the hybridization scheme.

In regional trials, where clones selected mainly from 1980/81 crosses (CMR 24 crosses) were evaluated; some clones out- yielded Rayong 1 on the average in all locations but the difference was not very large (Table 6). CMR 24-14-266 and CMR 24-07-12 were advanced to on-farm trials.

More promising results were obtained from advanced trials in which clones selected from 1981/82 crosses (CMR 25 crosses) were evaluated (Table 7). Both clones selected from Thai crosses such as CMR 25-34-159, and CIAT crosses such as CM 3299-15, showed good results. The major difference of these clones from the highly versatile local cultivar Rayong 1 was their higher harvest index.

Preliminary trials, in which clones from 1982/83 crosses (CMR 26 or OMR 26) or 1982/83 seed introduction from CIAT were evaluated also offered a number of promising clones (Table 8). Many more clones are being evaluated, the best seem to combine high yielding ability with good germination.

Planting cassava at the beginning of the wet season (April/May) has been the standard practice in Thailand, but recently more and more farmers are shifting their plantings toward the end of wet season (September to November). Clonal evaluation for 2nd season planting was started in 1983 and now a comprehensive set of genotype evaluations covering from F_1 seedling selection to on-farm trials has been established. In all the 2nd season trials so far obtained, selected clones have shown a clear yield advantage over Rayong 1 than in 1st season trials.

CMR 24-63-43, which had been outyielding Rayong 1 in nearly all the evaluation trials, also showed highly promising results in on-farm trials (Table 9). CMR 24-63-43 is of high harvest index, good plant type and root shape.

In advanced trials, promising clones such as CMR 25-105-112 showed clear yield superiority, not only under high, but also under low

yielding conditions (Table 10). All these high yielding clones had distinctly higher harvest indexes than Rayong 1.

The cassava breeding program at Kasetsart University is now functioning well. CIAT helped train the personnel and contributed much of germplasm. The best selections from this program are also incorporated into the evaluation network of the D.A. program.

The local cultivar Rayong 1, which is characterized by moderately high harvest index and excellent plant type and is superbly adapted to local conditions, has greatly contributed to the present successful level of the Thai Cassava industry. Virtually all of the total 1.2 millon ha of Thai cassava fields are currently planted with a single clone Rayong 1. Broadening the genetic variability of cultivars is desirable. Individual farmers are keen on acquiring new high yielding clones, since cassava is a cash crop. Starch factories are favoring Rayong 3 because of its higher processing efficiency, and pay a premium for Rayong 3 roots. Higher production efficiency rendered by high yielding clones is ever necessary for cassava products to be competitive and for cassava fields to retreat from erosion threatened land surfaces. Since Rayong 1 is already a very good cultivar, a yield improvements are unlikely to be spectacular, yet the necessity and demand for new higher yielding cultivars is high.

Philippines

In the early years of cassava research program establishment in the Philippines, an introduction of 12 clones from CIAT was made through the CIAT/SEARCA/IDRC project. After several cycles of multiplication, these clones were handed to IPB (Institute of Plant Breeding), at the UPLB, and PRCRTC (Philippine Root Crop Research and Training Center) at VISCA, and were later evaluated in regional trials (Philippines Seed Board trials). After some years of trials, CM 323-52 was officially released together with G 50-3, a high yielding selection from the IPB root crop breeding project based on local germplasm. Several selected clones found their way into the hybridization scheme of PRCRTC as cross parent (Table 11). Some clones were unofficially released for large planters in Mindanao and Visayas during 1980 and 1981 (Table 11). They are reportedly planted in hundreds of hectares in these areas now.

CM 323-52 comes from the M Col 22 x M Mex 50 cross. It is characterized by high harvest index, good plant type and good shape. It was first selected from the CM 323 population at CIAT-Palmira, yet, it was at Carimagua during the years when CBB, was controlled in the trial fields, that CM 323-52 showed outstanding performance (see CIAT Cassava Program Annual Report 1987) Report). It has since shown stable preformance in the predominantly rainforest climate of the Philippines.

Introductions of CIAT cassava hybrid seeds have been made periodically to the cassava breeding program of PRCRTC since 1982 (Table 12) and their capacity of systematically evaluating a large quantity of genotypes has been greatly enhanced (Table 13). In many trials selected CIAT clones showed highly promising results (Table 14, 15). The distinctive feature of the high yielding clones is their high harvest index.

Such clones as CM 323-52, M Col 1684 and CMC 40 have been actively crossed with local germplasm and the resulting hybrids are now in preliminary yield trials. Recent selections from seed introductions are also entering the hybridization scheme.

CIAT has been contributing hybrid seed populations to the cassava varietal improvement section of IPB, UPLB, since 1975 (Table 16). With the improvement in the evaluation schemes, those materials from later introductions are being evaluated in a more systematic manner (Table 17). Many promising selections were identified in the preliminary trials with cross numbers above CM 3000 (Table 18). Lakan 1 and Datu 1, selections from local varietal collection previously recommended by UPLB also seemed to have been well selected cultivars.

Until recently, cassava was a relatively minor crop, mainly consumed as human food in the Philippines. Cassava plantations have now been set up to supply raw material for starch factories. At present, the government is promoting cassava and sweet potato to replace the huge importations of maize for animal feed. The government cassava project also allocates a significant portion of total resources for development of cassava for human consumption due to the acute food shortages. Overall demand for new, high yielding cultivars, appears to be high.

Indonesia

CIAT's contribution to cassava hybrid seeds to the cassava varietal improvement section of CRIFC (Central Research Institute for Food Crops, Bogor) started as early as 1975. The capacity of CRIFC cassava program was constrained by the very limited resource allocated to cassava, thus germplasm transfer from CIAT to CRIFC has been sporadic (Table 19) and the resulting clones were not evaluated systematically (Table 20).

CRIFC's cassava program now carries out a major part of its varietal improvement work with P.T. Umas Jaya Farm, Lampung, Southern Sumatra, using resources of PTUJF, and this has made it possible to evaluate large CIAT seed populations in an organized fashion. All the clones evaluated in preliminary trials gave higher root yield than that of the leading local cultivar, Kretek (Table 20). Root dry matter content and harvest index of the selected clones were much higher than those of Kretek. The best selection from the earlier CRIFC breeding work based on local germplasm, M-31, also showed highly promising results.

Brawijaya University, Malang, East Java, is a relatively young university and has taken cassava as the major research commodity of the Faculty of Agriculture. CIAT has been helping them train the research personnel and contributed germplasm materials. Its cassava breeding section now includes F_1 seedling, single-row, and preliminary trials.

Cassava is produced with a wide variety of cultural practice under a wide a range of environmental conditions in Indonesia. Eventually, (after a variety of processing methods) nearly all cassava is consumed by people. Where cassava is produced on a large scale for starch production, production cost is a vital factor and demand for higher yielding clones is strong. M-31 is rapidly replacing old cultivars and new CIAT selections are being intensively multiplied in a large

plantation. In Java, where cassava is produced by small farmers mainly for self-consumption or cottage industry, the demand for high yielding cultivars is not clearly understood. Yet, land in Java is very limited and agriculture, therefore, is extremely intensive. High yielding cultivars would provide an additional alternative in these tightly packed production systems.

China

Our contact with the cassava research team at SCATC (South China Academy of Tropical Crops) Hainan, started in 1982 and CIAT has contributed hybrid seeds on several occasions (Table 22). With CIAT's cooperation their varietal evaluation scheme is rapidly building up and materials are being evaluated in an organized manner (Table 23).

Some selection from the earlier introductions showed similar, or slightly higher yielding capacity, than the local cultivar South China 205 in a preliminary trial (Table 24). S.C. 205 is a selection from the local germplasm. It is characterized by a high harvest index and good plant type. Its successful adaptation to sub-tropical conditions with three months of winter, seems not to be rendered by tolerance to cold temperature per se, but rather by its ability to give good root bulking before the onset of winter. Since S.C. 205 is endowed with a high harvest index and is well adapted to the local environment, rapid, spectacular yield improvement by breeding can not be expected.

Cassava is grown mainly for hog feeding and starch production in the southern states of Guangdong and Guangsi. As the structure of agricultural production is changing rapidly, and the hog and poultry production is coming increasingly to private hands, it is difficult to predict what the future structure of cassava production and its demand would be. Yet, the agricultural production in China is basically extremely intensive, thus, even a modest improvement in production efficiency would have a chance of immediate adoption. Demand for new higher yielding clones seems to be substantial.

Malaysia

Cassava seed introduction to the cassava varietal improvement section of MARDI started in 1975 (Table 24). It was discontinued after 1982 because of the MARDI's decision that they had introduced sufficient germplasm variability for the limited importance of cassava in their national economy. It was recently resumed with hybrid seeds from crosses between Malaysian and CIAT germplasm. The CIAT hybridization section produces hybrids with the Malaysian leading cultivar, Black Twigg, which rarely flowered under MARDI, Malaysian conditions. Though small in size, the cassava varietal improvement program of MARDI is well organized and functional, thus, the introduced germplasm has been evaluated in an organized fashion (Table 26).

Black Twigg is well adapted to local conditions, having good plant type and a moderately high harvest index. Selected CIAT clones occasionally showed yield superiority over Black Twigg, however, the difference was not large. In many other trials, selected CIAT clones did not yield significantly more than Black Twigg and in some others, no CIAT clone outyielded Black Twigg. Cassava is a minor crop in Malaysia,

thus, new clones must demonstrate a spectacular yield superiority over the currently available cultivar, Black Twigg, to be introduced. Although promising genotypes are emerging, the results so far obtained are not highly convincing.

Overview on CIAT cassava breeding materials in Asia

Summarizing the results of numerous yield trials in the past, the average root dry yield of the top five CIAT selections was compared with those of the local cultivar(s) in each trial to appraise the superiority (or inferiority) of selected CIAT clones relative to leading local cultivar(s). An average score of 150% indicates an immediate and excellent opportunity for selecting new, high yielding cultivar(s); 120-150% suggests good possibilities, 100-120% suggests some opportunity for selection; while less than 100% indicates little or no hope.

In Thailand, the analyses suggest that it will be difficult to select for much higher yielding clones for the early season planting, but for late season planting there are many very promising selections (Fig. 1 and 2). In the Philippines, CIAT genotypes offer magnificent selection opportunities (Fig. 3). In Indonesia, though the number of trials is too small to draw a general conclusion, selected CIAT genotypes are far superior to the current local cultivar(s) (Fig. 4). CIAT selections are showing some promise in China (Fig. 5). In Malaysia, however, CIAT genotypes so far selected seem not to be offering much opportunity for selection (Fig. 6). The superiority of CIAT clones over traditional cultivars in the Philippines and Indonesia, may be because traditional cultivars in these countries are low harvest index types adapted to traditional plantings of a few plants and not to new ways of planting cassava for commercial production.

Among major tropical food crops, cassava is unique in that, improving its harvest index is effective in improving economic yield not only under high but also low (poor soil fertility, long dry season) yielding environments. Selecting for higher harvest indexes was the main strategy of yield breeding in the early days of the CIAT cassava varietal improvement program. Experience in Asia endorse this, indicating that yield improvement through harvest index is effective, not only for the favorable growing conditions of experiment stations, but also for the limited-input conditions of the average farmers.

In many parts of Asia, as in the American tropics, traditional cultivars used for fresh consumption are adapted to small scale plantings, often in the backyard; major selection criteria are eating quality and yield per plant rather than yield per unit area. These cultivars (eg: Hanatee in Thailand, Golden Yellow in the Philippines and Kretek in Indonesia) are usually of low harvest index. When the need arises for more efficient genotypes for commercial production, new cultivars are usually obtained by improved harvest index. Rayong 1 in Thailand, Lakan in the Philippines, Kretek in Indonesia, South China 205 in China and Black Twigg in Malaysia belong to this category. Further increasing harvest index is not difficult, especially selecting from CIAT breeding materials, but it becomes increasingly difficult to maintain a suffficient leaf canopy and high harvest index occasionally

results in reduced total biological yield. These types of clones are usually well adapted to high yielding environments, but not to low yielding environments due to their deficient leaf canopy. Rayong 3 may belong to this category. CIAT's selection goal is to further improve harvest index while maintaining the same leaf canopy strength of traditional cultivars. This should eventually result in improved harvest index and total biological yield. This type of genotype, if realized, would give significantly higher yield than currently available cultivars, not only under high but also low yielding environments. New breeds of clones such as CMR 24- 63-43, seem to indicate that this ambitious goal may be attainable (Fig. 7).

Experience gained in the Asia program amply supports the view that Latin American germplasm in general, and CIAT hybrid seed populations in particular, are rich sources of genetic variability not only for yield, but also for disease and pest resistance or root characteristics. CIAT germplasm is offering high yielding potential for immediate varietal selection as well as other desirable characteristics to be utilized in the long term breeding endeavors of the Asian national programs.

Future projection

General summary on present achievement of our cooperation with Asian national programs and future projection is presented in Table 27.

Table 1. Development of cassava breeding programs in Asia

Country / Institution	Situation of Cassava Breeding program 1973	1986
Thailand		
Dept. Agr.	+	+++++
Kasetsart U.	0	+++
Philippines		
VISCA	0	+++
UPLB	+	++
Indonesia		
CRIFC	+	++
Brawijaya U.	0	+
China		
SCATC	+	++
Malaysia		
MARDI	0	+++
Sri Lanka		
CARI	0	+
India		
ICAR	+++	++++

0: Non-existent
+++++: Functioning in desired capacity

Table 2. CIAT cassava F_1 hybrid seeds distributed to Asian program.

Year / Country	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	Total
Thailand	900		6170	7720		3050	1400	7450	7900	8000	9300	8000	59890
Indonesia	900			700					4600		6000	4950	17150
Philippines	900			950			5100	4700	5500	2350	5000		24500
China								2300	6100		3500	1800	13700
Malaysia	900		1500			2050	1250	4050				200	9950
India	900			850					1050	7900			10700
Vietnam									1900				1900
Rep.China(Taiwan)	500							1200					1700
Total	5000		7670	10220		5100	7750	19700	27050	18250	23800	14950	139490

Table 3. CIAT cassava hybrid seeds supplied to the cassava varietal improvement program, Department of Agriculture, Thailand.

Year	No.seeds	No.crosses	Principal cross no.	Principal parents
1975	800	16	CM 305 CM 407	M Col 22 M Col 113 M Mex 55
1977	5300	120	Crosses made by Charn T. at CIAT	M Col 1684 M Mex 17 M Ven 218
1978	5400	95	Crosses made by Somsak at CIAT	M Col 1684 M Ven 218 CM 309-41
1980	3050	42	CM 1442 - CM 2516	M Ven 62 CM 430-51 CM 516-6
1981	1400	28	CM 2450 - CM 3305	CM 520-5 CM 523-7 CM 727-14
1982	7450	128	CM 2515 - CM 4234	M Bra 12 CM 517-1 CM 523-7 CM 1103-7
1983	7900	153	CM 2784 - CM 4284	M Pan 51 CM 342-170 CM 681-2 CM 849-1 CM 1015-19
1984	6650	133	CM 3965 - CM 5124 SM 302 - SM 493 Some CG and SG	M Col 1823 M Col 2207 CM 681-2 CM 922-2 CM 1559-5
1985	6150	123	CM 3322 - CM 5834 SM 315 - SM 615 SG 563 - SG 831	M Bra 12 M Cub 31 CM 1983-2 CM 847-11
1986	8000			

Table 4. Utilization of CIAT seed introduction by the cassava varietal improvement program, Department of Agriculture, Thailand during the past ten years. Schematic presentation by number of genotypes.

	75/76	76/77	77/78	78/79	79/80	80/81	81/82	82/83	83/84	84/85	85/86	86/87
Seed introduction No.seeds(No.crosses)	800 (16)		5300 (120)	5400 (95)		3050 (42)	1400 (28)	7450 (128)	7900 (158)	6650 (133)	6150 (123)	8000
Seedling selection									5816	5377	3642	4598
Single-row trial									419	1237	568	370
Preliminary trial									22	62	69	52
Advanced trial											16	10
Regional trial									6			4
On-farm trial									2	2		
On farm test										2		
Multiplication									1			
Varietal recommendation									1 (Rayong 3)	1 (Rayong 2)		

Table 5. Selection of cross parents for hybridization from CIAT germplasm by the cassava varietal improvement program, Department of Agriculture, Thailand. Schematic presentation by number of genotypes.

	75/76	76/77	77/78	78/79	79/80	80/81	81/82	82/83	83/84	84/85	85/86	86/87
Seed introduction (No. seeds)	800		5300	5400		3050	1400	7450	7900	6650	6150	8000
Clonal introduction			10							6		
Evaluation at Rayong												
Incorporation into hybridization				6	15	15	15	12	10	30	30	30

Table 6. Results of Regional Trials 1985/86 - 1st season planting, Thailand.

Clone	Parents	Root dry yield (t/ha) Location								Root dry matter content Average	H.I. (Average)
		Rayong	Banmai	Khon-Kaen	Mahasa-kharm	Kala-sin	Roi et	Sriracha(KU)	Average		
CMR 24-14-266	R3 x R1	8.5	13.9	10.5	14.1	11.2	14.5	10.4	11.9	33.2	.68
CMR 24-14-1038	R3 x R1	8.5	12.2	10.7	12.1	11.2	11.6	9.3	10.8	33.3	.63
Rayong 3	M Mex 55 x M Ven 307	8.5	9.8	9.6	12.7	12.6	12.4	9.3	10.7	34.3	.66
CMR 24-07-12	CM 305-15	10.4	10.9	11.5	10.2	12.4	7.7	10.5	10.5	31.0	.67
CMR 24-89-65	R1 x M Col 1684	8.2	13.9	7.5	11.4	11.2	14.1	7.2	10.5	31.1	.62
Rayong 1		7.0	11.6	8.5	13.4	11.4	13.0	8.8	10.5	31.7	.52
CMR 24-14-532	R3 x R1	8.8	12.0	9.4	13.5	12.5	9.3	7.3	10.4	33.6	.63
CMK 24-23-4	CM 309-211 x R1	9.5	11.4	8.2	11.5	7.3	12.2	8.0	9.7	31.0	.67

Table 7. Result of Advanced Trials, 1985/86 - 1st season planting, Thailand.

Clone	Parents	Root dry yield (t/ha) Location				Root dry matter content (Average)	H.I. (Average)
		Rayong	Banmai	Khon Kaen	Average		
CM 3299-15	CM 849-1 x M Col 22	7.2	14.4	6.9	9.5	32.4	.54
CMR 25-34-159	R 3 x M Col 1684	6.8	13.1	7.4	9.1	30.4	.58
M KU 2-151	M Col 113 x M Col 22	6.3	13.0	8.1	9.1	31.7	.56
CMR 25-32-532Q	(V1 x R)20-15 x R 3	6.1	13.7	6.5	8.8	34.5	.55
CM 3281-11	M Bra 12 x M Col 22	5.3	13.4	7.6	8.8	31.3	.57
CMR 25-33-134	R 3 x R 1	7.9	10.4	6.0	8.1	34.9	.50
Rayong 1		5.0	9.3	7.9	7.4	31.3	.49
Rayong 3	M Mex 55 x M Ven 307	7.7	8.4	4.6	6.9	35.8	.58

Table 8. Result of preliminary trial, 1985/86 - 1st season planting, Rayong, Thailand

Clone	Parents	Root dry yield (t/ha)	Root dry matter content(%)	H.I.
OMR 26-07-15	(V1 x R)20-20	11.5	35	.72
CMR 26-65-13	R3 x M Col 22	9.6	35	.66
CMR 26-38-7	V25 x R3	9.1	37	.68
CMR 26-08-61	CMC 76 x R1	8.9	32	.66
OMR 26-14-9	M Col 22	8.7	35	.68
CMR 26-03-159	CM 305-15 x R1	8.6	34	.63
OMR 26-18-161	R2	8.6	35	.70
CMR 26-13-17	V25 x R1	8.2	32	.62
CM 3511-5	CM 825-3 x M Col 22	7.9	34	.57
CMR 26-65-75	R3 x M Col 22	7.9	33	.61
Rayong 3	M Mex 55 x M Ven 307	7.9	37	.69
OMR 26-18-95	R2	7.8	34	.70
CM 4146-96	CM 586-1 x M Ven 131	7.4	33	.61
CM 3862-15	CM 1278-7 x CM 586-1	7.3	34	.61
CM 4054-36	CM 1015-34 x CM 849-1	7.3	34	.62
CMR 26-82-54	R3 x M Col 1684	7.3	33	.55
CMR 26-03-184	CM 305-15 x R1	7.2	33	.55
CMR 26-79-77	CM 305-15 x M Col 1684	7.2	31	.50
OMR 26-11-24	CM 378-26	7.2	34	.60
OMR 26-07-25	(V1 x R)20-20	7.1	33	.67
CMR 26-69-136	CMC 76 x M Col 22	7.0	34	.62
Rayong 1		6.5	33	.58

Table 9. Result of on-farm trials, 1985/86 - 2nd season planting, Thailand.

Clone	Parents	Root dry yield (t/ha) Location					Root dry matter content(%) (Average)	H.I. (Rayong)
		Rayong	Satahip	Huay Pong	New Road	X		
CMR 24-63-43	M Col 1684 x R1	12.4	7.6	6.8	7.9	8.7	32.5	.74
Rayong 3	M Mex 55 x M Ven 307	14.0	4.6	5.0	6.6	7.6	36.7	.72
CMR 24-14-1308	R3 x R1	10.4	5.2	6.1	6.4	7.0	33.4	.63
CMR 24-78-1	Hanatee x CM 305-15	10.5	3.2	5.8	6.3	6.5	33.1	.62
CMR 24-14-183	R3 x R1	8.6	5.1	4.7	5.7	6.0	34.0	.72
Rayong 1		7.3	4.5	5.6	4.4	5.4	31.6	.58

Table 10. Result of advanced trials, 2nd season planting, Thailand.

Clone	Parents	Root dry yield (t/ha) Location A	B	C	X	Root dry matter content(%) (Average)	H.I. (Average)
CMR 25-105-112	27-77-10 x R3	16.9	9.7	6.7	11.1	35.1	.67
CMR 25-82-88	CM 309-211 x CM 305-13	20.0	5.9	6.2	10.7	35.5	.66
CMR 2502-4	M Ven 142 x M Col 1684	18.4	6.7	5.6	10.2	31.4	.67
CMR 25-105-47	27-77-10 x R3	17.1	6.7	6.7	10.2	35.6	.58
Rayong 3	M Mex 55 x M Ven 307	17.5	6.2	4.9	9.5	35.6	.62
CMR 25-33-105	R3 x R1	15.4	7.5	5.1	9.3	35.2	.59
CMR 25-106-26	M Col 22 x M Col 1684	16.9	6.9	3.7	9.2	34.0	.65
Rayong 1		10.7	5.8	3.1	6.5	33.9	.48

A: Rayong Station, 1984/85 (12 months)
B: Rayong Station, 1985/86 (10 months)
C: Huay Pong, 1985/86 (10 months)

Table 11. Utilization of CIAT clonal introduction by various institutions in Philippines.

Year / Utilization step	1978/79	79/80	80/81	81/82	82/83	83/84	84/85	85/86	86/87
Clonal introduction	12 (SEARCA/CIAT)						15 (PRCRTC)	14 (UPLB)	
Evaluation/ Multiplication		12 (SEARCA/CIAT)	12 (SEARCA/CIAT)					7	4
Regional trial				10 (UPLB)	10 (UPLB)	5 (Philippines seed Board)	5 (PSB)	5 (PSB)	2
Hybridization						6 (PRCRTC)	4 (PRCRTC)	4 (PRCRTC)	6 (PRCRTC)
Release			Unofficial CMC 40 CMC 84 HMC 4	Unofficial M COL 1684 CM 305-38 CM 308-197 CM 323-52					CM 323-52

Table 12. CIAT cassava hybrid seeds supplied to PRCRTC, VISCA Philippines.

Date	No.seeds	No.crosses	Principal cross no.	Principal parents
Aug 1976	250	5	CM 585 CM 690	M Mex 55 M Col 638
Jan 1982	2200	43	CM 2450 CM 3320 CM 3504 CM 3816	M Col 22 CM 342-170 CM 523-7 CM 586-1
Nov 1982	5550	100	CM 3341 CM 4011 CM 4049 CM 4234	CM 681-2 CM 849-1 CM 922-2 CM 1015-19
Jan 1985	2800	56	CM 4397 CM 5371 SM 306 SM 418	M Bra 12 CM 942-14 CM 1335-4 CM 1523-19
Oct 1985	3000	60	SM 457 - SM 598	M Bra 35 CM 681-2 CM 2452-5 M Tal 1

Table 13. Utilization of CIAT seed introduction by the cassava varietal improvement program, PRCRTC, VISCA, Philippines. Schematic presentation by number of genotypes.

Year / Evaluation step	1976/77	77/78	78/79	79/80	80/81	81/82	82/83	83/84	84/85	85/86	86/87
Seed introduction No. seeds No. crosses	250 (5)					2200 (43)	5500 (100)		2800 (56)	3000 (60)	
Seedling selection		?							2105		1200
Single-row trial							418	319		294	
Preliminary trial								119	147 →	29	62
Advanced trial									24 →	8	13
Regional trial											4

Table 14. Result of advanced yield trial at PRCRTC, VISCA, Philippines

Planting 26 July 1985
Harvest 11 June 1986

Clone	Parents	Root dry yield (t/Ha)	Root dry matter content(%)	H.I.
CM 3504-8	CM 728-2 x CM 523-7	12.0	39	.66
CM 3590-1	CM 859-12 x M Col 22	11.0	37	.63
CM 323-52	M Col 22 x M Mex 59	10.4	34	.63
CM 3320-11	M Bra 12 x CM 523-7	9.4	36	.54
CM 3340-3	CM 342-170 x CM 586-1	8.9	32	.63
M Col 1684		8.1	30	.62
CM 3422-3	CM 630-122 x CM 728-2	6.6	33	.64
CM 3341-4	CM 342-170 x CM 523-7	5.7	31	.61
CMC 40		5.7	30	.56
CM 3380-30	CM 586-1 x CM 523-7	5.1	35	.54
Golden Yellow (Local control)		4.8	35	.38
CM 3816-4	CM 1191-9 x CM 523-7	4.4	34	.50

Table 15. Result of preliminary yield trial at PRCRTC, VISCA, Philippines

Planting 25 July 1985
Harvest 12 June 1986

Clone	Parents	Root dry yield (t/Ha)	Root dry matter content(%)	H.I.
CM 4066-1	CM 1016-6 x CM 922-2	8.0	34	.67
CM 4050-1	CM 1015-19 x CM 922-2	7.4	31	.69
CM 4054-3	CM 1015-34 x CM 849-1	7.3	32	.70
CM 4063-6	CM 1015-42 x CM 849-1	7.3	34	.60
CM 4011-5	CM 728-2 x CM 681-2	7.2	31	.69
CM 4050-7	CM 1015-19 x CM 922-2	7.1	32	.68
CM 3309-4	M Col 22 x CM 728-2	6.9	29	.68
CM 4049-8	CM 1015-19 x CM 849-1	6.9	35	.66
CM 4049-1	CM 1015-19 x CM 849-1	6.2	33	.58
CM 4012-11	CM 728-2 x CM 849-1	6.0	31	.74
CM 4014-3	CM 728-3 x CM 681-2	5.8	31	.73
CM 3998-3	CM 681-2 x CM 922-2	5.7	37	.63
Java Brown (Local control)		5.5	31	.49
CM 4012-18	CM 728-2 x CM 849-1	5.1	29	.67
CM 3341-105	CM 342-170 x CM 523-7	5.0	29	.70
CM 4039-7	CM 950-3 x CM 922-2	5.0	32	.66
CM 3997-8	CM 681-2 x CM 849-1	4.9	34	.66
CM 3986-12	CM 621-88 x CM 849-1	4.8	28	.68
CM 4052-7	CM 1015-34 x CM 91-3	4.8	32	.66
CM 4107-1	M Col 1515 x CM 681-2	4.7	30	.65
CM 4039-3	CM 950-3 x CM 922-2	4.6	29	.70
CM 4050-8	CM 1015-19 x CM 922-2	4.5	32	.64
CM 4047-22	CM 1015-19 c CM 91-3	4.3	30	.63
CM 4234-10	CM 982-20 x MCR2	4.2	28	.67
CM 3974-10	CM 342-170 x CM 922-2	4.1	32	.56
CM 4005-10	CM 727-38 x M Pan 51	4.0	30	.66
CM 4011-1	CM 728-2 x CM 681-2	3.7	29	.65
CM 4044-2	CM 1015-13 x CM 849-1	3.7	33	.62
CM 4005-12	CM 727-38 x M Pan 51	3.5	31	.57
Golden Yellow (Local control)		3.2	31	.49
CM 4049-5	CM 1015-19 x CM 849-1	3.2	30	.62

Table 16. CIAT cassava hybrid seeds supplied to IPB, UPLB, root crop breeding program, Philippines.

Date	No. seeds	No. crosses	Principal cross no.	Principal parents
Feb 1975	900	18	CM 305 CM 378 SM 61	M Col 22 M Col 113 M Mex 1
May 1977	950	19	CM 692 CM 791 CM 825	M Col 638 M Col 1684
Jan 1981	1400	28	CM 2098 - CM 3248	M Col 1515 M Col 1684 M Ven 77
Jan 1981	1050	21	CM 2450 - CM 3304	CM 520-5 CM 523-7 CM 727-14
Mar 1982	2500	50	CM 2527 - CM 3906	M Ven 77 M Bra 12 CM 342-170 CM 523-7
Sept 1984	2350	38	CM 3433 - CM 4238	CM 681-2 CM 849-1 CM 922-2 CM 1015
Oct 1985	2000	40	SM 425 - SM 520	M Bra 5 CM 507-37 CM 681-2 CM 2088-1

Table 17. Utilization of CIAT seed introductions by the cassava varietal improvement program, Institute of Plant Breeding, UPLB, Philippines. Schematic presentation by number of genotypes.

Year / Evaluation step	1975/76	76/77	77/78	78/79	79/80	80/81	81/82	82/83	83/84	84/85	85/86	86/87
Seed introduction No. seeds (No. crosses)	900 (18)		950 (19)			1400 (28)	1050 (21)	2500 (50)		2350 (38)	2000 (40)	
Seedling selection										1208		353
Single-row trial			?	?	?	?	?	?			155	
Preliminary trial										53	45	64
Advance trial									20	14	8	21
Regional trial												

Table 18. Result of 2nd Preliminary Yield Trial at IPB, UPLB, Philippines.

Planted 8 May 1985
Harvested 31 Mar 1986

Clone	Parents	Dry yield (t/ha)	Fresh yield (t/ha)	Root dry matter content(%)
CM 3380-2	CM 586-1 x CM 523-7	17.9	45.5	39.4
CM 3895-3	CM 1307-3 x CM 586-1	16.0	38.8	41.3
CM 3665-1	CM 1011-4 x M Col 22	15.0	36.8	40.7
CM 3732-1	CM 1103-7 x CM 728-2	13.3	35.6	37.3
CM 3897-2	CM 1320-1 x M Col 22	12.1	33.9	35.8
CM 3895-5	CM 1307-3 x CM 586-1	11.3	31.2	36.2
CM 3745-2	CM 1105-28 x CM 728-2	11.1	25.8	43.0
CM 3263-1	CM 621-214 x CM 523-7	10.6	26.1	40.6
G 50-3	(Control - IPB Selection)	10.1	29.9	33.7
CM 3422-2	CM 630-122 x CM 728-2	9.9	27.1	36.6
Lakan 1	(Control - recommended cult.)	9.7	24.5	39.6
CM 3374-2	CM 517-1 x CM 841-58	9.6	22.7	42.3
CM 2975-2	CM 1252-12 x CM 523-7	9.5	25.0	38.1
CM 3270-1	CM 727-38 x CM 91-3	9.4	24.4	38.5
CM 3304-1	CM 1130-2 x M Col 22	9.0	21.9	40.9
CM 3745-6	CM 1105-28 x CM 728-2	8.9	26.0	34.3
CM 3675-7	CM 1015-34 x CM 523-7	8.8	25.0	35.3
CM 3297-5	CM 848-4 x M Col 22	7.3	19.6	37.0
CM 3297-7	CM 848-4 x M Col 22	6.8	16.8	40.5
CM 3308-2	M Col 22 x CM 586-1	5.5	13.6	40.1
CM 3297-1	CM 848-4 x M Col 22	4.2	11.8	35.9

Table 19. CIAT cassava hybrid seeds supplied to CRIFC, Bogor, Indonesia.

Date	No.seeds	No.crosses	Principal cross no.	Principal parents
Feb 1975	850	17	CM 305 CM 407 CM 690	M Col 22 M Col 113 M Col 638
May 1978	700	14	CM 1006 CM 1305 CM 1371 CM 1405	M Col 1684 CM 323-142 CM 462-1 CM 499-49
Jun 1983	4600	80	CM 3341 CM 3993 CM 4031 CM 4049 CM 4063	CM 523-7 CM 681-2 CM 849-1 CM 922-2 CM 1015-19
Oct 1985	3000	20	SM 446 - SM 598	M Bra 35 CM 682-2 CM 2174-7 M Tai 1
Feb 1986	2000(from CIAT)	50	SM 443 CM 521	CM 955-2 CM 996-6
	2950(from Thai/ CIAT)	73	CMR 28-97 OMR 28-45	(CM776 x V43)21-1 CMR 23-149-128

Table 20. Utilization of CIAT seed introductions by the cassava varietal improvement program of CRIFC/P.T. Umas Jaya Farm, Indonesia. Schematic presentation by number of genotypes.

Year / Evaluation step	1975/76	76/77	77/78	78/79	79/80	80/81	81/82	82/83	83/84	84/85	85/86	86/87
Seed introduction No. Sseeds (No. crosses)	850 (17)			700 (14)				4600 (80)		3500 (20)	4950 (123) (PTUJ)	
Seedling selection		?							2600 (PTUJ)			2952 (PTUJ)
Single-row trial					?					574 (PTUJ)		
Preliminary trial						? →	20				97 (PTUJ)	
Advanced trial								2	2			31 (PYUJ)
Regional trial									2 ?	2 ?		

Table 21. Result of preliminary trial at P.T. Umas Jaya Farm, Lampung, Sumatra, Indonesia

		Harvested March 1986		
Clone	Parents	Root dry yield (t/ha)	Root dry matter content(%)	H.I.
CM 4013-3 UJF	CM 728-2 x CM 922-2	19.6	37.8	.63
CM 4013-8 UJF	CM 728-2 x CM 922-2	19.1	35.0	.73
CM 4049-7 UJF	CM 1015-19 x CM 849-1	19.1	38.2	.68
CM 4014-5 UJF	CM 728-3 x CM 681-2	18.5	35.7	.78
CM 3997-19 UJF	CM 681-2 x CM 849-1	18.2	37.7	.65
CM 3970-4 UJF	CM 342-170 x M Col 1684	17.5	37.0	.68
CM 3970-1 UJF	CM 342-170 x M Col 1684	17.3	37.6	.55
CM 4036-24 UJF	CM 1015-42 x CM 849-1	17.2	36.3	.72
CM 3433-6 UJF	CM 681-2 x CM 91-3	16.8	36.3	.73
CM 3967-2 UJF	M Bra 12 x CM 922-2	16.8	37.1	.65
CM 4058-9 UJF	CM 1015-42 x CM 180-5	16.8	36.7	.77
CM 4031-11 UJF	CM 922-2 x CM 507-37	16.6	33.7	.66
CM 4031-10 UJF	CM 922-2 x CM 507-37	16.3	39.2	.62
CM 3997-5 UJF	CM 681-2 x CM 849-1	16.1	35.3	
CM 3998-13 UJF	CM 681-2 x CM 922-2	16.0	40.0	.58
CM 4050-2 UJF	CM 1015-19 x CM 922-2	15.6	37.4	.71
CM 4049-2 UJF	CM 1015-19 x CM 849-1	15.5	37.2	.71
CM 3997-26 UJF	CM 681-2 x CM 849-1	15.4	37.6	.73
CM 4045-6 UJF	CM 1015-13 x CM 922-2	15.4	39.3	.70
CM 3504-9 UJF	CM 728-2 x CM 523-7	15.2	38.0	.72
CM 3433-5 UJF	CM 681-2 x CM 91-3	15.2	36.0	.71
CM 4051-4 UJF	CM 1015-34 x M Pan 51	15.2	36.3	.63
M-31 (CRIFC selection)		15.0	36.5	.62
CM 3993-28 UJF	CM 681-2 x M Col 1684	15.0	38.4	.70
CM 3341-2 UJF	CM 342-170 x CM 523-7	14.0	40.0	.51
CM 3380-10 UJF	CM 586-1 x CM 523-7	14.0	37.1	.63
CM 3341-9 UJF	CM 342-170 x CM 523-7	13.8	38.5	.67
CM 3997-7 UJF	CM 681-2 x CM 849-1	13.8	35.3	.64
CM 3959-5 UJF	M Col 22 x CM 180-5	13.8	36.5	.69
CM 3997-14 UJF	CM 681-2 x CM 849-1	13.6	35.1	.70
CM 4045-1 UJF	CM 1015-13 x CM 922-2	13.6	33.9	.73
CM 3341-13 UJF	CM 342-170 x CM 523-7	12.2	38.2	.68
Kretek (Local control)		9.3	33.0	.48

Table 22. CIAT cassava hybrid seeds supplied to SCATC, Hainan, China.

Date	No.seeds	No.crosses	Principal cross	Principal parents
June 1982	2300	38	CM 3281 - CM 4081	M Col 22 M Bra 12 CM 523-7 CM 849-1
Nov 1982	6100	100	CM 3009 - CM 4238 SG 504 - SG 709	CM 523-7 CM 681-2 CM 922-2 CM 1015-19
Oct 1985	2500	50	SM 465 - SM 616	M Bra 35 M Cub 65 CM 430-37 CM 2452-5

Table 23. Utilization of CIAT seed introductions by the cassava varietal improvement program, SCATC, Hainan, China. Schematic presentation by number of genotypes.

Year / Evaluation step	1981/82	82/83	83/84	84/85	85/86	86/87
Seed introduction No. seeds (No. crosses)	2300 (38)	6100 (100)			2500 (50)	
Seedling selection				2300	1200	
Single-row trial				30	232	
Preliminary trial					12	26
Advanced trial						3

Table 24. Result of preliminary yield trial at SCATC, Hainan, China

Harvested 21 Jan/86

Clone	Parents	Dry yield (t/ha)	Root dry matter cont (%)	H.I.
CM 4031-1	CM 922-2 x CM 507-37	11.6	35	.68
CM 3044-1	CM 1297-9 x CM 523-7	10.0	39	.61
South China 205	(local check)	9.9	35	.69
CM 3044-2	CM 1297-9 x CM 523-7	9.7	37	.60
CM 3505-1	CM 728-2 x CM 586-1	9.3	36	.60
CM 3380-1	CM 586-1 x CM 523-7	8.5	38	.63
CM 4034-1	CM 950-3 x CM 91-3	8.4	38	.55
CM 4198-1	CM 950-3 x M Fan 51	8.0	38	.63
South China 205	(local check)	7.7	36	.64
CM 4189-1	CM 942-14 x M Ven 131	7.2	39	.52
CM 3044-3	CM 1297-9 x CM 523-7	7.2	38	.57
CM 3422-1	CM 630-122 x CM 728-2	7.0	36	.55
CM 4054-1	CM 1015-34 x CM 849-1	6.5	37	.54

Table 25. CIAT cassava hybrid seeds supplied to MARDI breeding program, Malaysia.

Date	No. seeds	No. crosses	Principal cross no.	Principal parents
1. Feb. 1975	850	17	CM 305 CM 378 CM 429 SM 61	M Col 22 M Col 113 M Mex 1
2. May 1977	550	11	CM 621 CM 845 CM 942	M Col 638 M Col 1684 M Ven 270 CM 309-37
3. Sept. 1980	2050	40	CM 1442 CM 1794-CM 2525	M Col 1684 M Ven 77 CM 430-51 CM 516-6 CM 516-7 CM 517-1 CM 533-15
4. Jul. 1981	1250	25	CM 2674-CM 3303	CM 507-37 CM 523-7 CM 727-14 CM 825-3 CM 849-1
5. Mar. 1982	4050	80	CM 2778-CM 3906	M col 22 M Bra 12 CM 342-170 CM 523-7 CM 586-1 CM 621-167 CM 728-2 CM 849-1
6. Dec. 1986	(1500)			M Mal 2(Black Twigg)

Table 26. Ten years of cassava varietal improvement work at MARDI, Malaysia. Schematic presentation by number of genotypes.

	75/76	76/77	77/78	78/79	79/80	80/81	81/82	82/83	83/84	84/85	85/86	86/87
Seed introduction No. seeds (No. Crosses)	CIAT 1 850 (17)		CIAT 2 550 (11)			CIAT 3 2050 (40)	CIAT 4 1250 (25)	CIAT 5 4050 (80)				
Seedling selection									2511			
Single-row trial									336	854		
Preliminary trial									66	64	159	
Advanced trial										66	64	
Regional trial								12 13	12 13	10	4	
Multiplication/release											3 ? 1 ?	

Table 27. Expected accomplishment by Asian national programs through CIAT cooperation.

		Present achievement	5 years	10 years
Experimental Station	Research capability building	++	+++	++++
	Germplasm distribution	++++	++++	++++
	Germplasm evaluation and utilization	++	+++	++++
	Improved yield potential	+++	++++	+++++
	Improved resistance and genetic diversification	+	++	+++
	Improved cultural practice and better land usage	+	++	+++
	Better erosion control and soil nutrient preservation	+	++	+++
Production Field	Varietal release	+	++	+++
	Increased yield and lower production cost on farms	0	+	++
	Low-input, stable, safe, efficient production system on farms	0	0	+

0: No effect
+++++: Maximum expected

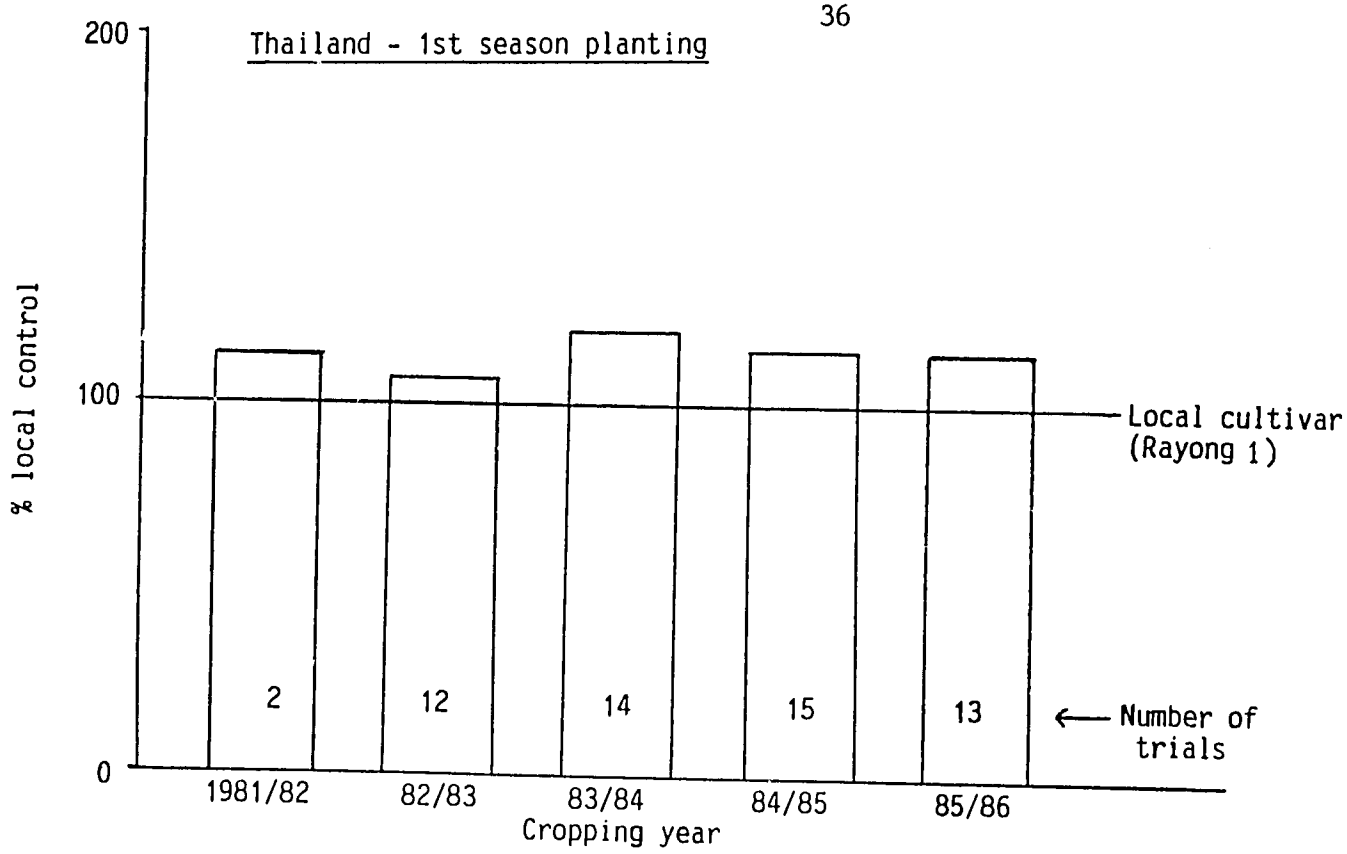


Fig. 1 Average root dry yield of five best clones (or upper 30% selection) in varietal yield trials relative to that of local control, 1st season planting, Thailand.

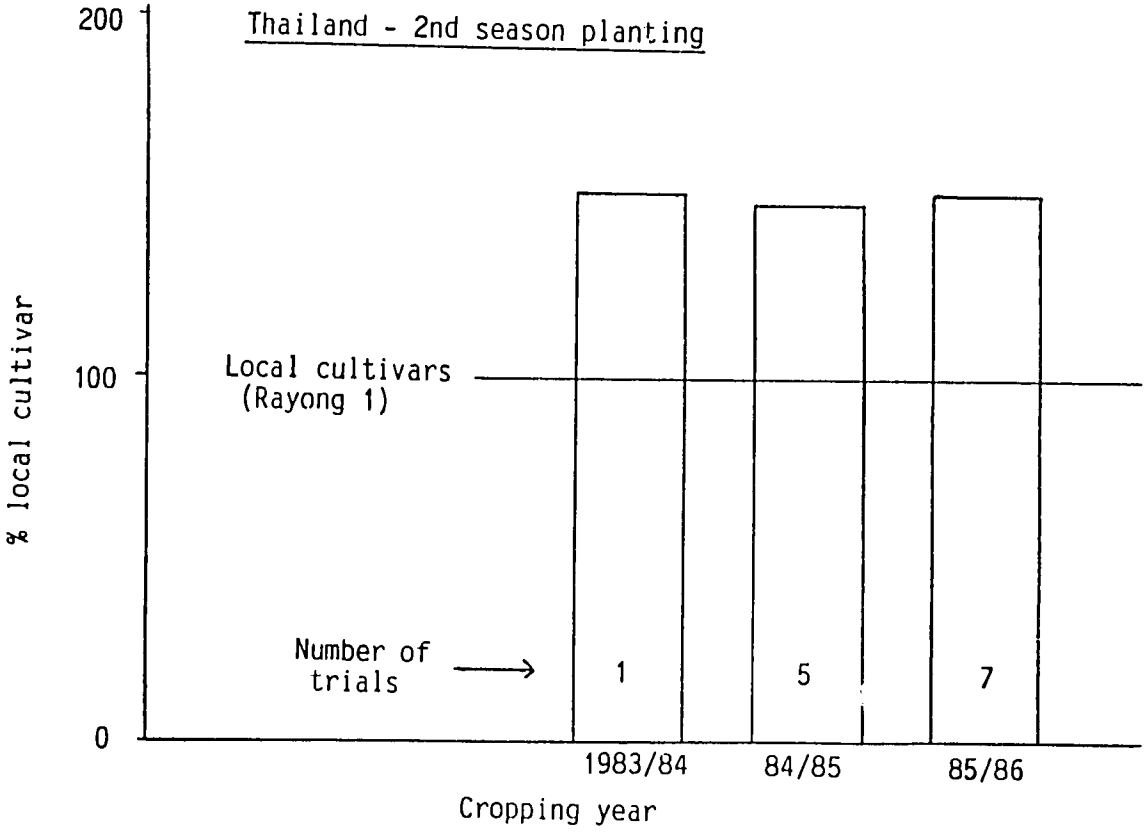


Fig. 2 Average root dry yield of five best clones (or 30% selection) in varietal yield trial relative to that of local control, 2nd season planting, Thailand.

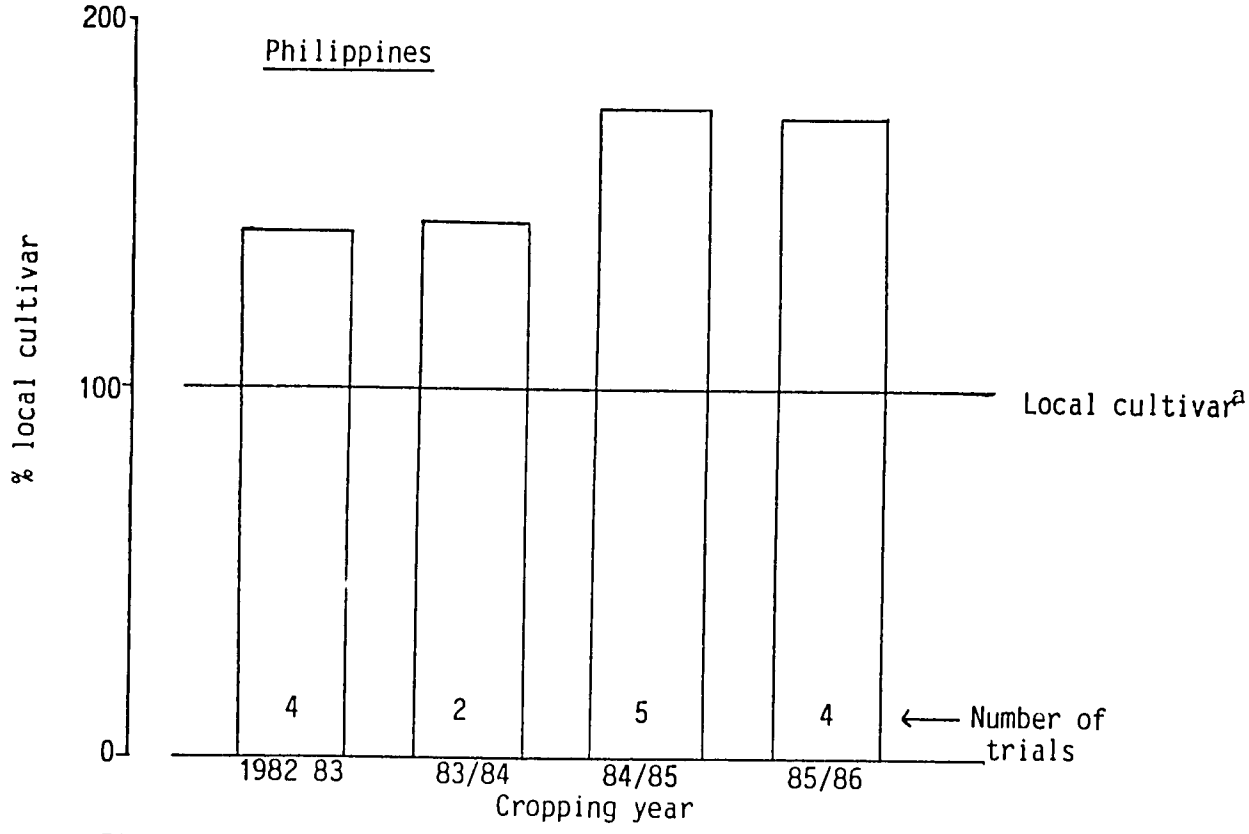


Fig. 3 Average root dry yield of five best clones (or 30% selection) in varietal yield trial relative to that of local control, Philippines.

[a]Golden Yellow, Kadabao and Java Brown

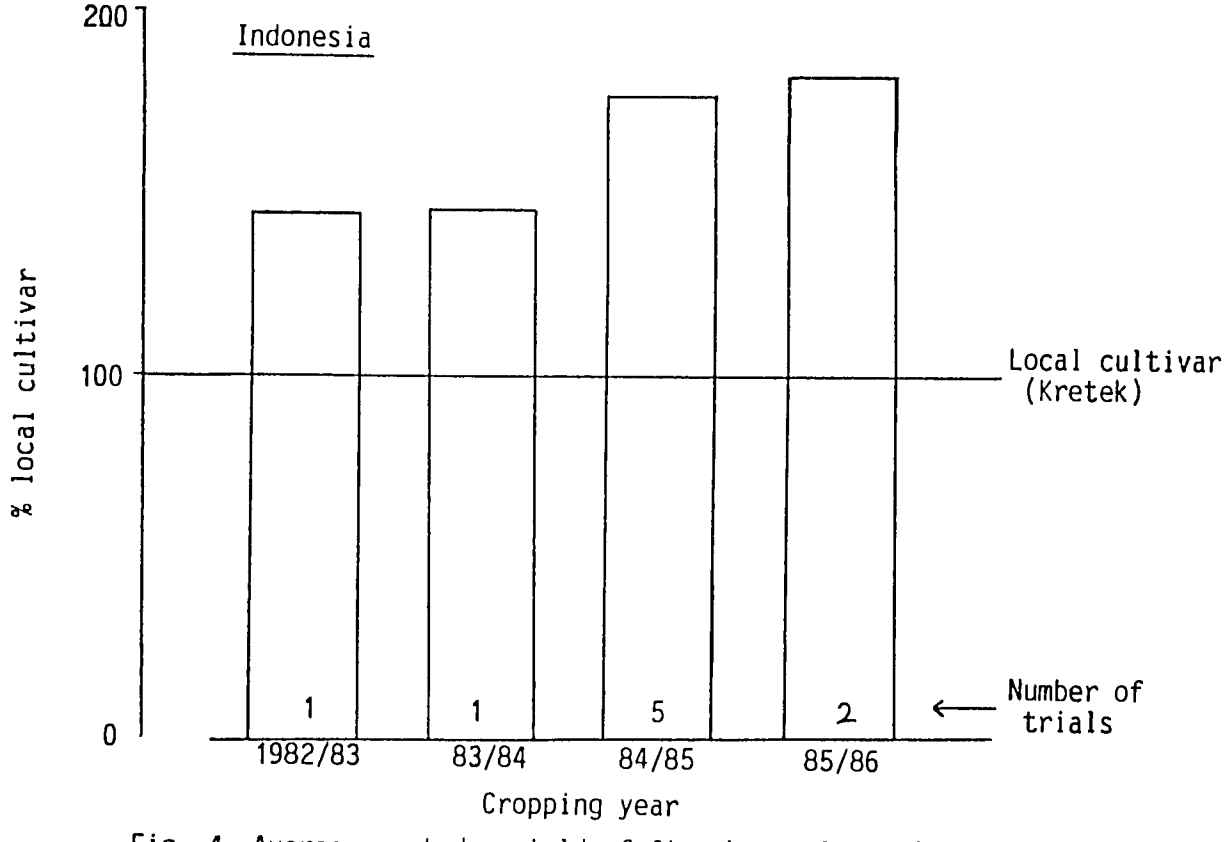


Fig. 4 Average root dry yield of five best clones (or 30% selection) in varietal yield trial relative to that of local control, Indonesia.

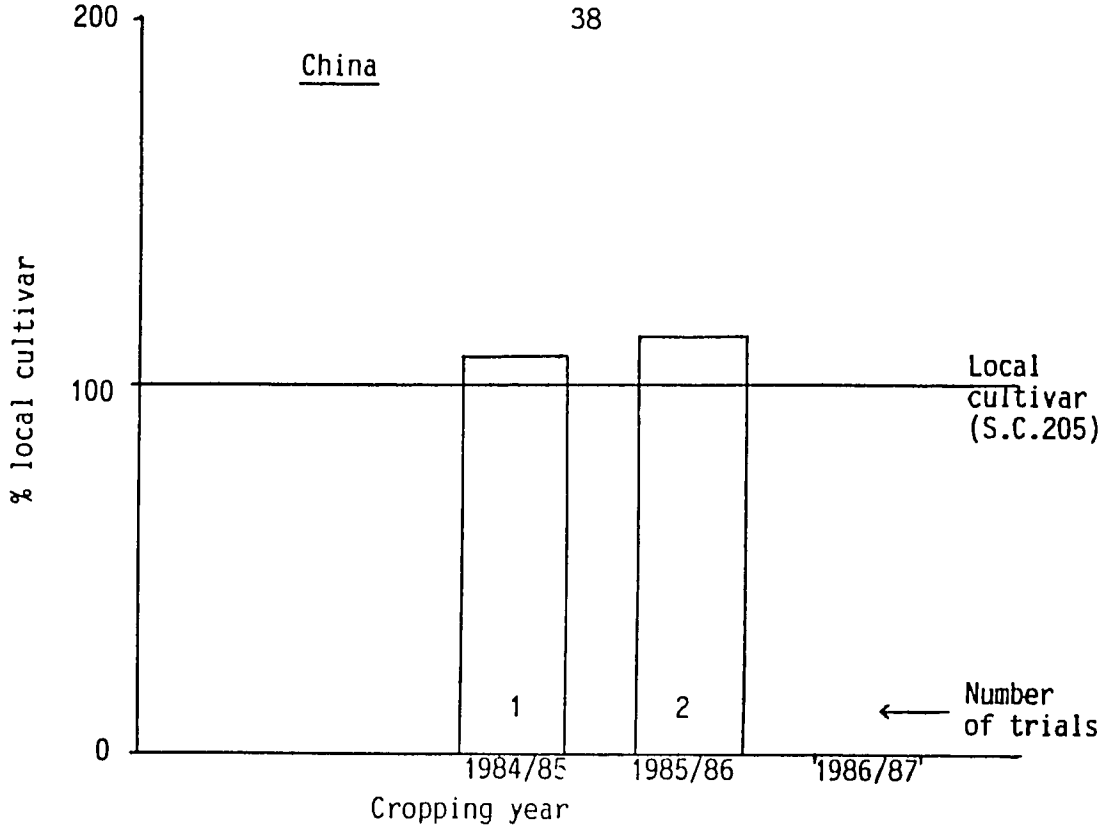


Fig. 5 Average root dry yield of five best clones (or 30% selection) in varietal yield trial relative to that of local control, 2nd season planting, China.

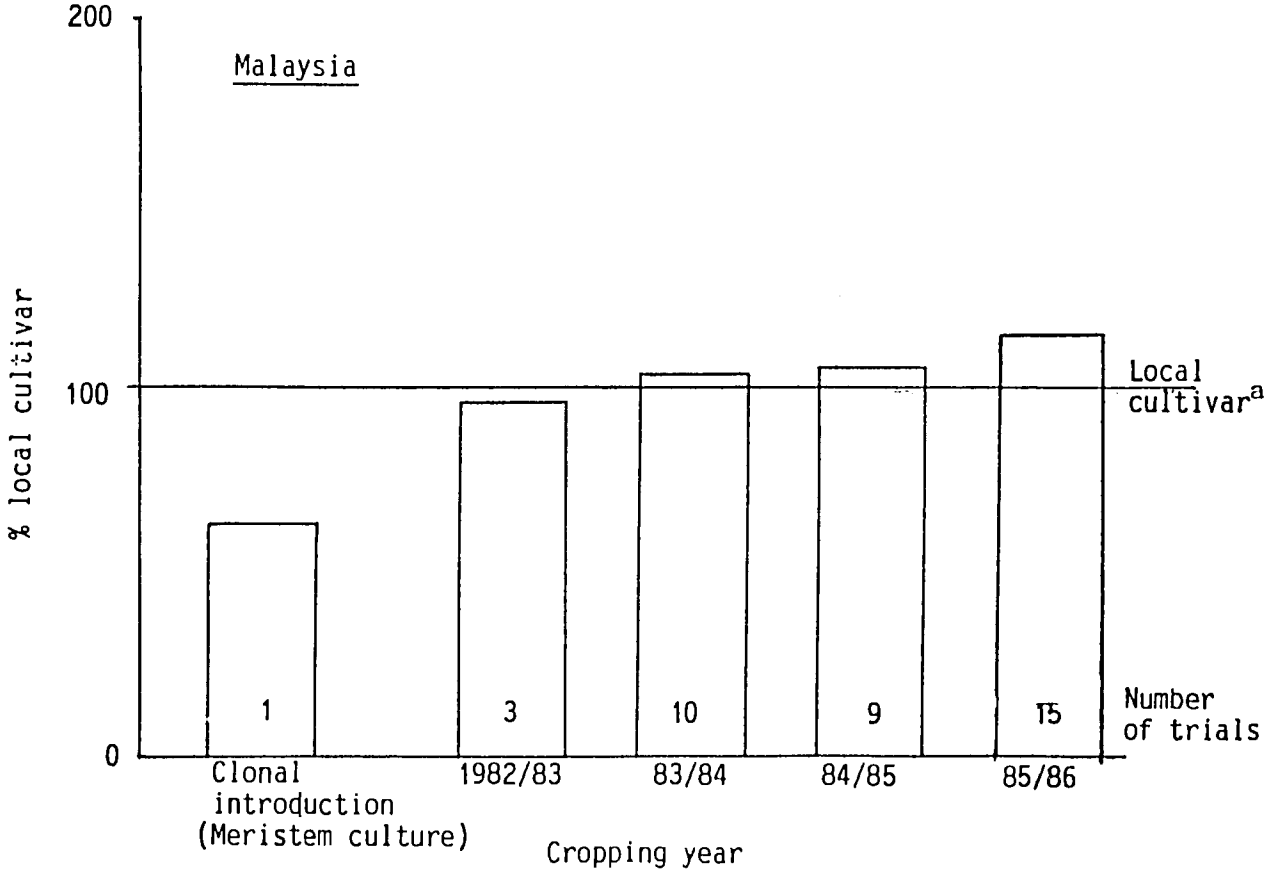


Fig. 6 Average root dry yield of five best clones (or 30% selection in varietal yield trial relative to that of local control, 2nd season planting, Malaysia.

[a] Black Twigg and CS.

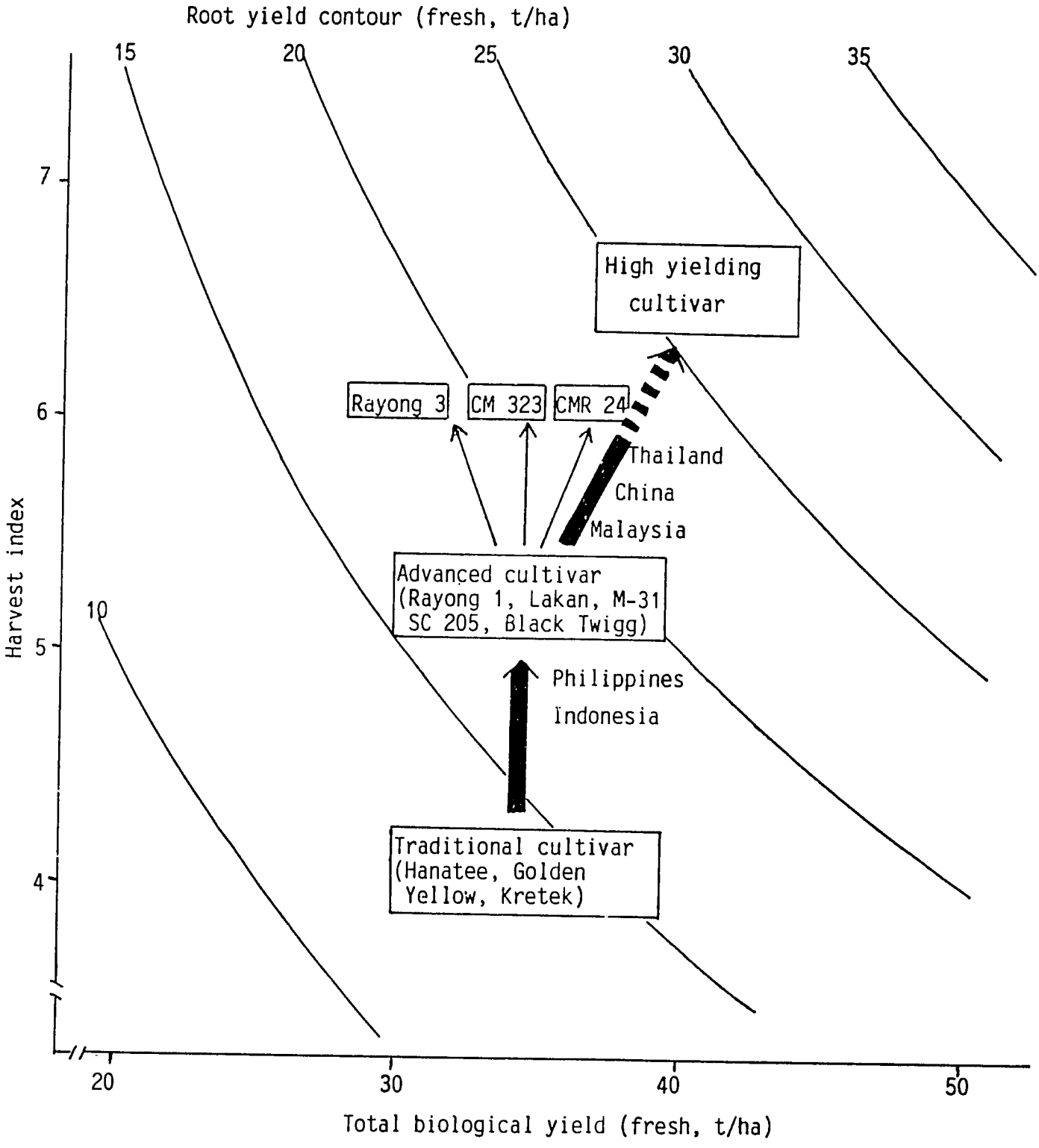


Fig. 7 Schematic presentation of root yield improvement by breeding for limited input growing conditions.

OUTREACH LATIN AMERICA

The outreach program in Latin America is based on the premise that cassava based development requires a very close integration of the production, processing and marketing of cassava. CIAT has gained considerable experience and developed methodologies in this area in the last few years. In describing the outreach efforts, it must be realised that it is impossible to separate the activities of CIAT per se, and that much of the effort is carried out by the national agencies themselves. Furthermore, many of the major achievements in this field are the rather difficult to define increases in national capacity to carry out effective develoment programs. In this report, a brief statement is made of the status of efforts in the various countries with which CIAT collaborates.

Colombia

Colombia, as the host country for CIAT, is an ideal test site for new technology and methodology. It was with this in mind that the first integrated cassava production and drying project was established in Colombia as described in previous CIAT Cassava Program Annual Reports. CIAT's role in this project has now greatly diminished as the national capacity to manage such projects has increased. However, at present there is a demand for new technology in the region to increase cassava production. CIAT's efforts this year have concentrated on assisting the national research program in its efforts to become more effective. CIAT has played a catalytic role in the organization of a group of researchers in the North Coast region. This group is dedicated to root crop research at the on farm level and has already met twice. The combined participation of the land reform agency, the Integrated Rural Development Program and the national research agency and CIAT has been used to organize research efforts. As a result a truly integrated research plan is being developed.

In addition, CIAT is providing the basic seed stock for the clean seed program that is being developed in the region.

Paraguay

Paraguay has the highest per capita cassava consumption in the Americas. The demand studies indicate that a further 90,000 ha of cassava will need to be grown by the year 2000 to meet the projected demand. Until recently Paraguayan officials paid little attention to cassava, however, declining yields in the traditional growing areas close to Asuncion led officials to seek CIAT's help in setting up an effective cassava program in the region. CIAT has assisted in the training of Paraguayan cassava research and extension agents and in the design of the natioanal program. Technical cooperation has been centered on the characterisation of the growing areas and the instigation of a survey of production systems that will serve as the basis for the diagnosis of the major production constraints. Coupled with this has been the development of trials on the farmers fields to test improved technology. Particular emphasis has been placed on systems that allow production to be sustained over time.

Over the longer term improved germplasm has an important role in this process and CIAT has assisted the Paraguayan program in the collection and evaluation of local germplasm.

Ecuador

In 1981, the National Research Institute, INIAP, requested CIAT's assistance in the establishment of research priorities in cassava. In the report to INIAP, it was indicated that the role of cassava in the country was very limited due to the support and subsidies to competing crops such as wheat and corn: unless these policies are modified there is little sense in establishing a concerted cassava research effort. As a result, the INIAP cassava program basically ceased to exist. Furthermore, in the unfavorable economic climate, the production of cassava declined. In 1985, substantial changes in the subsidy policies were made in Ecuador and a visit by CIAT indicated that cassava could enter into the animal feed industry. In late 1985, a CIAT post doctoral fellow with special project funding was sent to Ecuador to see if it was possible to establish a cassava drying industry in the province of Manabi, which produces about one quarter of the cassava in Ecuador. A series of support activities began immediatley with training of Ecuadorian staff and a survey of the production area and the production practices. A critical point was the feasability of drying cassava in the area which has heavy cloud cover during the long dry season. The Agroecological Studies Unit assisted in identifying the areas where drying should be possible and on the basis of this a drying trial was established and the feasability demonstrated. Two drying plants were set up by farmers associations and dried cassava was produced. In 1986, the industry was further expanded and there are now six operational plants. Certain marketing problems occurred as this was a very wet year leading to a record maize crop and low cereal grain prices. Further exploration of the Ecuadorian situation indicated that milled dry cassava could command a very high price in the expanding shrimp feed market due to its cohesive properties that reduce waste of the feed. The drying plants are now milling cassava and selling into this market. In addition, a large banana company expressed interest in using the CIAT technology for cassava preservation to export to the US. The farmers groups in Manabi were trained in the new technology and now select and treat the fresh cassava for sale to the banana company which is exporting several tons per week.

The INIAP program has now been revived and with CIAT help is setting up trials to test improved technology in the region.

Panama

In Panama the possibility of drying cassava for the animal feed industry was identified several years ago and the technical feasability was demonstrated in the pilot project established with a farmers group. In the past year, emphasis has been on the development of research capacity. A survey of production systems has been completed and analysed and a series of technology packages are being tested in the most important production area of the Llanos of Ocu. In addition, the channels for the testing and selection of improved varieties has been established. At present the development of a cassava drying industry

needs to be stimulated by a development rather than a research agency in Panama.

Mexico

The Mexican the government has expressed interest in the expansion of cassava production to replace sorghum in animal feed rations. Over the last few years a strong cassava research team has been established with assistance from CIAT . This has provided the technology for the ambitious production plans in the state of Tabasco. However, problems have however been identified in the implementation of the project due to difficulties in the coordination of the activities of the multiple agencies involved in the plan. CIAT is assisting the Mexicans in the analysis of the present organisational structure and needs of the producers, so that a more effective structure can be designed and implemented.

Cuba

Cuban officials who visted CIAT in the late seventies expressed an interest in transferring CIAT technology to Cuba to increase cassava production. The "Colombian System" was widely adopted in Cuba and total production on the island was doubled. At the same time, production costs per hectare were reduced by decreasing the number of irrigations and insecticide applications.

The Cuban program has been so effective in increasing production, that efforts are now focusing on the diversification of the use of cassava. CIAT is actively involved in assisting the Cubans in this process. The first step in this process will be the establishment of a cassava drying plant in Cuba early in 1987.

Brazil

Brazil is the largest cassava producer in the region. The national program has modeled its new decentralised strategy on that of the CIAT program. This involves the setting up of testing sites for new technology in the five different major ecosystems that have been identified in Brazil. The channels of germplasm flow in this system have now been established and CIAT lines are being tested effectively.

In the NE of Brazil, interest in developing a cassava drying industry has been shown and in 1986, the first in country course on cassava drying was held. Coupled with this effort, CIAT has cooperated in the formation of a network of different agencies working on improved production practices, with particular emphasis on crop protection. This network is based on the capacity developed in the region through cooperation and training over the last few years.

CIAT is, however, not content with its present role in Brazil and feels that its efforts should be reinforced by a permanent presence in that country.

DISTRIBUTION OF CASSAVA AMONGST DIFFERENT CLIMATE AND SOIL TYPES IN SOUTH AMERICA

A hierarchical classification of climate and soil conditions has been developed by the Agroecological Studies Unit (Fig. 1). The classification is based on the identification of some simple crop-environment relationships based on the experiences of members of the Cassava Program. Both soil and climate components of the classification have been used to produce a map of environmental homologues for cassava.

The production of this map has allowed the cassava program to:

1. Obtain an overview of the relative importance of the different climate-soil homologues.
2. Reconcile the former classification of cassava ecosystems (CIAT 1981, 1982) with the present study.

Cassava distribution among the climatic and soil homologues.

Table 1 gives the number of hectares of cassava grown in each of the climate and soil homologues. The homologues are identified by a letter (climate) and number (soil) system. The percentage of cassava by area in each climate and soil class is given in Tables 2 and 3.

Percentages of cassava given in Table 2 are for the lowest members of each branch of the classification dendrogram (Figure 1). These data can be aggregated for each of the different levels of the classification, depending on the requirements of the user. For example, the data indicate that about 77 percent of the cassava, is grown in lowland conditions (mean growing season temperatures above 22C) and 23 percent in highland conditions (mean growing season temperatures). A similar calculation could be made for length of dry season, daily temperature ranges and seasonality.

If we examine the individual climatic classes, there are only seven which have more than five percent of the cassava each. Between them they account for 87.3 percent.

The class in which most cassava is grown is "Lowland humid subtropical" with 21.7 percent. This includes areas like Eastern Paraguay, and much of the Parana basin in Brazil. The second most important homologue is "Lowland semihot isothermic" with 19.7 percent. This includes areas like Eastern Paraguay, much of the Parana basin in Brazil, most of Colombia's North Coast, parts of coastal Ecuador and Venezuela, and the "litoral" of North-East Brazil. Following this in importance is the "Lowland humid tropical" class (15.3 percent), which represents much of the Amazon Basin, Colombian Choco and middle Magdalena, and part of the Ecuadorian coastal lowlands. Fourth is "Lowland hot isothermic" (10.7 percent). This includes the Colombian and Venezuelan Llanos, the Bolivian savannas, and much of Maranhao and Piaui in Brazil. Fifth is "lowland semi-arid isothermic" (7.9 percent), which includes Western Manabi (Ecuador), parts of coastal Venezuela and much of North-East Brazil. Sixth is "Highland semi-arid isothermic", mainly in North-East Brazil, and one or two areas in

coastal Venezuela (6.4 percent). Seventh is "Highland humid tropical" (5.6 percent) which is mainly restricted to Andean Colombia and the Piedmont to the East of the Peruvian Andes. The remaining classes have no more than 3 percent of the cassava each. One class, "highland semi-arid non-isothermic", has little or no cassava (it is only represented by two small areas in Brazil).

Table 3 shows the quantity of cassava grown under different edaphic conditions. 42.6 percent is grown on soils with high acidity. About 2.4 percent of this is grown on soils which also have permanent depth restrictions, and about 1.7 percent on soils with potential depth restrictions (soils with plinthite). 23.6 percent of cassava is grown on soils with none of the restrictions listed in Table 3. 17.1 percent is grown on soils with permanent depth restrictions, 8.8 percent on soils with permanent drainage problem, and 6.8 percent on soils with seasonal drainage problems. The other restrictions, potential depth and fine texture, account for negligible percentages, 2.8 and 0.6 respectively.

These data bring to light an important problem with the soil classification system used, which is is based on the soil map of the world (Food and Agriculture Organization of the United Nations). It is unlikely that nearly 9 percent of cassava should grow on permanently wet soils; rather, this cassava is probably found on associated soils included within the major "mapping-unit" soil used on the FAO soil map. The same may be true for the soils with depth restrictions; however, many of these are located in North-East Brazil, and the soils map is quite clear about the widespread existence of stony phases. How much this will affect cassava producers' choice of where to plant is difficult to tell. In the case of permanent drainage problems, it is likely that much of the cassava grown in areas with these characteristics experiences seasonal soil drainage problems. Given the nature of the available data, we can only accept the relative importance of these soil restrictions in cassava producing areas in South America as a whole.

Table 4 gives the 12 principal soil-climate homologues in order of the proportion of cassava grown within them. Together they account for 68 percent of the cassava in South America. The acid soils of the humid lowland subtropics and tropics, and soils without restrictions in the subtropics, are the most important homologues (25 percent of cassava).

Reconciliation with the Cassava Program's Traditional Ecosystems.

The cassava program's ecosystems have been defined according to a mixture of soil and climate criteria. It is possible to compare these with the climate-soil homologues which have been defined, to see how well they fit into this system, and how much of the area in cassava they may represent. Those which coincide with any of the 12 major climate-soil homologues are included in Table 4.

Ecosystems 2, 3 and 6 fit logically into the classification (Homologues B6, A6 and E6 respectively - 23.7 percent of the cassava in total). The climatic classification makes no distinction between Ecosystem 1 and 4; neither seasonal rainfall pattern nor differences in

mean growing season temperatures at a level detailed enough distinguish these two ecosystems from each other, are included in the classification. That is not to say that it could not be done; however, it would raise the question of what other homologues would require similar such divisions. In other words, the classification would have to be extended further.

In some ecosystems the climatic comparison is valid, but soil conditions may not be represented by the ecosystem, or by the current testing sites (Table 4). The major omission in the Ecosystem classification is that soil conditions are specified for some ecosystems and not for others. Ecosystem 5, represented by Popayan, corresponds climatically with the "highland humid tropical" class. While 5.6 percent of cassava is grown in this type of climate, no soil specifications are given for the ecosystem. Table 1 shows that cassava is grown on soils with permanent depth restrictions (1 percent), high acidity (2 percent) and with no restrictions (2.6 percent) within this climatic type.

Finally, allowing for the climatic similarities which the various ecosystems cover, there are some important climatic types which are not included in the system (Table 5). The semi-arid areas of North-East Brazil, both highland and lowland are particularly important. These differ from Ecosystem 1 because the dry season is longer, 6-9 months, and, in the case of the highlands, because mean growing season temperatures are lower. The other areas which the Ecosystem classification neglects are highland areas with varying lengths of dry season, and the humid subtropical highlands of southern Brazil. With the exception of the Andean areas (4-6 dry months), these have large daily temperature ranges during the growing season. Between them they account for about 10 percent of cassava.

Conclusions

By subdividing cassava-growing areas on the basis of a simple climatic and edaphic classification, it is apparent that the classification of ecosystems used hitherto covers some important climate-soil homologues. A more systematic approach towards soils is required if that system is to continue to be used, and there are some important semi-arid and highland areas which are not currently covered by these, and which might warrant expansion of the number of ecosystems. It is recognised that the Cassava Program cannot work specifically for all the different classes identified. However, knowledge of their existence and relative importance can help the program in the process of deciding where to work and how many different ecosystems to work for.

Given the restrictions of the climate and soil classifications, the individual classes of each are easily assessed in terms of importance by overlaying a dot distribution map on the homologue map and totalling the area of cassava falling within each homologue. Care should be taken in interpreting the results of this sort of exercise, particularly when considering soils. Rather than be restricted by this type of classification, and the problems of mapping and interpretation that go with it, organization of raw-data in a micro-regions framework is seen by the Agroecological Studies Unit as a longer-term solution to specific

climatic and edaphic classification problems which arise in the Cassava Program's research and planning.

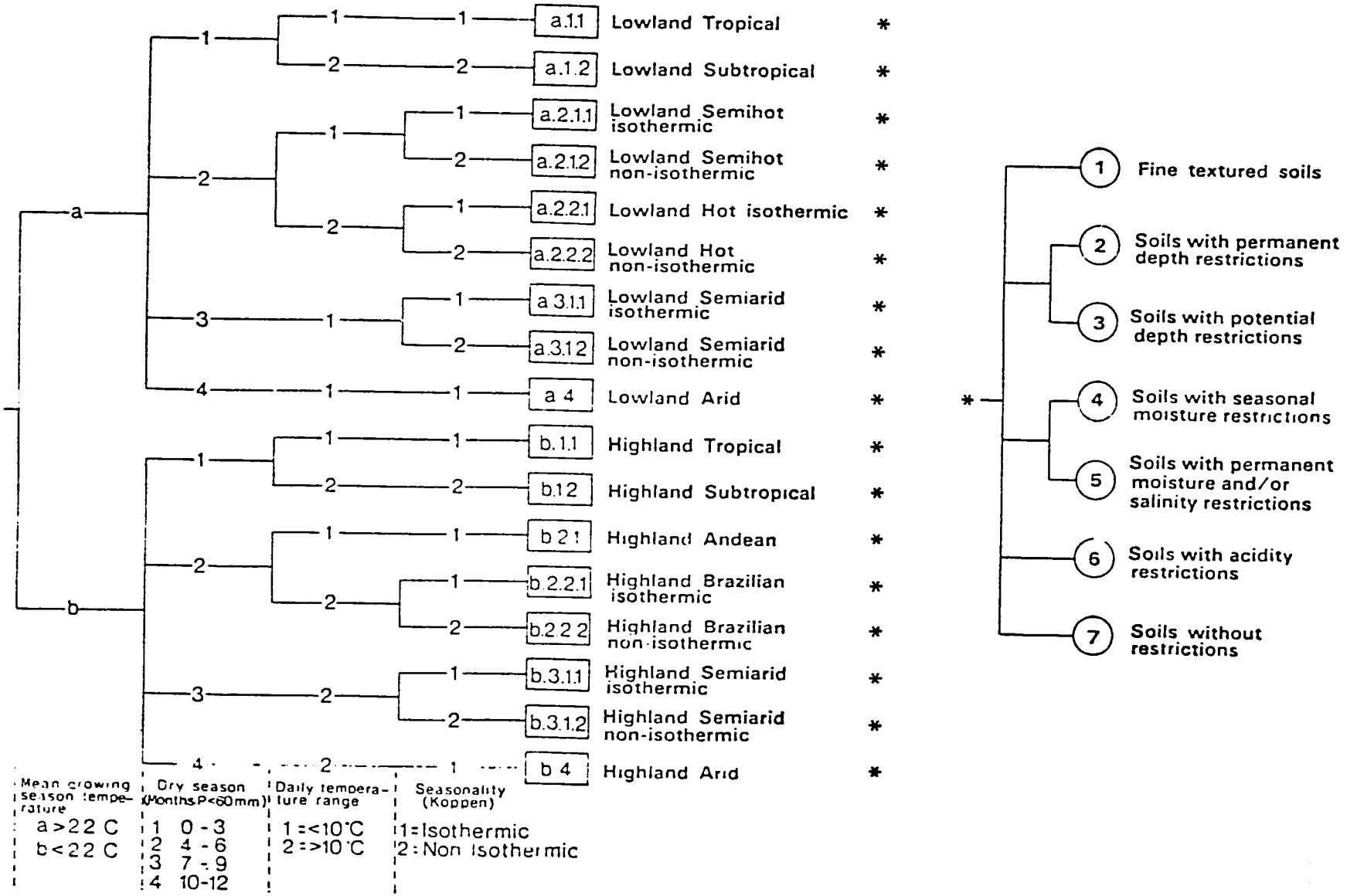


Figure 1: A simple climatic and edaphic classification for cassava producing areas in South America

TABLE 1: Hectares of cassava according to climate and soil conditions.

CLIMATE	SOIL RESTRICTIONS 1. Fine texture	2. Permanent depth restrict.	3. Potential depth restrict.	4. Seasonal drainage problems	5. Permanent drainage problems	6. Acidity	7. No restrictions	TOTAL
A LOWLAND HUMID TROPICAL	500	8,500	40,000	18,000	71,000	154,000	19,000	278,000
B LOWLAND HUMID SUBTROPICAL	-	-	-	74,000	14,000	155,000	151,000	394,000
C LOWLAND SEMIHOT ISOTHERMIC	10,000	59,000	-	24,000	19,000	145,000	100,000	357,000
D LOWLAND SEMIHOT NON-ISOTHERMIC	-	2,000	-	-	-	11,000	2,000	15,000
E LOWLAND HOT ISOTHERMIC	-	23,000	10,000	4,000	55,000	121,000	8,000	195,000
F LOWLAND HOT NON-ISOTHERMIC	-	-	-	2,000	-	3,000	2,000	7,000
G LOWLAND SEMI-ARID ISOTHERMIC	-	82,000	-	-	-	52,000	24,000	144,000
H LOWLAND SEMI-ARID NON-ISOTHERMIC	-	2,000	-	-	-	2,000	1,000	5,000
I LOWLAND ARID ISOTHERMIC	-	5,000	-	-	-	4,000	-	9,000
J HIGHLAND HUMID TROPICAL	-	17,834	-	-	-	36,432	47,834	102,000
K HIGHLAND HUMID SUBTROPICAL	-	-	-	-	-	26,000	25,000	51,000
L 'ANDEAN' SEMIHOT ISOTHERMIC	-	3,000	1,500	-	-	15,500	13,000	33,000
M 'BRAZILIAN' HOT ISOTHERMIC	-	20,333	-	-	-	12,333	8,333	41,000
N 'BRAZILIAN' HOT NON-ISOTHERMIC	-	6,333	-	-	1,000	32,333	14,333	54,000
O HIGHLAND SEMI-ARID ISOTHERMIC	-	70,333	-	1,000	-	35,333	11,333	117,000
P HIGHLAND SEMI-ARID NON-ISOTHERMIC	-	-	-	-	-	-	-	-
Q HIGHLAND ARID ISOTHERMIC	-	12,000	-	-	-	-	2,000	14,000
TOTAL	10,500	311,333	51,500	123,000	160,000	804,831	428,833	1,816,000

NOTE: Some Cassava is grown on soils with more than one kind of restriction. In these cases the totals have been included in all of the relevant columns; column totals do not, therefore, add up to the correct total of hectares, 1,816,000. These are detailed below.

Hectares of cassava grown with more than one soil restriction.

CLIMATE	SOIL RESTRICTIONS 2 and 6	3 and 6
A	8,000	25,000
E	21,000	5,000
G	14,000	-
O	1,000	-

TABLE 2. Percentage of cassava area by climate.

CLASS		CLIMATE	Percentage of cassava
a.1.1	A.	Lowland Humid Tropical	15.3
a.1.2	B.	Lowland Humid Subtropical	21.7
a.2.1.1	C.	Lowland Semihot Isothermic	19.7
a.2.1.2	D.	Lowland Semihot Non-Isothermic	0.8
a.2.2.1	E.	Lowland Hot Isothermic	10.7
a.2.2.2	F.	Lowland Hot Non-Isothermic	0.4
a.3.1.1	G.	Lowland Semi-Arid Isothermic	7.9
a.3.1.2	H.	Lowland Semi-Arid Non-Isothermic	0.3
a.4	I.	Lowland Arid Isothermic	0.5
b.1.1	J.	Highland Humid Tropical	5.6
b.1.2	K.	Highland Humid Subtropical	2.8
b.2.1.	L.	'Andean' Semihot Isothermic	1.8
b.2.2.1	M.	'Brazilian' Hot Isothermic	2.2
b.2.2.2	N.	'Brazilian' Hot Non-Isothermic	3.0
b.3.1.1	O.	Highland Semi-Arid Isothermic	6.4
b.3.1.2	P.	Highland Semi-Arid Non-Isothermic	0.0
b.4	Q.	Highland Arid Isothermic	0.8

TABLE 3: Percentage of cassava area by soil restriction.

Type Of Soil Restriction	Percentage of cassava
1. Fine textured	0.6
2. Permanent depth restrictions	17.1
3. Potential depth restrictions	2.8
4. Seasonal drainage problems	6.8
5. Permanent drainage problems	8.8
6. High acidity	42.6
7. No restrictions	23.6

Note that the percentages add up to more than 100, as some cassava is grown in soils with more than one kind of restriction (depth and acidity restrictions combined).

TABLE 4: Twelve most important climate-soil homologues in terms of cassava area.

Mapping Unit Code	CLIMATE-SOIL HOMOLOGUE	Hectares of Cassava	% of total	CASSAVA PROGRAM ECOSYSTEMS
B6	LOWLAND HUMID SUBTROPICAL-ACID	155,000	8.5	EASTERN PARAGUAY (ECOSYSTEM 6)
A6	LOWLAND HUMID TROPICAL-ACID	153,000	8.5	FLORENCIA (ECOSYSTEM 3)
B7	LOWLAND HUMID SUBTROPICAL-NO RESTRICTIONS	151,000	8.3	ECOSYSTEM 6[a]
C6	LOWLAND SEMIHOT ISOTHERMIC-ACID	145,000	8.0	ECOSYSTEM 1[a] 4[a]
E6	LOWLAND HOT ISOTHERMIC-ACID	121,000	6.7	CARIMAGUA (ECOSYSTEM 2)
C7	LOWLAND SEMIHOT ISOTHERMIC-NO RESTRICTIONS	100,000	5.5	PALMIRA, BETULIA (ECOSYSTEM 1,4)
G2	LOWLAND SEMI-ARID ISOTHERMIC-PERMANENT DEPTH	82,000	4.5	-
B4	LOWLAND HUMID SUBTROPICAL-SEASONAL DRAINAGE	74,000	4.1	ECOSYSTEM 6[a]
A5	LOWLAND HUMID TROPICAL-PERMANENT DRAINAGE	71,000	3.9	ECOSYSTEM 3a
02	HIGHLAND SEMI-ARID ISOTHERMIC-PERMANENT DEPTH	70,333	3.9	-
C2	LOWLAND SEMIHOT ISOTHERMIC-PERMANENT DEPTH	59,000	3.0	ECOSYSTEM 1[a] 4[a]
E5	LOWLAND HOT ISOTHERMIC-PERMANENT DRAINAGE	55,000	3.0	ECOSYSTEM 2[a]
	T O T A L	1,237,333	68.1	

[a] Climatically valid comparison, but soil conditions may not be represented by the ecosystem or the current testing sites.

TABLE 5. Climatic types not covered by current ecosystems.

	C L I M A T E	Hectares Cassava	% of Total
a.3.1.1	Lowland Semi-Arid Isothermic	144,000	7.9
b.3.1.1	Highland Semi-Arid Isothermic	117,000	6.4
b.2.2.2	Brazilian Hot Non-Isothermic (Highland)	54,000	3.0
b.1.2	Highland Humid Subtropical	51,000	2.8
b.2.2.1	Brazilian Hot Isothermic (Highland)	41,000	2.3
b.2.1	Andean Semihot Isothermic	33,000	1.8
a.2.1.2	Lowland Semihot Non-Isothermic	15,000	0.8
b.4	Highland Arid Isothermic	14,000	0.8
a.4	Lowland Arid Isothermic	9,000	0.5
a.2.2.2	Lowland Hot Non-Isothermic	7,000	0.4
a.3.1.2	Lowland Semi-Arid Non-Isothermic	5,000	0.3
b.3.1.2	Highland Semi-Arid Non-Isothermic	0	0.0

PHYSIOLOGY

During 1986 the Cassava physiology program directed its effort toward the following areas of research:

I. Studies of the mechanisms underlying the photosynthetic process in cassava as compared with some C_3 and C_4 crop species. The objectives of this research were to generate fundamental information about the photosynthetic characteristics of cassava in order to enhance knowledge of the crop and particularly its potential productivity.

II. Continuing previous research on stomatal response to humidity. The main objective of this research was to test the proposed hypothesis (CIAT Cassava Program Annual Reports, 1984, 1985) that stomata on the upper surface of the leaf may be less sensitive to changes in humidity than stomata on the lower surface. This research has important implications for adopting a breeding strategy to select for cultivars with a significant number of stomata on the upper surface, i.e. amphistomatous leaves, to be grown in areas with abundant soil water and with occasional warm and dry air.

III. Screening for amphistomatous leaves among F_1 populations. This research was cooperatively conducted by the Cassava breeding program to document the genetic variability in upper-surface stomatal characteristics among F_1 families grown in the field. Identified F_1 plants with significant stomatal density on the upper-surface will be propagated vegetatively to test the stability of this characteristic in consequent growth cycles. Gas exchange characteristics (both CO_2 uptake and H_2O loss) of materials with stable upper-surface stomata will be studied under controlled laboratory conditions.

IV. Quality of planting material. The quality of cassava stakes as affected by storage conditions, duration of storage period, and by genetical factors was collectively studied by teams from cassava pathology, utilization, breeding and physiology. The levels of carbohydrates, e.g starch, were determined in stakes (longer than one meter) of a few cultivars that were stored under different conditions for a period of four months. Results of carbohydrate analysis will be compared with germination and establishment in the field.

V. Research on response of cassava to long periods of water deficit in the field. Field trial was established in May, 1986 in the Quilichao Station, using the field lysimeter to test, for the second year (CIAT 1985), varietal differences in response to long period of water deficit. The hybrid CM 507-37 and its parent M Col 1684 were used in both years.

Photosynthetic Characteristics of Cassava.

1. Gas exchange studies:

Research on the photosynthetic efficiency of cassava (CIAT Cassava Program Annual Reports, 1981 to 1985) has shown that cassava leaves posses a relatively high CO_2 uptake rate ($\approx 30 \mu mol\ CO_2\ m^{-2}\ s^{-1}$) despite the absence of stomata on the upper leaf surface of the majority of the cultivars studied. The rate of CO_2 uptake was observed at a wide optimum temperature (25 to 40° C). Moreover, the photosynthetic CO_2 compensation point was found to be lower than those reported for C_3 plants (25 $cm^3\ m^{-3}$ in cassava as compared with 40 - 100 $cm^3\ m^{-3}$ in C_3 species). Leaf anatomy of cassava also shows chloroplast-containing bundle sheath cells, although less developed than in C_4 plants, tightly surrounding the vascular bundles in the spongy layer. The palisade tissue consist of a single and long palisade layer (occupies 70% of leaf volume) (Figure 1).

Gas exchange characteristics of cassava are illustrated in Figure 2. The apparent CO_2 uptake rate (P_A) increased linearly with increasing internal CO_2 (C_i) by changing CO_2 in external air over the range zero to 450 $cm^3\ m^{-3}$. The CO_2 compensation point is around 25 $cm^3\ m^{-3}$ and the photorespiration (the intercept of the curve with the ordinate) is 12% of the P_A in normal air. Both values are considerably lower than in C_3 plants and higher than in C_4 plants.

The pattern of CO_2 release in CO_2-free air in light is also different in cassava as compared with other C_3 and C_4 species (Figures 3, 4). In cassava, the rate of CO_2 release declined rapidly in the first few minutes of measurement in light and CO_2-ree air. Upon switching to dark, a post-illumination CO_2 burst (PIB) occured. However, the PIB disappeared in consequent light/dark cycles in all studied cultivars. Compared with cassava, common beans (C_3) showed a stable and reproduceable PIB and a greater CO_2 release in light at the initial time of measurement. Moreover, the CO_2 release in light did not show the rapid decline with time noted in cassava. On the other hand, the C_4 species, maize and amaranthus, Amaranthus retroflexus, showed close to zero CO_2 release in light and an absence of PIB. The PIB in cassava and bean may represent the photorespiratory CO_2 evolved from the oxidative process of phosphoglycolate produced by the bifunctional enzyme ribulose -1,5 bisphosphate carboxylase/oxygenase. However, the basic difference between cassava and bean is the disappearance of the PIB in cassava after a few minutes in CO_2-free air.

"Differential release of CO_2" from the upper surface of amphistomatous leaves (lower stomata were blocked with silicone grease) was nil in light and CO_2-free air (Figure 5) and the CO_2 compensation point was less than 6 $cm^3\ m^{-3}$. In contrast, the CO_2 was freely released from the lower surface (upper stomata blocked) in light and CO_2-free air. These patterns of CO_2 release from either surface of the leaves were consistently observed at a wide range of light intensity and constant leaf temperature (Figure 6).

Figure 7 illustrates the patterns of CO_2 release in CO_2-free air in light and dark for the clone M BR 314 at different leaf temperatures. From 11° C to 30° C, there was no CO_2 release from the upper surface in

light (Photon flux density was 1200 μmol m^{-2} s^{-1}). At higher temperature, however, CO_2 release was detectable. The release of CO_2 of the same leaf in the dark increased with increases in temperature. In constrast, the lower surface released CO_2 in light at all leaf temperatures. However, the rate increased with increase in temperature up to 30° C and then remained relatively unchanged with higher temperature. The CO_2 release in the dark increased linearly with temperature.

The PIB was detectable in both surfaces and its magnitude increased with temperature up to 30° C and then declined. At 40° C, the PIB was not observed from either surface (Figure 8). The disappearance of PIB at high temperatures suggests that the oxygenation activity of the emzyme ribulose -1,5 bisphosphate carboxylase/oxygenase was reduced. Moreover, the pronounced CO_2 surge at 40° C within 3 minutes in darkness indicates an elevated CO_2 in light and this might have led to a higher coarboxylation/oxygenation ratio.

It can be concluded from these data of "differential release of CO_2" from cassava leaves in light and CO_2-free air that when endogenous respiratory CO_2 was forced to diffuse through the palisade layer (by blocking the lower surface stomata) it was completely recycled or refixed before it could escape from the leaf.

2. Radioisotope $^{14}CO_2$ studies:

The Cassava Physiology Program, in cooperation with the Facultad de Ciencias Agropecuarias at Palmira, and with the Instituto de Asuntos Nucleares at Bogota, conducted a series of experiments using the radioisotope $^{14}CO_2$. Attached leaves of cassava, maize (C_4) and common bean (C_3) were fed with $^{14}CO_2$ for 5 or 10 seconds in light in order to determine the patterns of radioactive labeling of the initial products of the photosynthetic CO_2 fixation in cassava as compared with maize and beans.

After 5 seconds exposure to $^{14}CO_2$, beans incorporated two thirds of the ^{14}C in the form of phosphoglyceric acid (PGA) whereas maize incorporated three quarters of the labelled carbon in C_4 acids (malic, aspartic and oxaloacetic acids) (Table 1). In cassava, approximately 40 to 60% of ^{14}C was recovered in C_4 acids and 30 to 50% in PGA. The data for 10 seconds exposure were essentially the same as those for 5 seconds (Table 2). These data suggest that cassava possesses the necessary enzyme systems to fix CO_2 directly via the C_3 and the C_4 cycles.

The possible existence of two separate CO_2 fixation cycles in cassava is indirectly supported by the pattern of temperature response of apparent CO_2 uptake by attached leaves. Earlier reports (CIAT Cassava Program Annual Report, 1981) have shown that photosynthetic rate of cassava in saturation light and with open stomata, increased with temperature up to 20° C then remained constant or was depressed between 20° C to 25° C before reaching a maximum at 30° C to 40° C (Figure 9). This form of bimodal temperature response is indicative of two different enzyme systems, functioning within their own optimum temperatures. We suggest that at lower temperature the C_3 cycle is dominant and that as temperature increases the activity of phosphoenolpyruvate carboxylase

and other complementary C_4 enzymes become more pronounced and the C_4 cycle dominates.

An hypothesis in relation to gas exchange mechanisms and its impact on cassava response to drought.

Results of the present studies clearly demonstrate that gas exchange characteristics of cassava are different in important ways from both C_3 and C_4 species. Cassava exhibits photorespiration and yet much less respiratory CO_2 is released in CO_2-free air in light. The CO_2 compensation point of whole leaves (25 cm^3 m^{-3}) is intermediate between those of C_3 species (40 - 100 Cm^3) and of C_4 species (0 - 10 cm^3 m^{-3}). It does not release CO_2 in CO_2-free air in light from the stomata of upper surface (lower stomata blocked) and the CO_2 compensation point in this case is less than 6 cm^3 m^{-3}. The patterns of $^{14}CO_2$ incorporation after few seconds of exposure in light, and the temperature response of CO_2 uptake in intact leaves, suggest that cassava possesses the enzyme systems of C_4 cycle. Due to the lack of the typical Kranz anatomy of C_4 species it appears as intermediate between C_3 and C_4 plants in many of its gas exchange characteristics.

It appears that the C_3-C_4 intermediate photosynthetic characteristics of cassava, are mainly due to an efficient mechanism for recycling the respiratory CO_2 in the long palisade layer. The possible existence of an active C_4 cycle in the palisade layer enhances the internal recycling of respiratory CO_2.

The ability of cassava leaves to recycle large portions of respiratory CO_2 in light has significant consequences for the response of the crop to a dry environment. Cassava is known to tolerate long periods of water deficit with warm and dry air. Under these conditions, the crop reduces its leaf area by shedding older leaves and by producing smaller and fewer new leaves (CIAT Cassava Program Annual Reports, 1980, 1985). In addition, stomata of cassava close rapidly upon exposure to dry air (CIAT Cassava Program Annual Reports, 1981, 1982, 1983, 1984 and Figure 10). The closure of stomata in dry air results in large reductions in net CO_2 uptake (CIAT Cassava Program Annual Reports, 1981 - 1984), and in a significant decrease in intercellular CO_2 (Figure 11). These mechanisms enable cassava to endure a long period of water deficit and to maximize water use efficiency. Even though the overall crop productivity decreases during prolonged drought, the crop nevertheless accumulates carbohydrates in its storage roots (CIAT Cassava Program Annual Reports, 1980 and 1984). This gain in root yield would be enhanced by the ability of the leaves to recycle their respiratory CO_2 when their stomata close in dry environment.

The majority of cultivars surveyed to date have hypostomatous leaves (only 1 to 2% of 1500 lines and cultivars are amphistomatous). When the numerous stomata on the lower surface (about 500 mm^{-2}) close in reaction to dry air or soil water deficit, dissipation of absorbed light energy becomes of life-saving importance. The efficient mechanism for internal recycling of respiratory CO_2 in cassava leaves, provides a means of dissipating excess energy via photosynthesis and/or photorespiration.

To maximize yield under nonlimiting water supply, we hypothesized (CIAT Cassava Program Annual Report, 1984) that cassava cultivars with less stomatal density on the lower surface, and with more stomata on the upper surface, would be advantageous. It is expected that amphistomatous leaves would be less sensitive to humidity and, thus, maintain the stomata open for a longer period during the day with more net CO_2 uptake. This hypothesis is further supported by this years data on the relative response of upper and lower stomata of cassava leaves to changes in humidity (Figures 12, 13). Moreover, the possible existence of a functioning C_4 cycle in the palisade layer may enhance the photosynthetic capacity of the leaf when more CO_2 diffuses through a greater number of stomata on the upper surface.

Current findings in the Cassava Breeding Program (see cassava breeding section) indicate that F_1 populations have greater frequencies of amphistomatous leaves than the vegetatively propagated cultivars. These findings document the genetic variability and the heritability of stomatal characteristics of cassava. Moreover, it is of importance to breed and select materials with the desirable amphistomatous leaves.

The observed effective internal CO_2 recycling in cassava, bears an evolutionary significance. Cassava is of the Euphorbiaceae and there are known species within the family representing the CAM, C_3 and C_4 photosynthetic pathways. It is possible, therefore, that cassava represents an evolutionary step towards the C_4 pathway. The biochemical components of the C_4 mechanism may have evolved in the cassava leaves without acquiring the structural components. Alternatively, cassava may represent a natural hybrid between C_3 and C_4 species. Whichever of these alternatives is correct, the existence of the C_4 biochemical pathway in the absence of the Kranz-type anatomy of the "efficient" C_4 species, indicates the possibility of searching for anatomical variation which can be used to increase photosynthesis efficiency, and hence productivity, of this important food crop.

Stomatal Response to Air Humidity

In view of the findings of previous research (CIAT Cassava Program Annual Reports, 1981 to 1985) that cassava stomata are highly sensitive to changes in air humidity under both adequate soil water and soil water deficit, and that the degree of sensitivity is closely related to stomatal density, it was hypothesized that cassava leaves with stomata on both sides might be less sensitive to humidity than leaves with numerous stomata on the lower surface only. Less sensitive varieties could be advantageous under nonlimiting soil water. Under such conditions, crop productivity could be maximized when stomata remain open for a longer period during the day with more CO_2 uptake.

This year, the Cassava Physiology Program studied the response of CO_2 uptake from upper and lower surface stomata to changes in air humidity. Results of these studies are illustrated in Figures 12 and 13.

There was no apparent change in the rate of CO_2 uptake via the upper surface in response to changes in air humidity (Figure 12). On the other hand, rates of CO_2 uptake via the lower surface tended to

decrease with decreasing air humidity. There was a highly significant, although moderate, negative correlation coefficient between lower surface net photosynthesis and leaf-air vapor pressure difference ($r = -0.43$, $P < 0.001$) (Figure 13). These data support the hypothesis that amphistomatous cassava leaves will be less sensitive to humidity than hypostomatous ones. Nevertheless, further research is required to detect possible varietal differences in response to air humidity.

Quality of Planting Material

It is a common practice among cassava farmers to store cassava stakes for several months after harvest, to be used later as planting materials. This practice often results in poor quality of the stored planting material and in poor establishment of the new crop. The Cassava Program studied some aspects related to the deterioration of planting material which were stored for a long period (CIAT Cassava Program Annual Reports, 1976, 1977). Among the factors studied were the level of dehydration of the stakes, pest infestation (pathogens and insects) and the sprouting of buds during the storage period. Recent field observations indicated that the level of carbohydrate, particularly starch, in the planting material, can affect the germination ability of the stakes and, consequently, the establishment of the crop.

This year, the pathology, physiology and utilization sections of the Cassava Program, initiated some experiments to investigate the effects of varieties, storage conditions and period of storage on stake quality. Three cultivars, M Col 1684, M Col 22 and CMC 40 were used as test materials. Long stakes (120 cm) of these cultivars were stored under various conditions at CIAT, Palmira and at Media Luna on the north coast of Colombia (See pathology section).

Analysis of starch and sugar was conducted at the start of storage and thereafter periodically, on stake samples taken at a time when these stakes were prepared for planting in the field. Percentage germination and establishment was recorded in the field. The results of these experiments at CIAT, Palmira, are illustrated in Figures 14, 15 and 16.

The clone CMC 40 consistently showed a very high percentage of germination (greater than 90%) for up to four months of storage, irrespective of the storage conditions. Only when stakes were stored under a nylon net with their base kept in moist soil, was there a large reduction in germination after four months of storage. On the other hand, the cultivar M Col 1684, showed a low percent germination after almost all storage treatments, with a tendency for decreased germination after longer storage times. The cultivar M Col 22 showed intermediate germination characteristcs.

Regardless of the storage conditions, the percent germination of stored stakes was found to be reasonably correlated with the level of starch content in the stakes prior to planting (see Figure 17, $r = 0.677$, $p < 0.001$). The starch content of stakes decreased with time of storage. The cultivar M Col 1684 showed the greatest reduction in starch with time of storage (Figures 18 and 19).

Moreover, M Col 1684 tended to have less soluble sugar in its stake than CMC 40 and M Col 22 at any period of storage (Figure 20). These results demonstrate the major role that the reserve carbohydrate level in the stake can play in controlling the quality of planting material. The level of the reserve carbohydrate appears to be affected by both the variety and the storage conditions. It is of interest to continue this line of research, and to develop a simple and practical technique, applicable at the farmer level, to store and maintain high quality stakes.

Table 1. Incorporation of ^{14}C into different compounds five seconds after exposure of leaf to $^{14}CO_2$ (% of total dpm in leaf extract).

Species	Apparent photosynthesis μmol CO_2 $m^{-2}s^{-1}$	Total dpm in leaf extract	Malic acid	Aspartic acid	Oxaloacetic acid	Total of C_4 acids	PGA	Others
Beans	20	120	2	1	1	4	70	26
Cassava								
cv MCol 22	45	343	33	9	7	49	34	17
cv CM 507-37	31	350	19	14	8	41	46	13
Maize	76	701	51	15	11	77	21	2
LSD 5%			9	2.2	2.4	6.7	4.6	2.6

Table 2. Incorporation of ^{14}C into different compounds ten seconds after exposure of leaf to $^{14}CO_2$ (% of total dpm in leaf extract).

Species	Total dpm in leaf extract	Malic acid	Aspartic acid	Oxaloacetic acid	Total of C_4 acids	PGA	Others
Beans	249	2	1	1	4	72	24
Cassava							
cv. MCol 22	509	28	6	6	40	34	26
cv. CM 507-37	454	36	21	7	64	30	6
Maize	1349	45	20	7	72	19	9
LSD 5%		3.4	5	4.7	9.8	3	4.7

LEGENDS TO FIGURES

Figure 1: Photomicrograph of a cross section in cassava leaf (CV M Col 90). Note the long single palisade layer and the conspicuous chlorophyllous vascular bundle sheath situated beneath the palisade layer.

Figure 2: Apparent CO_2 uptake rate (P_A) of cassava leaves as a function of intercellular CO_2.

(●) Average maximum P_A across cultivars in normal air (upper circle), and CO_2 release in CO_2-free air (lower circle).

Figure 3: Traces of CO_2 release in CO_2-free air in light and dark for cassava and common beans (C_3 species).

↓ light off

↑ light on

PIB: Post-illumination CO_2 burst

Note the disappearance of PIB in cassava after the initial period of measurement.

Figure 4: Traces of CO_2 release in CO_2-free air in light and dark for maize and Amaranthus (C_4 species).

↓ light off

↑ light on

Note the absence of PIB in both species and the pronounced CO_2 surge in Amaranthus within 3 minutes in darkness.

Figure 5: Traces of differential CO_2 release in CO_2-free air in light and dark from the upper and lower surfaces of amphistomatous cassava leaves (cv. MBR 314)[a].

↓ light off

↑ light on

PIB: Post-illumination CO_2 burst

[a] Light: 1200 μmol m^{-2} s^{-1}, Leaf temperature: 25 + 2°C.

Figure 6: Differential CO_2 release in CO_2-free air from the upper and lower surfaces of amphistomatous cassava leaves (cv. M Col 89, and cv. MBR 314) as a function of light intensity. Leaf temperature 27°C.

Figure 7: Differential CO_2 release in CO_2-free air in light and dark from the upper and lower surfaces of amphistomatous cassava leaves (cv. MBR 314) as a function of leaf temperature.

● : steady CO_2 release after 25 minutes in dark

o : steady CO_2 release after 15 minutes in light

□ : PIB - post-illumination CO_2 burst within 30 seconds.

Light intensity: 1200 μmol m^{-2} s^{-1}.

Figure 8: Traces of CO_2 release in CO_2-free air in light and dark from the upper surface of amphistomatous cassava leaf (cv. MBR 314) at 30°C, 35°C and 40°C leaf temperature. Light intensity 1200 μmol m^{-2} s^{-1}.

↓ light off

↑ light on

PIB: post-illumination CO_2 burst.

Note the disappearance of PIB at 40°C and the pronounced CO_2 surge within 3 minutes in darkness.

Figure 9: Response of apparent CO_2 uptake rate to leaf temperature (cv. M Col 22). Light: 1800 μmol m^{-2} s^{-1}; VPD: <1.5 KPa.

Figure 10: Leaf conductance of cassava as a function of leaf-air vapor pressure difference (well-watered plants).

Figure 11: Intercellular CO_2 as a function of leaf conductance to water vapor (variations in leaf conductance were induced by changes in leaf-air vapor pressure difference).

Figure 12: Response of CO_2 uptake via the upper leaf surface to changes in air humidity.

Figure 13: Response of CO_2 uptake via the lower leaf surface to changes in air humidity.

Figure 14: Percentage of germination and water loss as a function of storage period. Long stakes were stored in the open, under tree, under net and inside a hut. Stakes were not supplied with water and were isolated from soil during storage.

Figure 15: Percentage of germination and water loss as a function of storage period. Long stakes were stored in the open, under tree, under net and inside a hut. Bases of the stakes were inserted into a wet soil during storage.

Figure 16: Percentage of germination and water loss as a function of storage period. Long stakes were stored in the open, under tree, under net and inside a hut. Bases of the stakes were kept in container supplied with water and copper sulfate during storage.

Figure 17: Percentage germination of stakes as a function of starch content prior to planting. Data represent three varieties (M Col 1684, M Col 22 and CMC 40) stored for 15, 45 and 75 days under conditions described in Figures 14, 15 and 16.

Figure 18: Starch content in stored stakes as a function of storage period for CV. M Col 1684, M Col 22 and CMC 40.

Figure 19: Percentage reduction in starch content in stored stakes as a function of storage period for CV. M Col 1684, M Col 22 and CMC 40.

Figure 20: Sugar content in stored stakes as a functioning storage period for CV. M Col 1684, M Col 22 and CMC 40.

Fig. 1

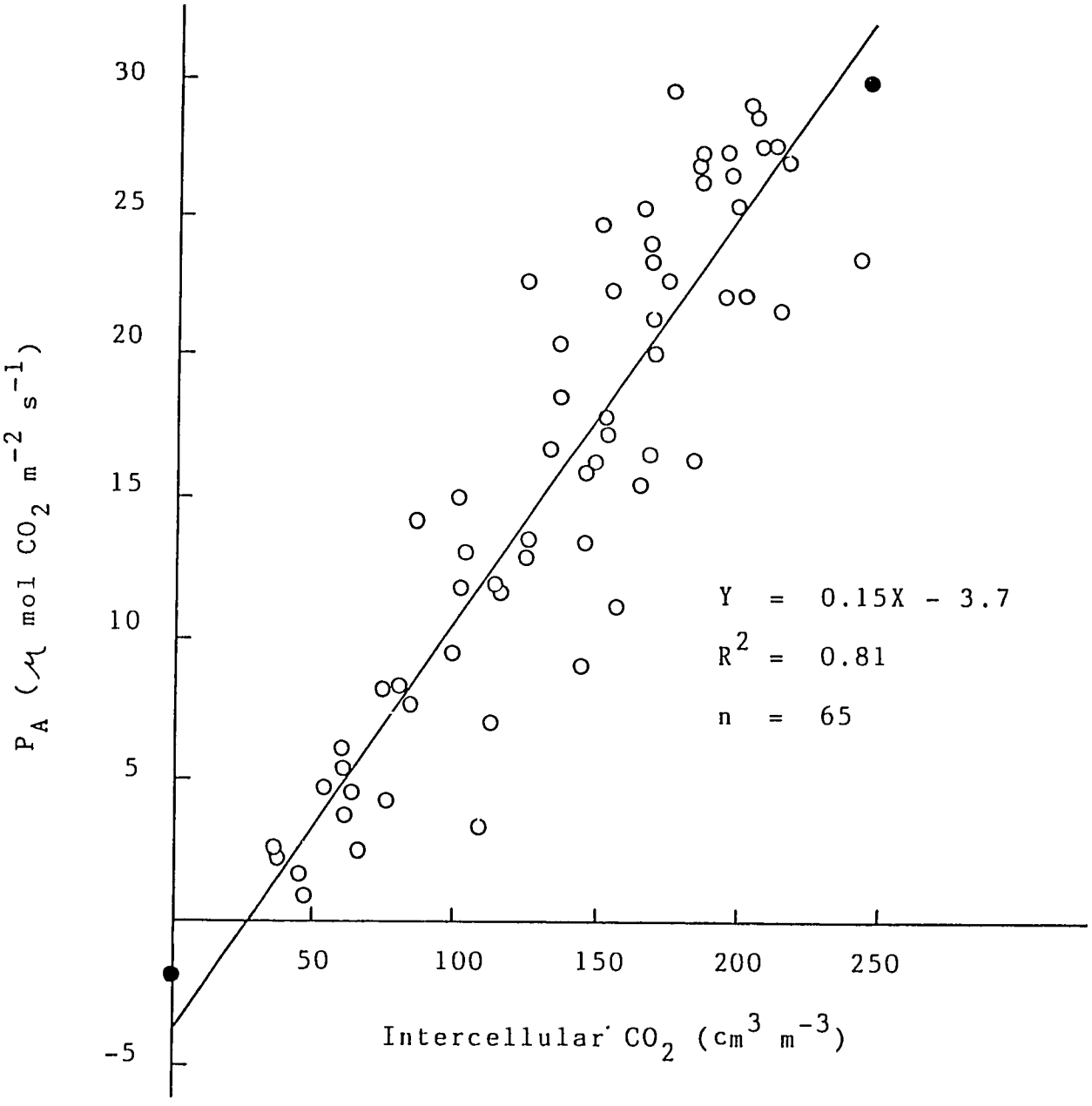

30
25
20
15
10
5
-5
50
100
150
200
250
P_A (μ mol CO_2 m^{-2} s^{-1})
Intercellular CO_2 (cm^3 m^{-3})
Y = 0.15X - 3.7
R^2 = 0.81
n = 65

Figure 2.

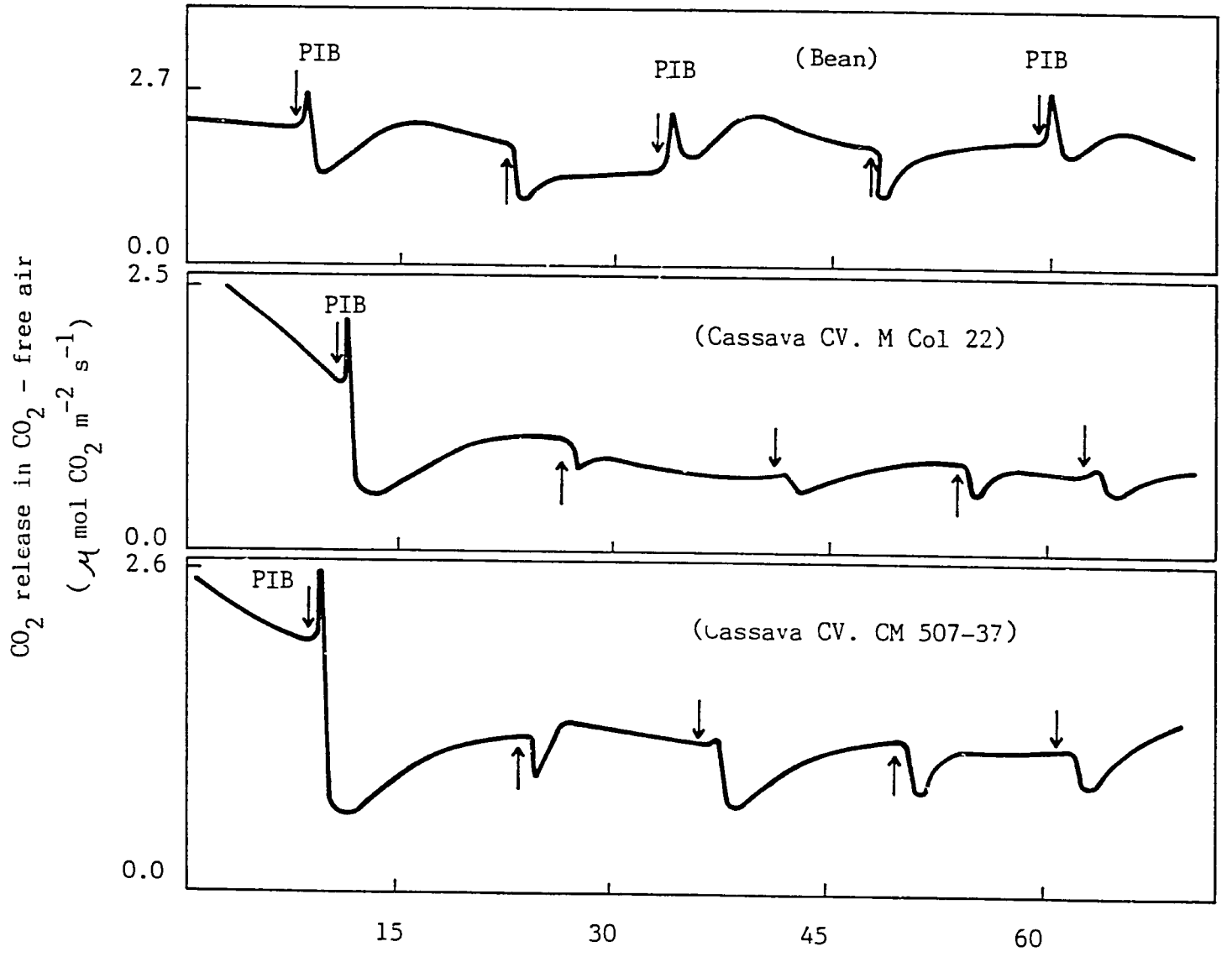

PIB
PIB
(Bean)
PIB
2.7
0.0
2.5
PIB
(Cassava CV. M Col 22)
0.0
2.6
PIB
(Cassava CV. CM 507-37)
0.0
15
30
45
60
Minutes
CO_2 release in CO_2 - free air
(μ mol CO_2 m^{-2} s^{-1})

Figure 3.

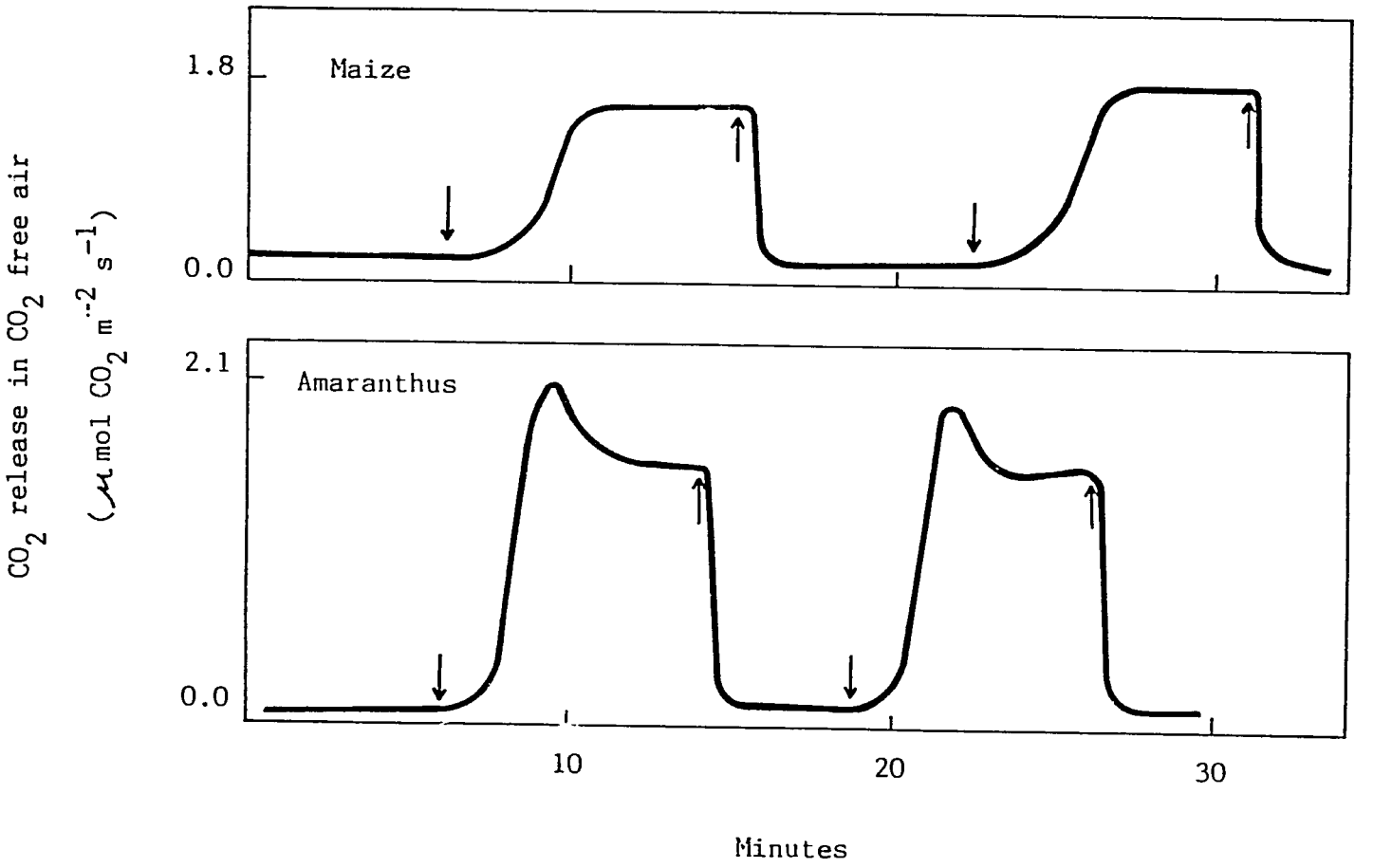

CO_2 release in CO_2 free air
(μmol CO_2 m^{-2} s^{-1})
1.8
0.0
Maize
2.1
0.0
Amaranthus
10
20
30
Minutes

Figure 4.

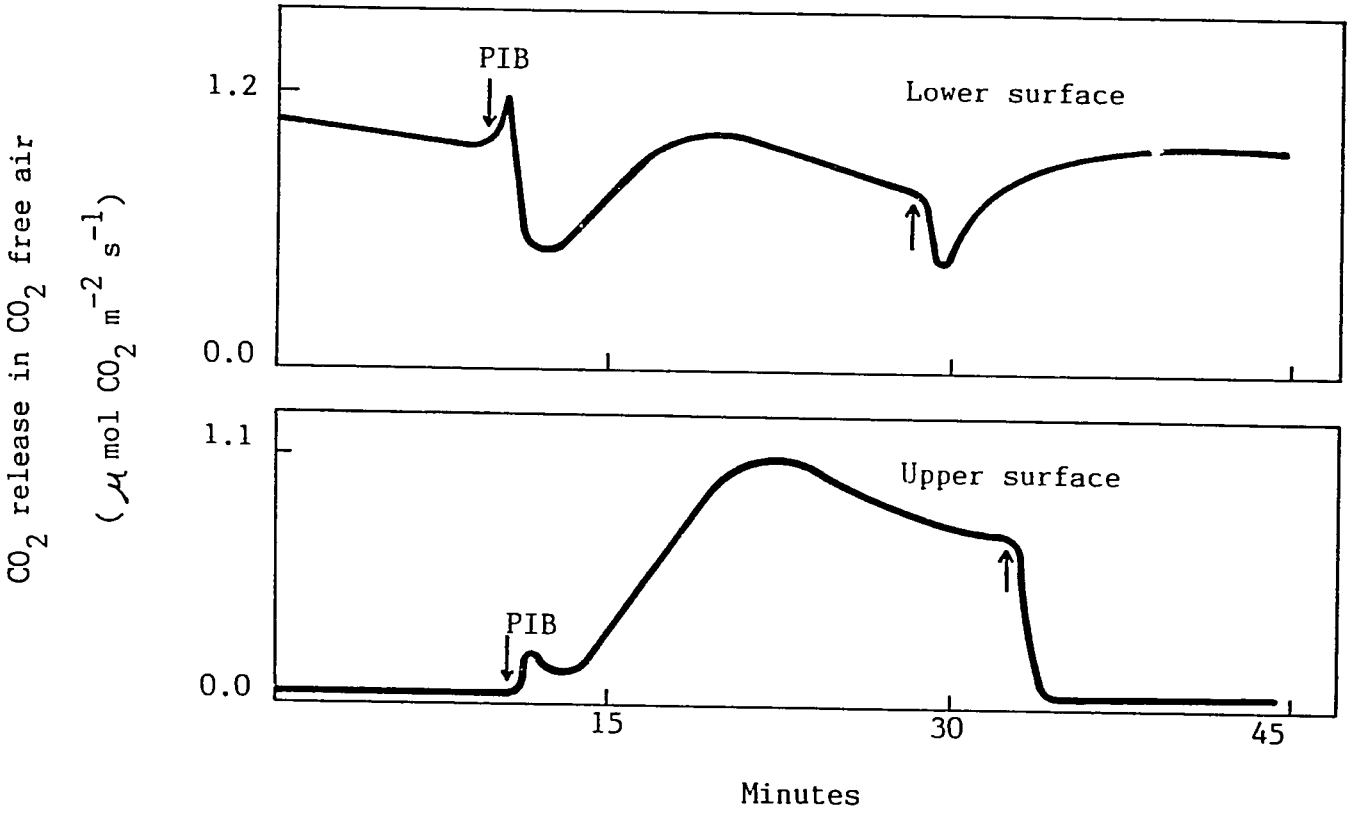

CO_2 release in CO_2 free air
(μ mol CO_2 m^{-2} s^{-1})
1.2
0.0
PIB
Lower surface
1.1
0.0
PIB
Upper surface
15
30
45
Minutes

Figure 5.

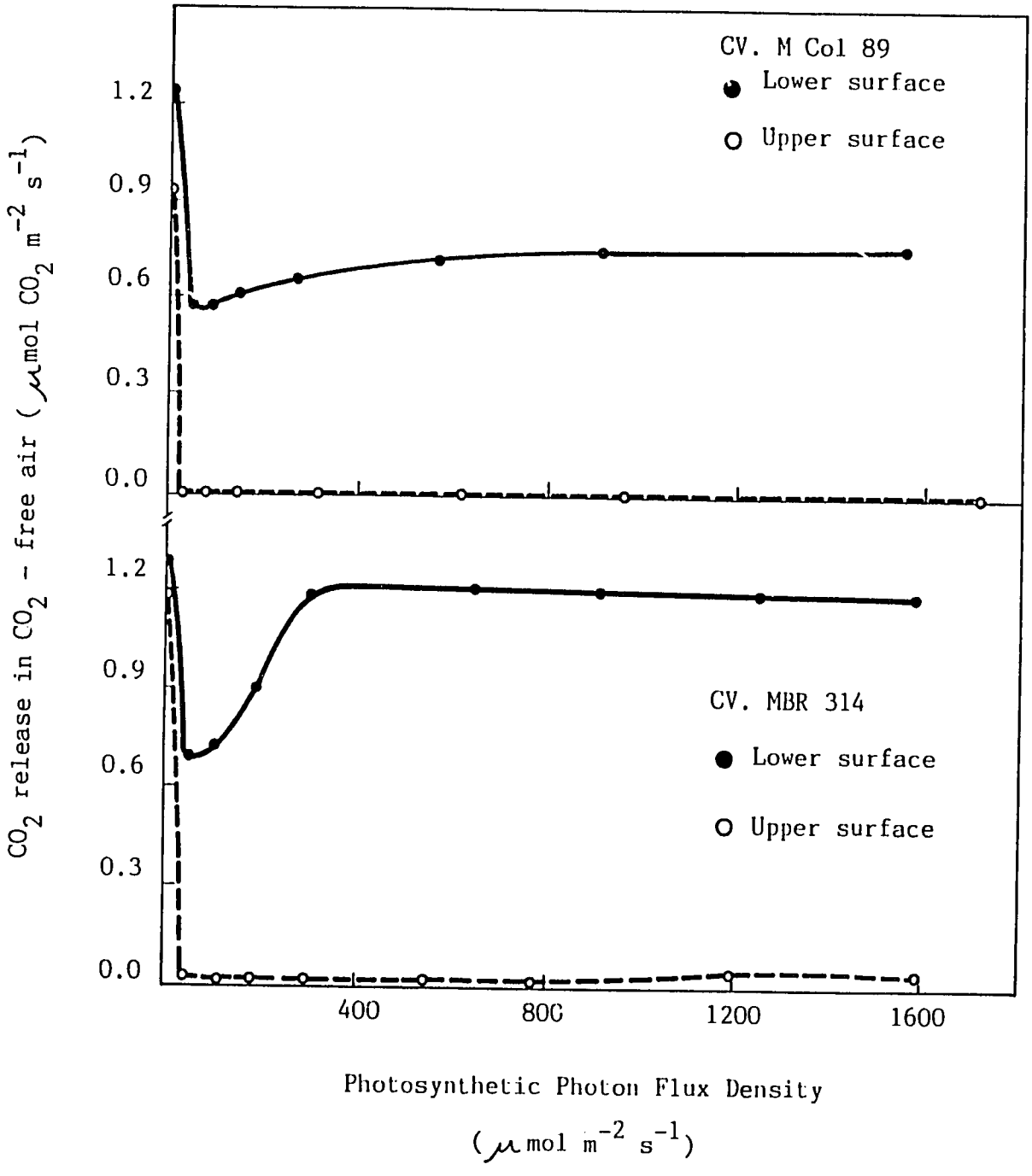

CV. M Col 89
Lower surface
Upper surface
CV. MBR 314
Lower surface
Upper surface
1.2
0.9
0.6
0.3
0.0
400
800
1200
1600
CO2 release in CO2 - free air (μmol CO2 m-2 s-1)
Photosynthetic Photon Flux Density
(μmol m-2 s-1)

Figure 6.

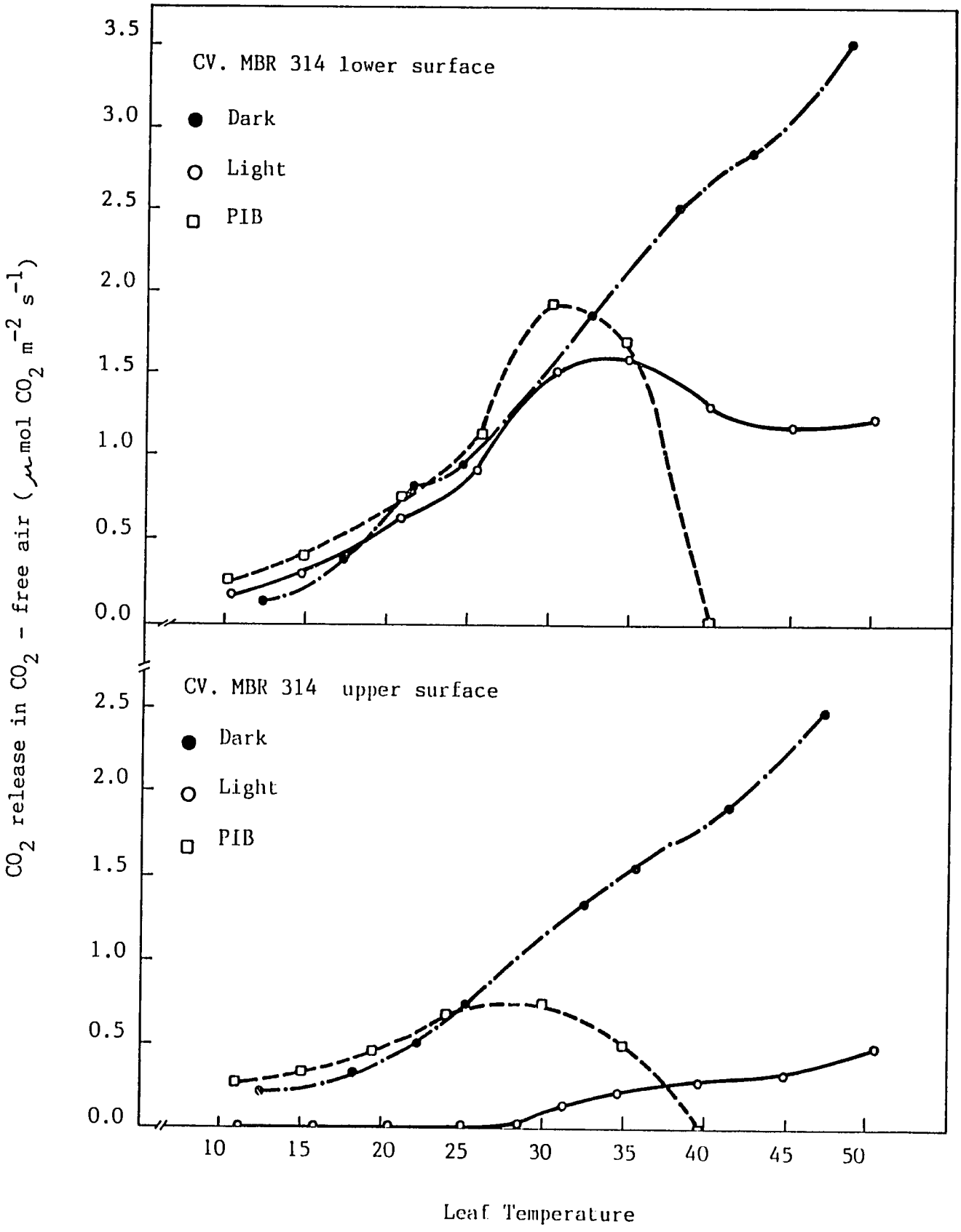

CV. MBR 314 lower surface
Dark
Light
PIB
CV. MBR 314 upper surface
Dark
Light
PIB
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2.5
2.0
1.5
1.0
0.5
0.0
10
15
20
25
30
35
40
45
50
Leaf Temperature
CO2 release in CO2 - free air (μmol CO2 m-2 s-1)

Figure 7.

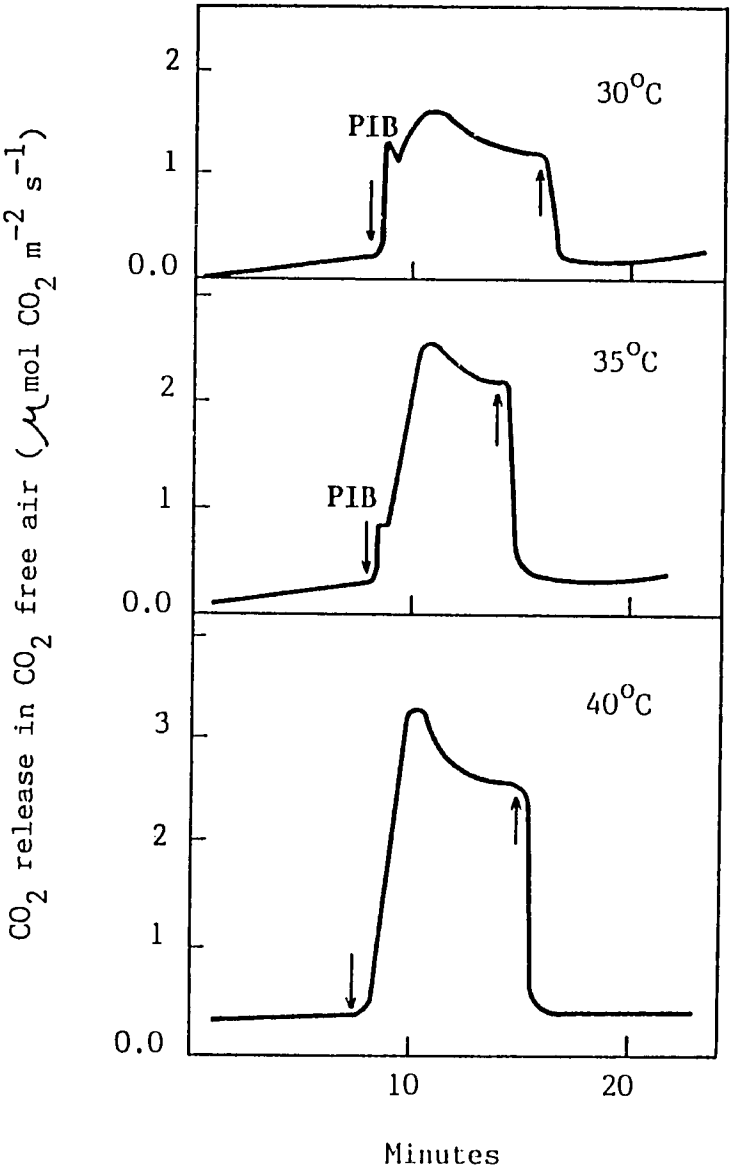

30°C
PIB
35°C
PIB
40°C
2
1
0.0
3
10
20
Minutes
CO_2 release in CO_2 free air (μmol CO_2 m^{-2} s^{-1})

Figure 8.

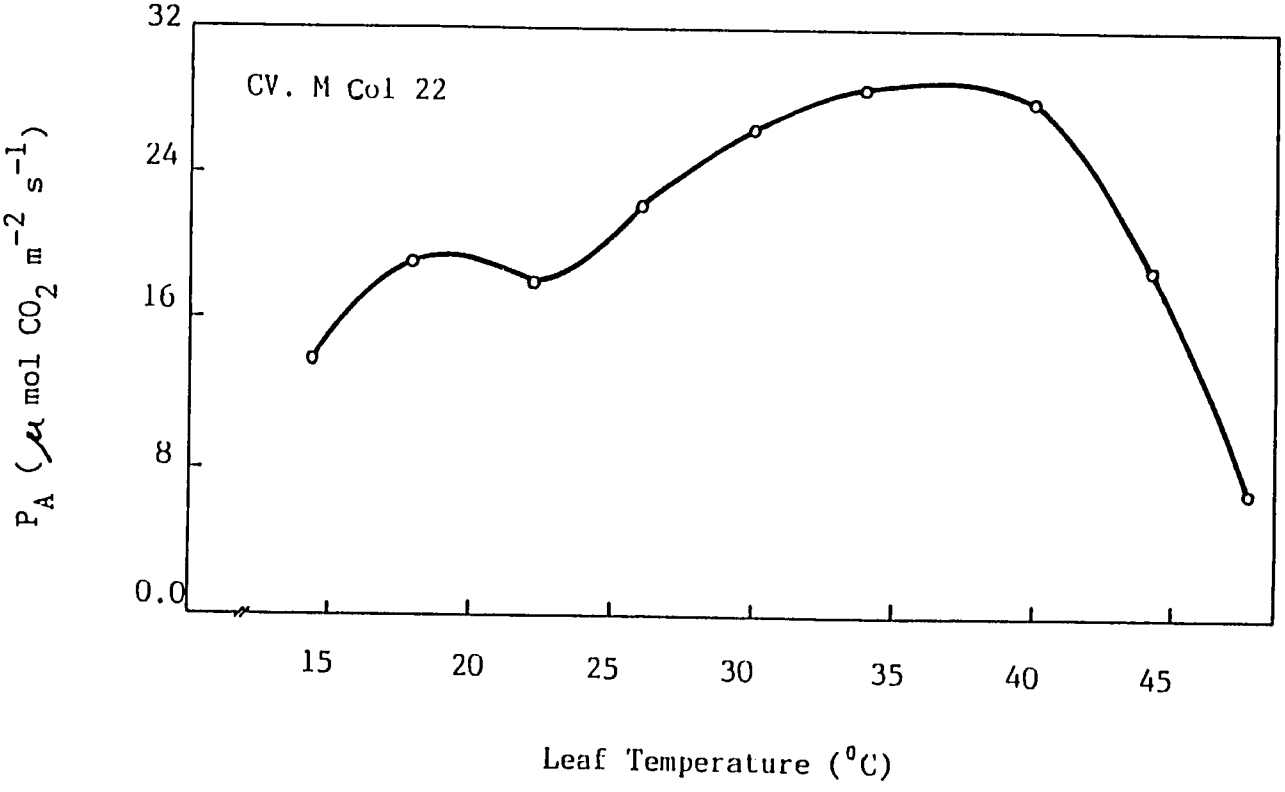

CV. M Col 22
32
24
16
8
0.0
P_A (μ mol CO_2 m^{-2} s^{-1})
15
20
25
30
35
40
45
Leaf Temperature (^{0}C)

Figure 9.

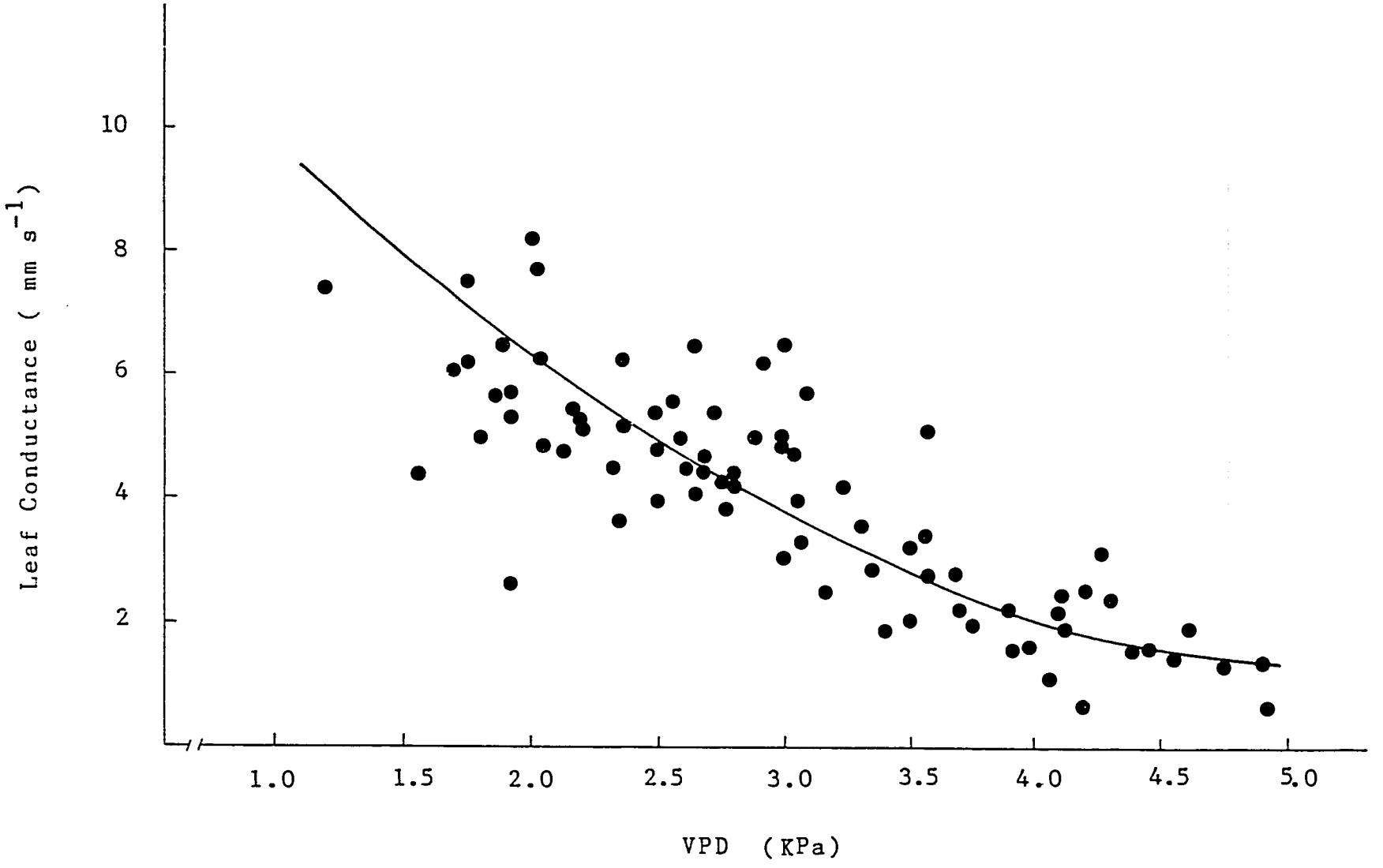


Figure 10.

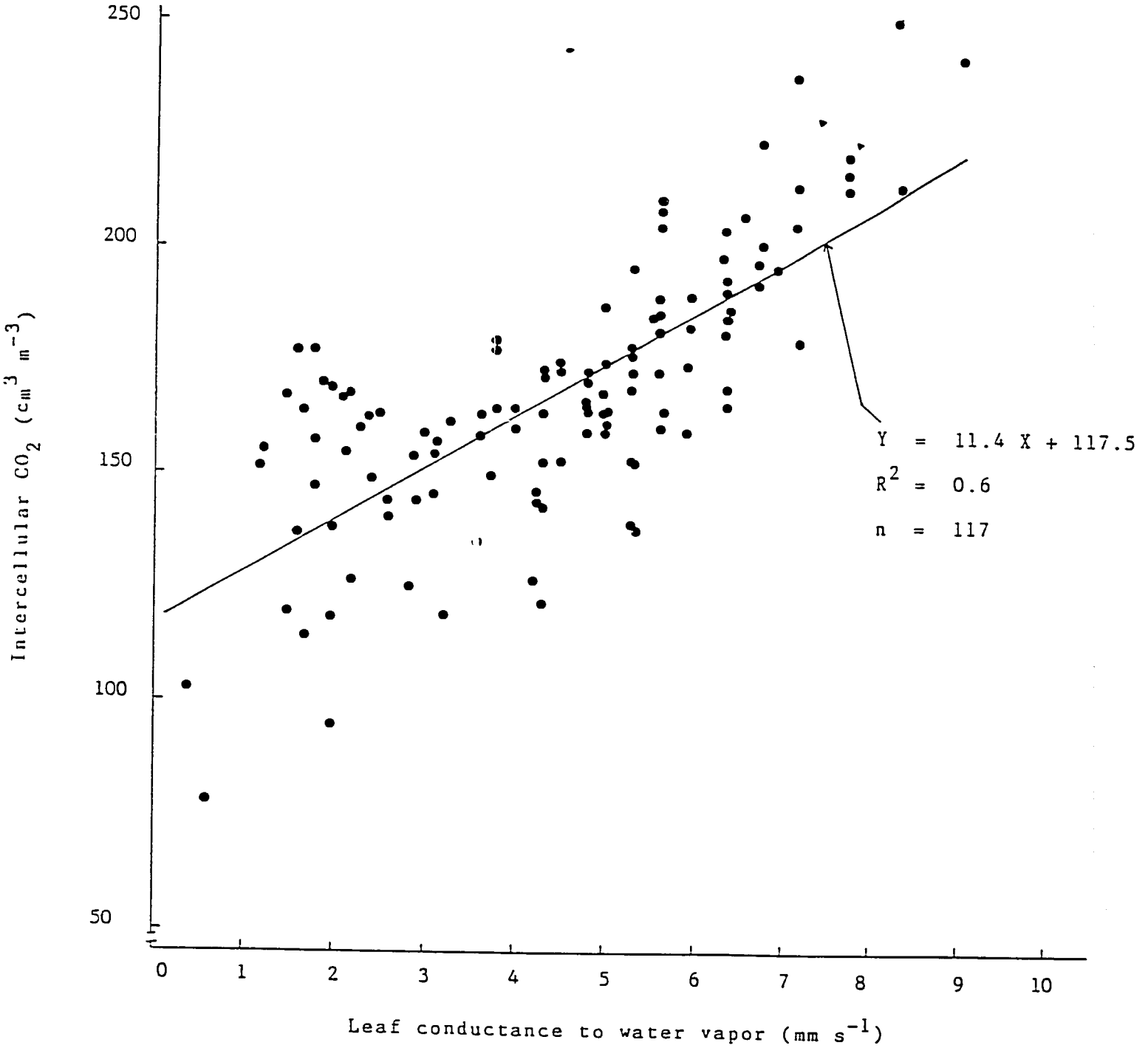

250
200
150
100
50
0
1
2
3
4
5
6
7
8
9
10
Intercellular CO_2 (cm^3 m^{-3})
Leaf conductance to water vapor (mm s^{-1})
Y = 11.4 X + 117.5
R^2 = 0.6
n = 117

Fig. 11

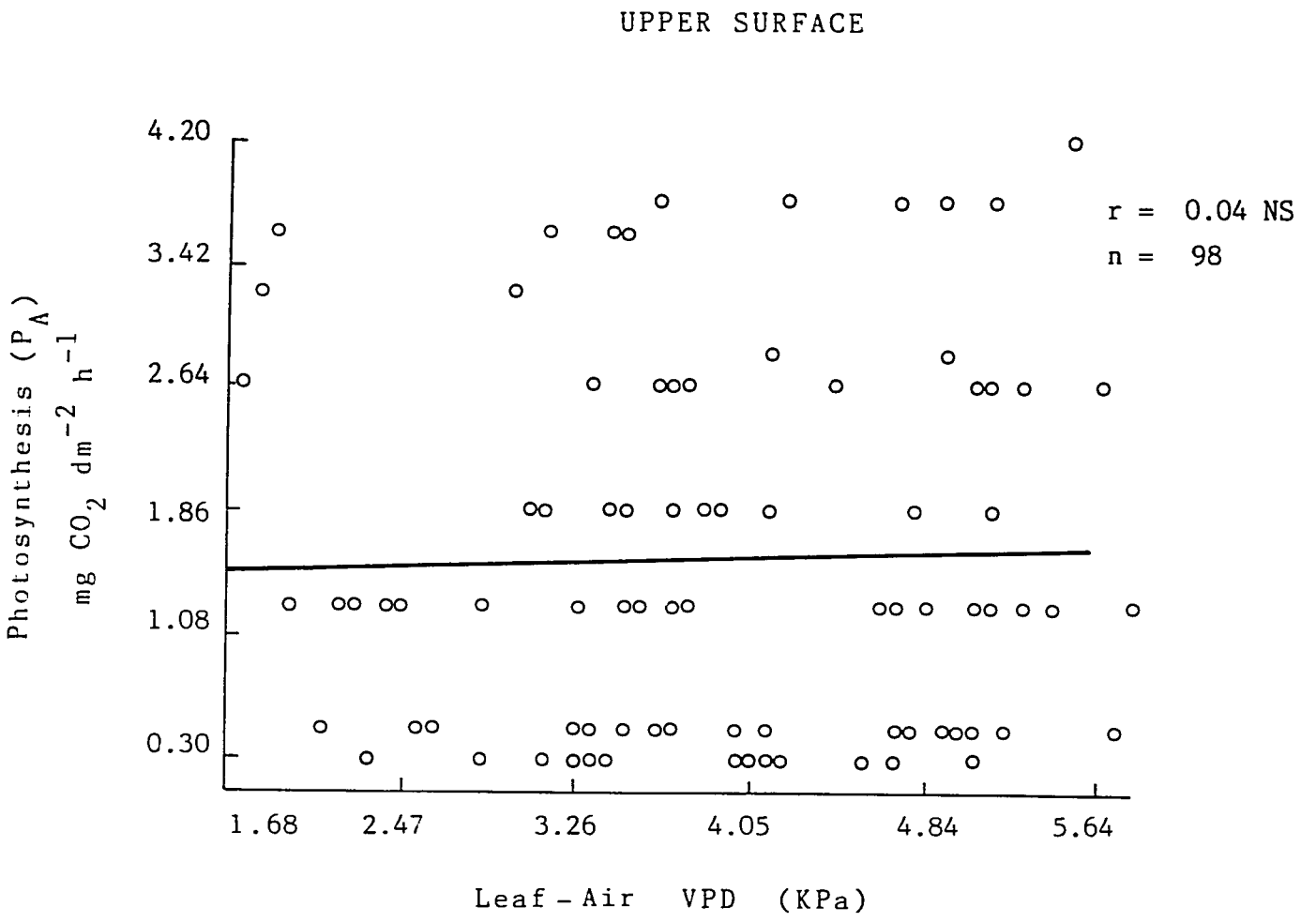

UPPER SURFACE
Photosynthesis (P_A)
mg CO_2 dm^{-2} h^{-1}
4.20
3.42
2.64
1.86
1.08
0.30
r = 0.04 NS
n = 98
1.68
2.47
3.26
4.05
4.84
5.64
Leaf - Air VPD (KPa)

Figure 12.

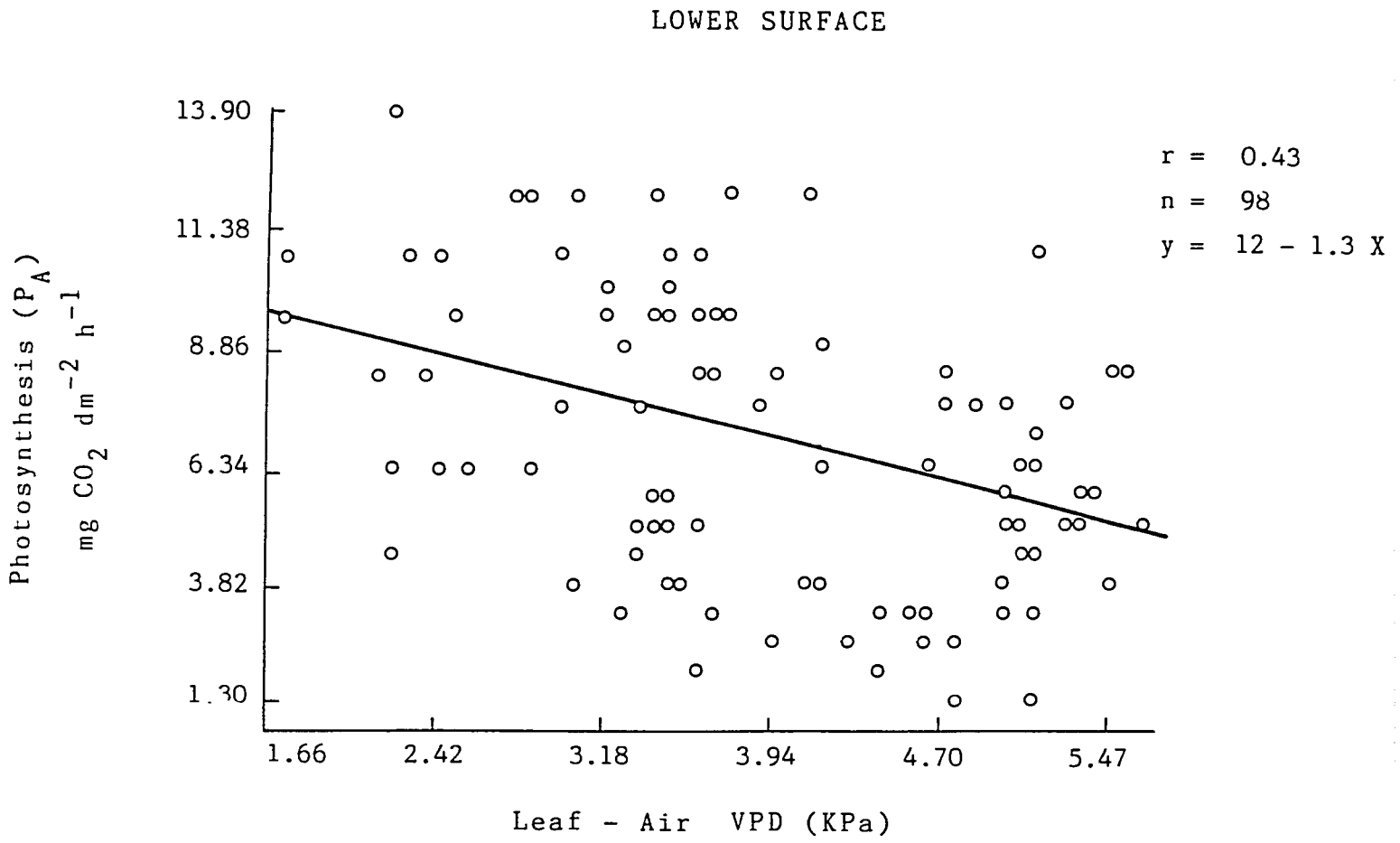
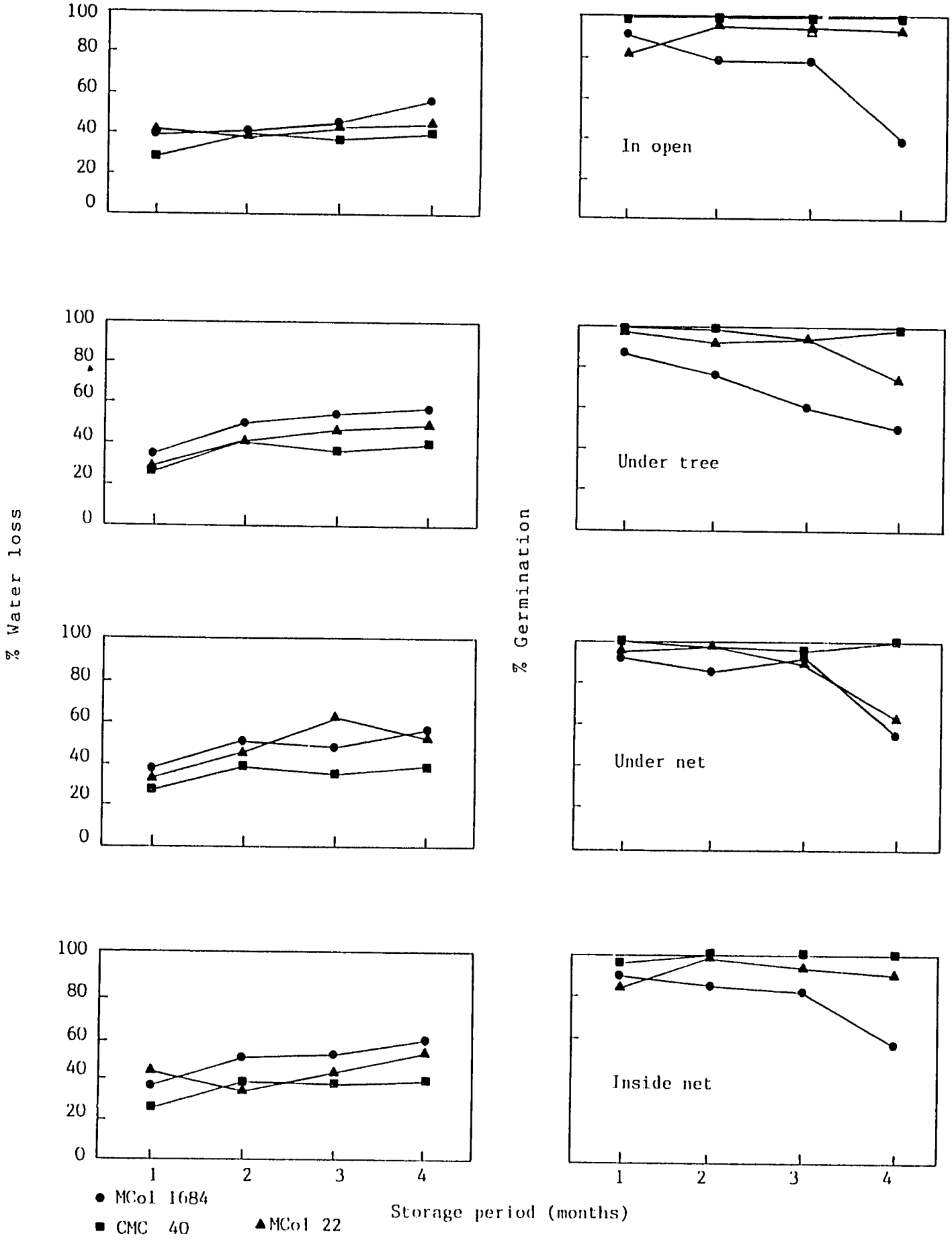
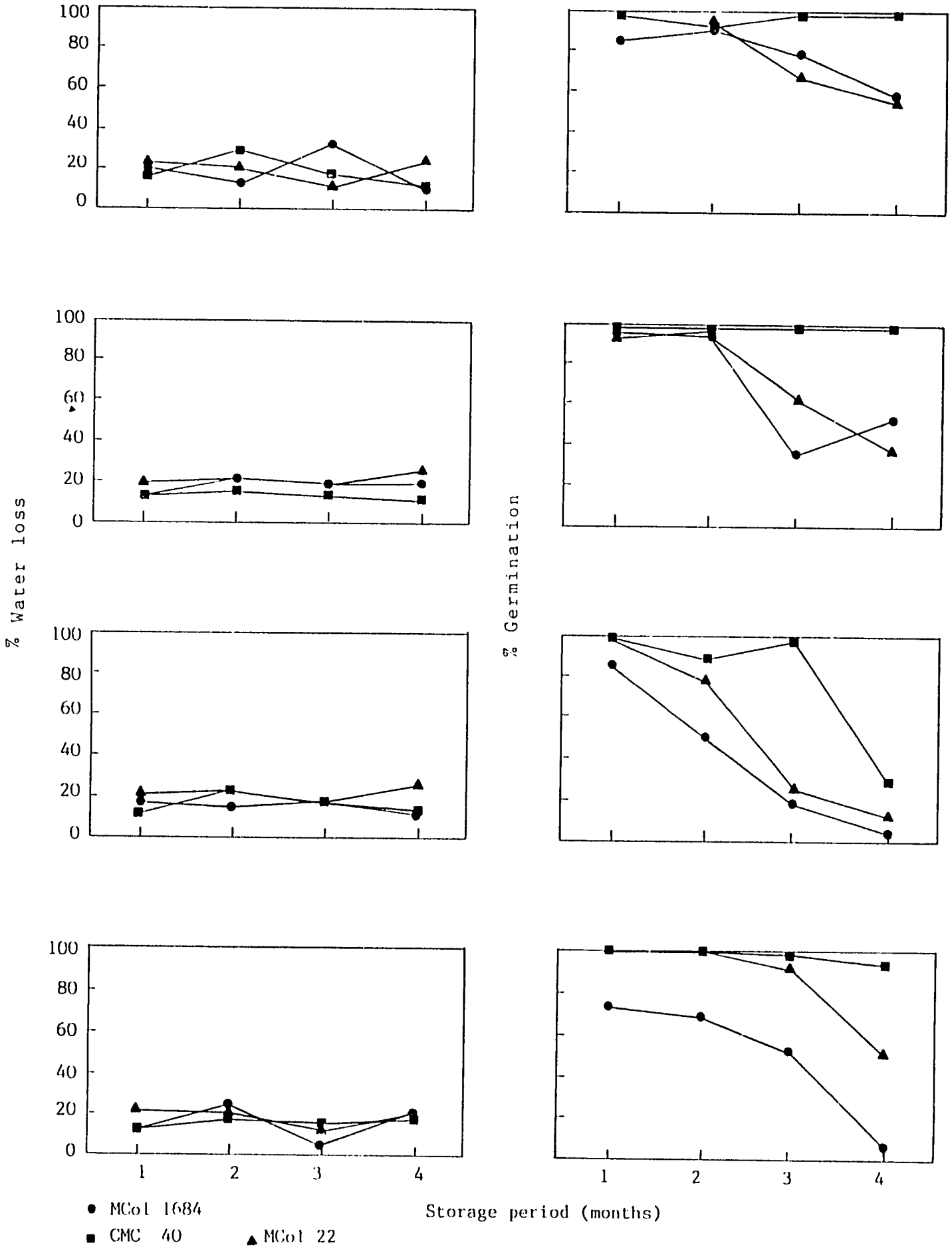
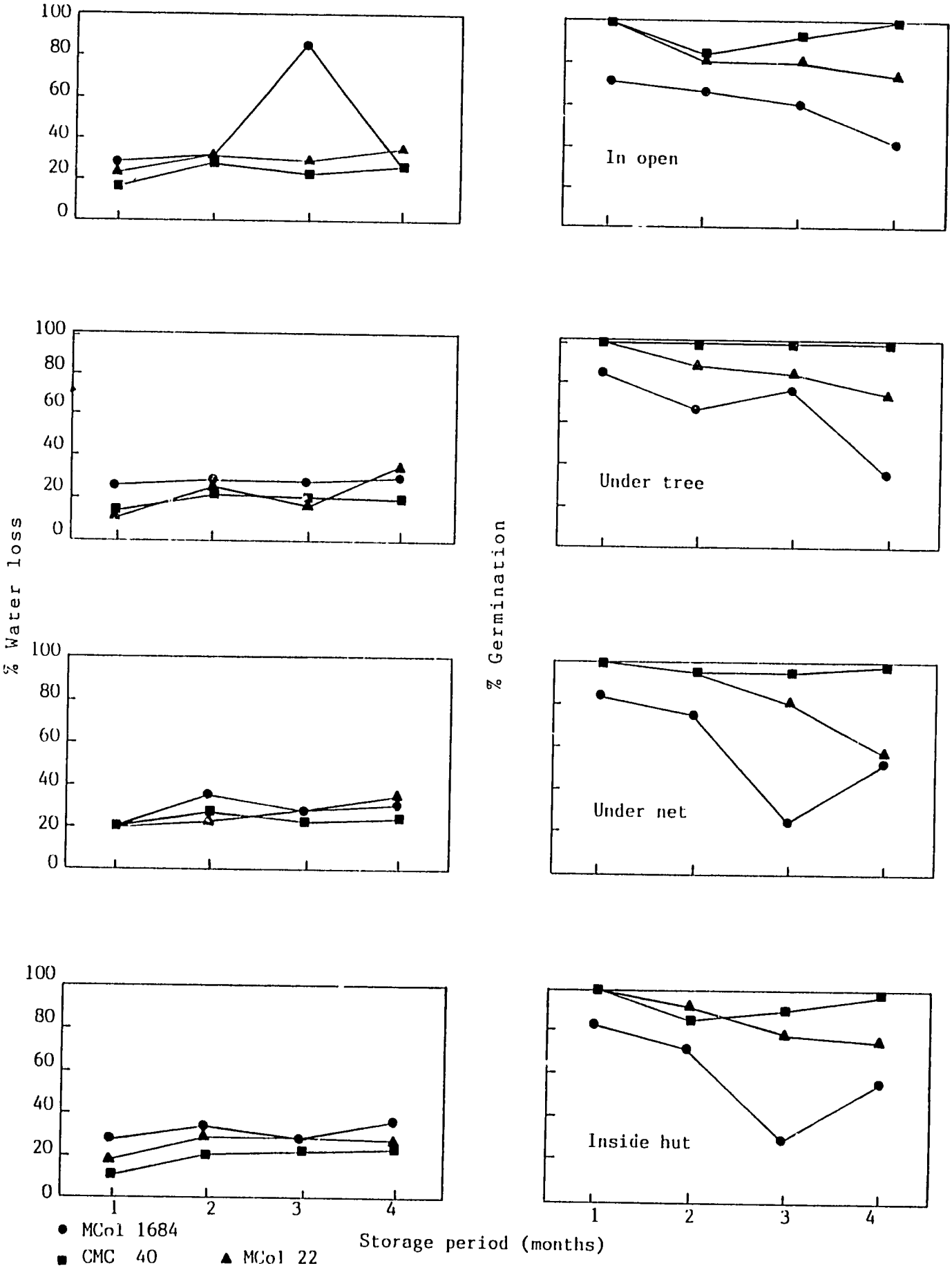

LOWER SURFACE
r = 0.43
n = 98
y = 12 - 1.3 X
13.90
11.38
8.86
6.34
3.82
1.30
Photosynthesis (P_A)
mg CO_2 dm^{-2} h^{-1}
1.66
2.42
3.18
3.94
4.70
5.47
Leaf - Air VPD (KPa)

Figure 13.

Fig. 14


% Water loss
% Germination
In open
Under tree
Under net
Inside net
100
80
60
40
20
0
1
2
3
4
● MCol 1684
■ CMC 40
▲ MCol 22
Storage period (months)


% Water loss
% Germination
100
80
60
40
20
0
1
2
3
4
Storage period (months)
MCol 1684
CMC 40
MCol 22


% Water loss
% Germination
In open
Under tree
Under net
Inside hut
100
80
60
40
20
0
1
2
3
4
MCol 1684
CMC 40
MCol 22
Storage period (months)

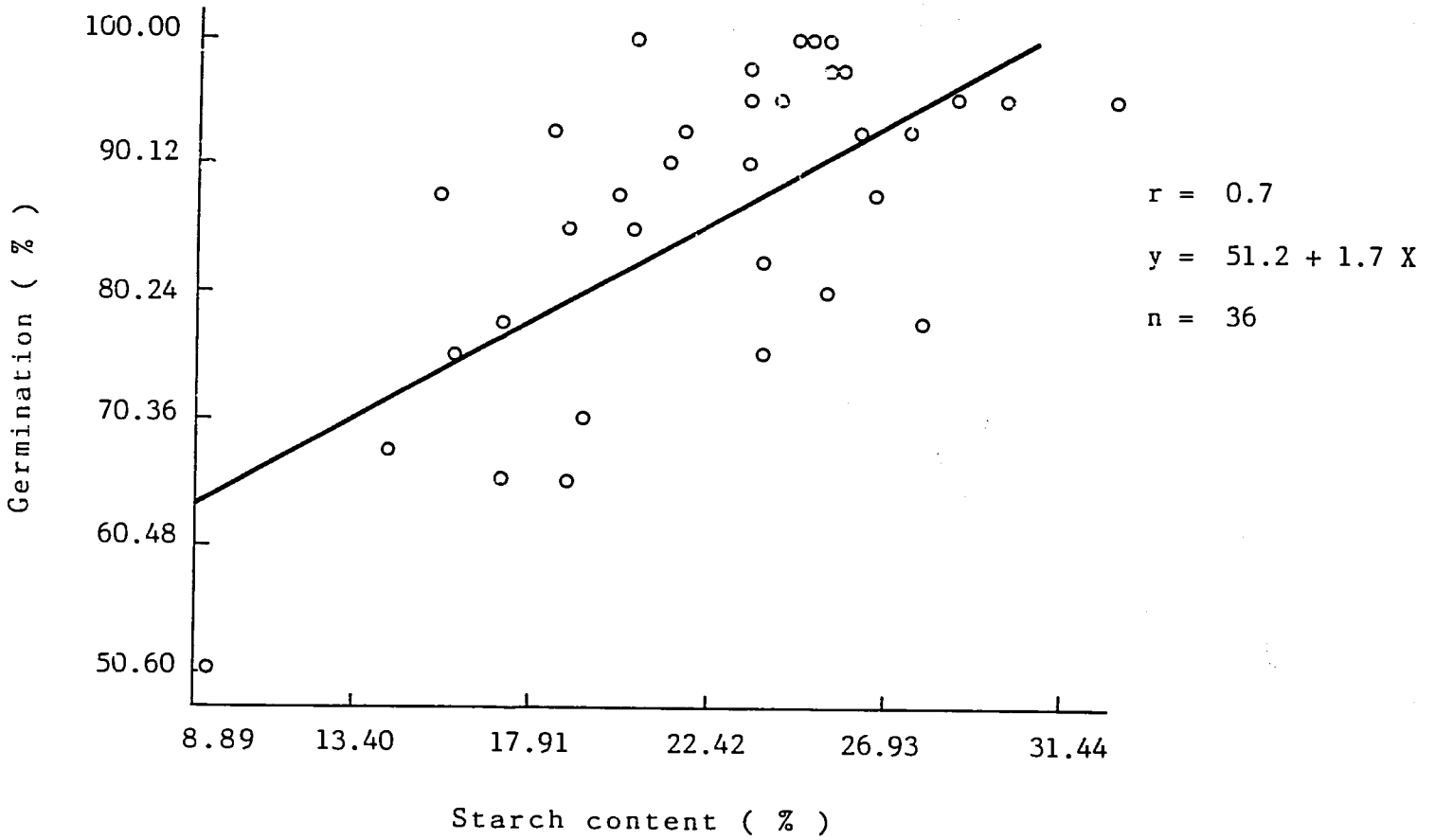

100.00
90.12
80.24
70.36
60.48
50.60
Germination (%)
8.89
13.40
17.91
22.42
26.93
31.44
Starch content (%)
r = 0.7
y = 51.2 + 1.7 X
n = 36

Figure 17.

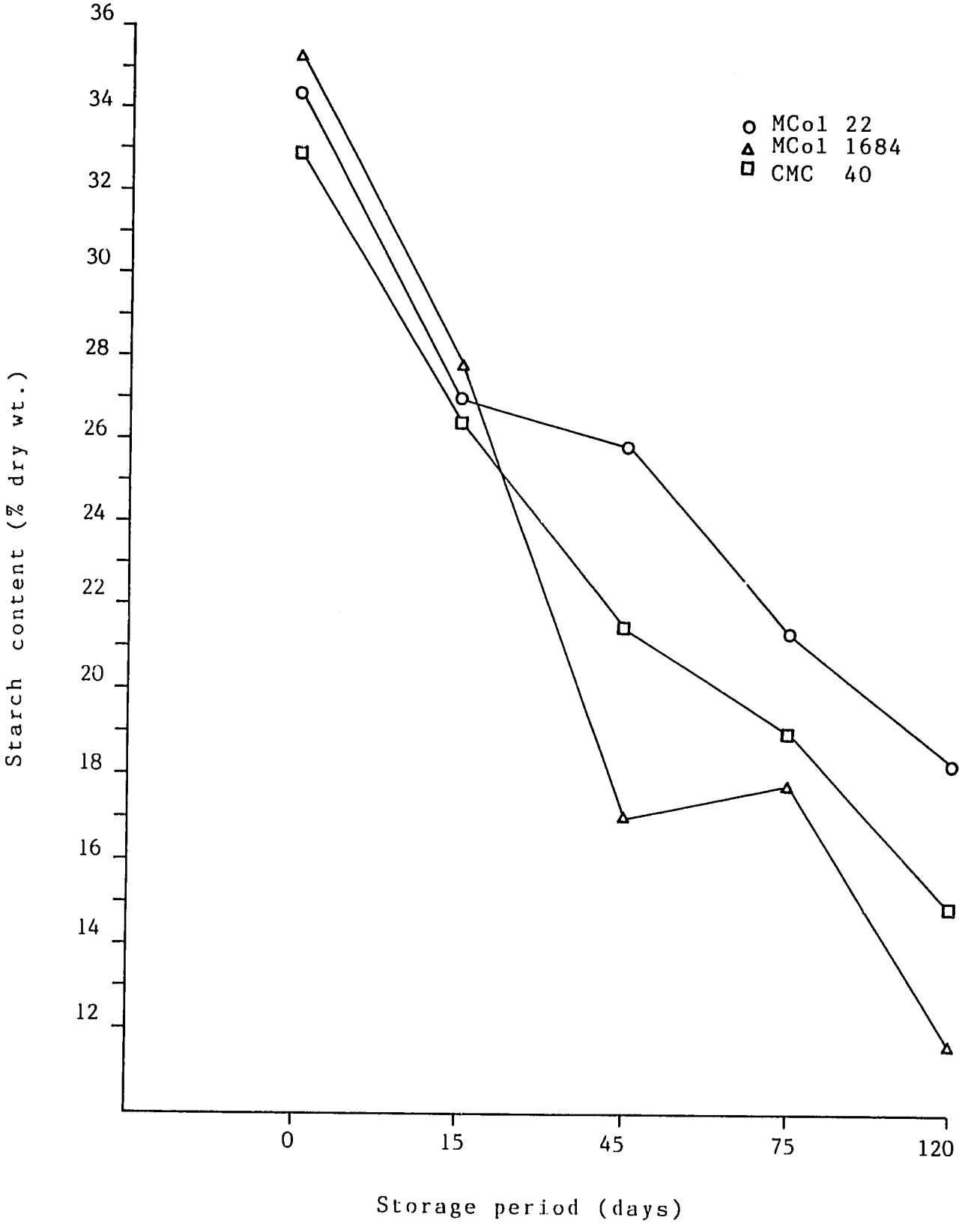

36
34
32
30
28
26
24
22
20
18
16
14
12
Starch content (% dry wt.)
MCol 22
MCol 1684
CMC 40
0
15
45
75
120
Storage period (days)

Figure 18.

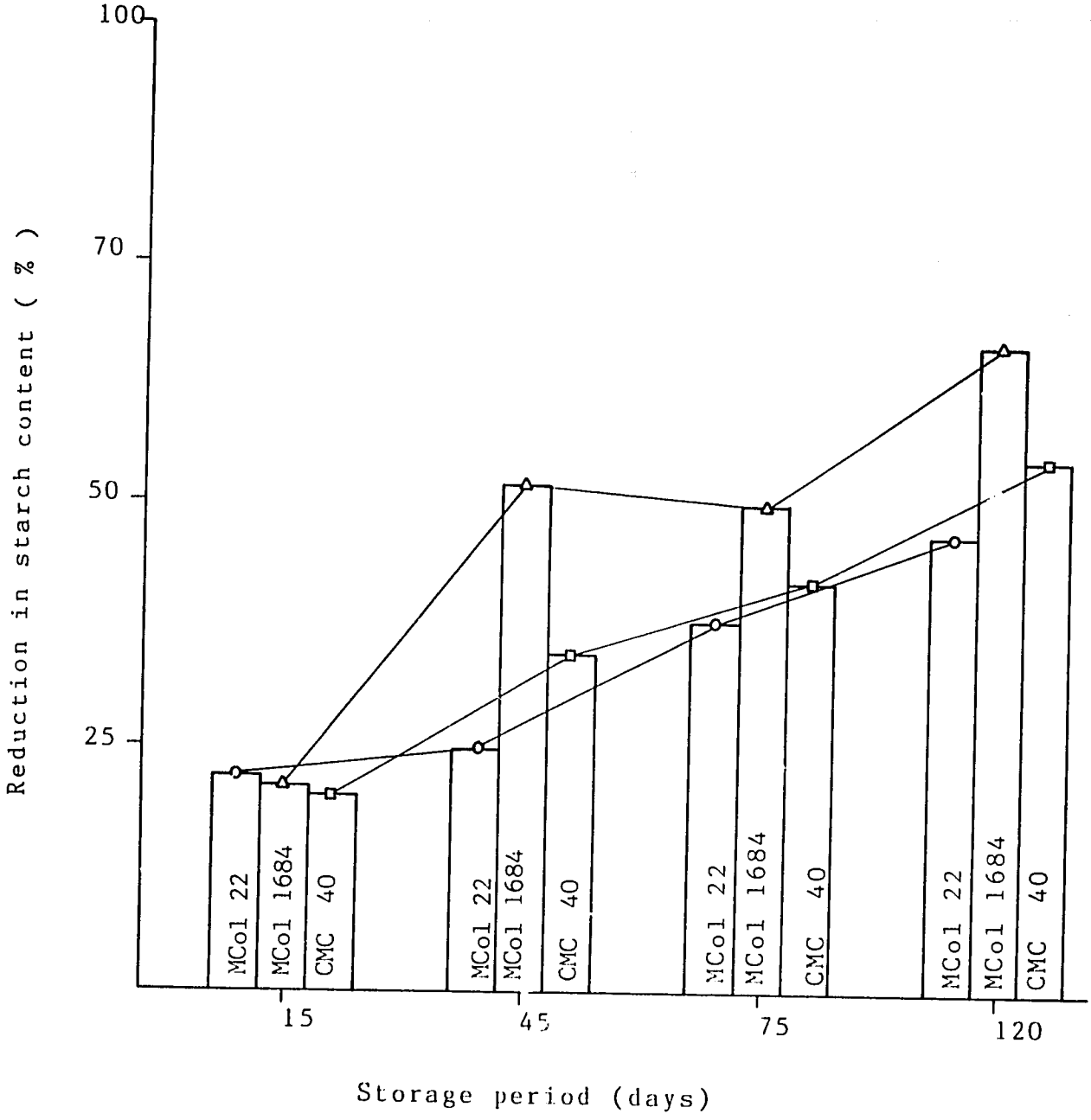

100
70
50
25
Reduction in starch content (%)
MCol 22
MCol 1684
CMC 40
MCol 22
MCol 1684
CMC 40
MCol 22
MCol 1684
CMC 40
MCol 22
MCol 1684
CMC 40
15
45
75
120
Storage period (days)

Figure 19.

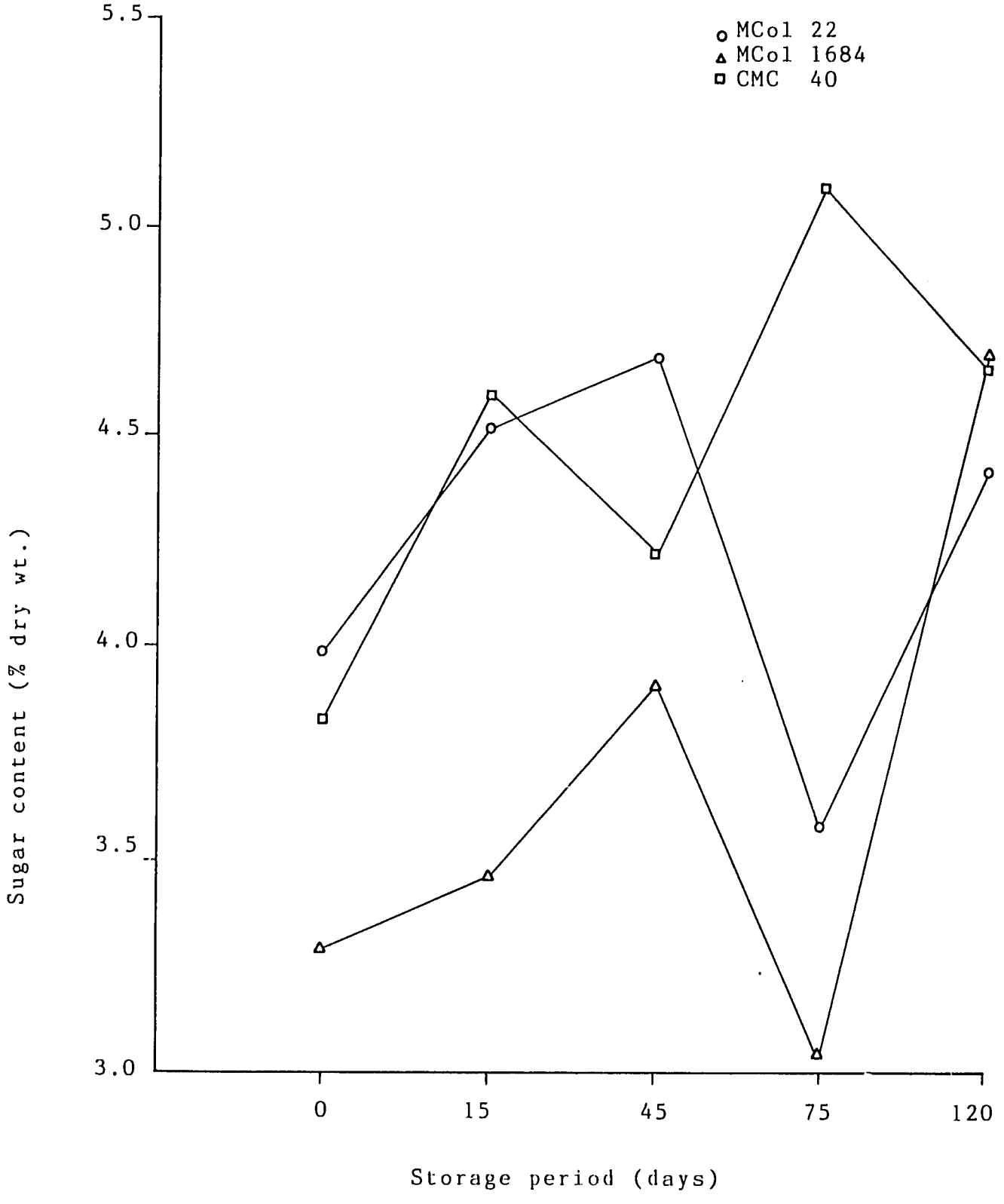

MCol 22
MCol 1684
CMC 40
5.5
5.0
4.5
4.0
3.5
3.0
Sugar content (% dry wt.)
0
15
45
75
120
Storage period (days)

Figure 20.

SOILS AND PLANT NUTRITION

Experiments in 1986 concentrated on the evaluation of germplasm for tolerance to adverse soil conditions, the determination of long-term effects of cassava on soil fertility, fertilization practices, and soil management to reduce erosion. Table 1 shows the characteristics of the soils in which these experiments were conducted.

Screening for low-P tolerance.

As in previous years, cassava germplasm accessions and breeding lines were evaluated in Quilichao and Mondomo, Cauca for their adaptation to low levels of soil P. In Quilichao, 70 varieties or lines were grown in plots which, during the past 5 years, had received annually either no P or 75 kg P/ha, banded at planting as triple superphosphate (TSP). In the first 4 years of planting cassava in these plots, yields tended to increase every year and the difference in yield between the two P treatments decreased with time, pressumably due to a build-up of a very effective native mycorrhizal population (Figure 1). However, in the 5th year average yields at both P levels declined compared with the previous year, probably due to excessive rainfall. Still, without any P applied the average yield was 27.4 t/ha. while with P this was 34.5 t/ha. Thus, even in a soil with only 1.8 ppm P (Bray II), cassava produced near 80% of the yield obtained with adequate P fertilization, indicating the crop's very low external P requirement in the presence of an efficient mycorrhizal association.

Of the 70 varieties tested, seven were considered well-adapted to low P soils, according to their high adaptation indices. These adapted materials were all accessions from Brazil or new breeding lines. The best material, M Bra 226, produced 41.8 t/ha without P and 45.5 t/ha with P.

Combining the results of several years of screening for low-P tolerance in Quilichao, Table 2 shows the best adapted materials that have been evaluated for at least 3 years. These should be included in future breeding programs to ensure that the new breeding lines have a high level of adaptation to low-P, since most cassava, at least in Latin America, is grown on low-P soils and without P fertilization.

Table 3 shows the results of a screening of 18 germplasm accessions in Mondomo, Cauca, located at about 1500 masl. This germplasm had previously been selected for its tolerance to low temperature (18-20°C) or adaptation to ECZ 5. In the extremely low-P soil (0.5 ppm P) the average yield without P application was 14.3 t/ha., and with 100 kg P/ha applied as banded TSP, the yields were 24.0 t/ha. Highest yields and adaptation indices were obtained with the local varieties Bajuna Negra, Regional Amarilla and Negrita. The latter two varieties also had the highest adaptation indices in a similar screening last year. None of the breeding lines in this screening, or in the adjacent Regional Trial, were as well adapted as the local varieties to the particular soil and climatic conditions of this important cassava growing region.

Long-term fertility trial.

A long-term fertility trial, iniciated in 1977 in CIAT Quilichao, completed eight consecutive cassava crops with the application of three levels of N,P, and K in all possible combinations. These fertilizers were either applied only once at the beginning of the trial in 1977, or annually with each crop. In addition, as far as the sixth crop, all plots were divided into two, one half receiving annual applications and the other half receiving no more fertilizers.

Figure 2 shows that in the eighth year the response to the initial NPK application (residual effect) had completely disappeared. However, there was not only a significant response to reapplication (during the past three years) of K, but also, for the first time, to N. Thus, while the large removal of K in each root harvest has led to severe K exhaustion and declining yields in the zero-K treatments, the same, but to a lesser extent, is true for N extraction, leading eventually to N exhaustion of the soil.

Figure 3 shows that highest yields in the eighth year were obtained only with the annual application of either intermediate or high levels of NPK, the difference between these two treatments not being statistically significant. Reapplication of fertilizers during the last 3 crops resulted in yields of about 85% of maximum, while the residual effect of applications in either the first or the first five years had practically disappeared in the eighth crop.

Figure 4 shows that without any fertilization, yields declined from 22 t/ha in the first year to 13 t/ha in the eighth year; on the other hand, annual application of intermediate levels of 100 kg N, 87 kg P and 125 kg k/ha resulted in a yield increase to about 40 t/ha, which could be maintained over the years. While P was the main limiting element during the first year, K became the most limiting element in the second crop. With annual applications of K alone (125 kg/ha), about 77% of maximum yields were obtained in the eighth crop; with N alone this was 50%, P alone 38%, and no fertilizer 33%. Thus, while application of all major nutrients contributes to sustainable high yields, it is clear that in these soils, K - and to a lesser extent N- applications are essential. This is probably true for most tropical soils, which tend to be low in K bearing primary and secondary minerals.

In another trial in Quilichao, cassava was grown with various combinations of NPK, both in a plot that was exhausted due to four consecutive Regional Trials without fertilization, and in an adjacent plot that was also used for Regional Trials but with adequate fertilization. Figure 5 shows the response of cassava to annual applications of NPK in these two plots during three consecutive cassava croppings. While yields in the exhausted plot in the first year were much lower than those in the fertilized plots, in the third year the maximum yields were very similar in both plots, reaching 50-55 t/ha. In both plots the response to N, P and K increased with each succesive cropping, but this was much more pronounced in the initially exhausted plot. In the third year there was an almost linear response to the highest level of 100 kg K/ha,the application of which increased yields from 19 to 52 t/ha in the exhausted plot, and from 27 to 52 t/ha in the

previously well-fertilized plot. In the latter plot there was no response to N, P, or K in the first year, only a K response in the 2nd year, and a response to all three elements in the third year. Thus, the need for fertilization may not always be apparent from one-year fertilizer trials, but becomes quite obvious in long-term trials, in which K is generally shown to be the most limiting nutrient for sustainable cassava production.

Figure 6 shows that the yields of both varieties in the third year were closely related to the exchangeable K content of the soil at time of harvest. While yield levels of the two varieties differred slightly, they showed an identical reponse to K application. For both varieties a critical level of about 0.16 me/100 g was determined; this is very close to the level of 0.17 me/100 g determined previously from NPK trials in 25 locations in Colombia. The annual application of 100 kg K/ha maintained the exchangeable K level around 0.15 - 0.16 me/100 g; this would be a minimum rate of application to maintain high yields, since 50 t/ha of roots removed about 75-100 kg K from the soil.

Sources and methods of N-application

Although cassava extracts large amounts of N from the soil for root and especially leaf production, there are few soils in Colombia where the crop responds to N fertilization. To determine the best sources and methods of N application for cassava, two trials were planted, one in the loamy sand soil of Media Luna (Magdalena) with only 0.6% organic matter (O.M.), and one in Pescador, Cauca in a clay soil with 7.7% O.M.

Table 4 shows the effect of different levels, times and methods of N application on stake germination and yield in Media Luna. Half of each plot was planted with stakes of M Ven 25 from Media Luna, and the other half with stakes from CIAT. The Media Luna stakes produced an average yield of 25 t/ha, and those from CIAT 42 t/ha. This large difference is mainly due to poor quality of stakes produced in Media Luna (also reported last year), possibly due to infection with diplodia. Thus, germination of Media Luna stakes was much lower than those from CIAT-Palmira. High levels of N application at planting had a marked negative effect on germination as well as on yield. Apparently, in this sandy soil urea is much more mobile than in heavier soils, and even band applications of only 50 kg N/ha affected germination and usually decreased yields. For that reason, split application of urea improved germination and generally resulted in higher yields. However, while root yields were very high, they tended to be quite inconsistent and treatment effects were different for the two sources of stakes. Highest yields of 52.3 t/ha were obtained with a complete fertilization of 50 kg N, 50 kg P and 50 kg K/ha. Thus, unlike previous years, there was some response to P and K, as well as to N.

Figure 7 shows the overall response of two varieties in Pescador, Cauca to four levels and four sources of N, half applied at planting and half at 60 days (except DAP and SCU, in which all was applied at planting). Only in M Col 113 was there a significant response to the first level of 25 kg N/ha, while in CMC 92, the response was not significant. In M Col 113, the ammonium sulphate was a superior source

of N, while in CMC 92 there were no significant differences among N sources. Sulphur-coated urea (SCU), was only efective at the highest rate of application, while diammonium phosphate (DAP) appeared toxic at the higher rates, resulting in decreased yields above 25 kg N/ha. Negative effects of high appliction of DAP on early growth of cassava have been observed before. Thus, this product should probably be used in split applications or in band applications further away (10 cm) from the stake. In the sandy soils of Media Luna it is definitely recommended to fractionate fertilizer applications, applying half at planting and half at the beginning of the next rainy season. A compound fertilizer like 15-15-15 is recommended to supply, not only N, but also P and K.

Cassava Forage Production: Varieties x Fertilization

Cassava tops are exceptionally high in crude protein; these can be harvested by cutting the unlignified part of the stem, after which the remaining stem resprouts. Under good growing conditions this can be repeated about every three months, resulting in four cuts per year. However, cassava varieties differ in their ability to produce vigorous top growth and to resprout after cutting. For that reazon, sixteen varieties or breeding lines were grown in CIAT-Quilichao, ten of which were adapted to the cold climate of ECZ 5 and six to the warmer climate of ECZ-4. Stakes were planted at 70x56 cm (25500 plants/ha). These plants received 1 t/ha of 10-20-20, either all applied at planting or fractionated with 40% at planting and 20% after each of three cuts.

Table 5 shows the total amount of dry forage produced in four cuts (the last corresponding to final harvest), as well as the yield of fresh roots at harvest at 14 months. Dry forage production varied from 7.5 to 13.9 t/ha. Varieties adapted to ECZ-5 had a more vigorous top growth and resprouted better than those from ECZ-4, as indicated by the average dry forage production of 11.6 t/ha for the former and 8.8 t/ha for the latter. However, those varieties producing much forage tended to have low root yields and vice versa. Thus, varieties can be selected that are mainly producers of tops (CG 358-3), those that produce mainly roots (CM 489-1), and those that produce relatively high yields of both tops and roots (Regional Negrita and CM 849-1).

Figure 8 shows that, in general, both the yields of forage and its crude protein content decreased with each successive cutting. When all fertilizers were applied at planting, forage yields were highest in the first two cuts but much lower in the last two cuts compared with the fractionated fertilization treatment. Thus forage yields are related to fertilization and decline when the soil becomes exhausted, mainly of N. Average N extraction in tops was 326 kg/ha, compared with 133 kg K, and 31 kg P; extraction in the root harvest was approximately 25 kg N, 26 kg K and 7 kg P/ha. The chemical fertilizer supplied about 100 kg N/ha, part of which would probably be lost through leaching. Thus, of the total amount of 350 kg N extracted by the crop, about 250-300 kg N must come from either the soil organic matter or from other sources. At planting the soil contained 6.8% O.M. and approximately 5,000 kg of total N /ha. If the soil were mineralizing N at a high rate of 3% per year, it would produce only 175 kg N/ha in 14 months. The remaining 75-125 kg N absorbed by cassava in this trial could have come from N in

rainwater (usually no more than 20-30 kg) or through N-fixation by association with N-fixing bacteria, either on the roots or on leaf surfaces. This should be further investigated.

Land preparation

Cassava, when grown on steep slopes, causes considerable soil erosion. Previous trials to determine cultural practices that reduce erosion indicated that soil losses increase dramatically as the intensity of soil preparation increases. Ideally, cassava should be grown without soil prepration or with a minimum of tillage. However, being a root crop, cassava needs a fairly loose soil to allow roots to expand, and intensive soil preparation is usually recommended to increase yields. To determine to what extent soil preparation can be reduced without significantly affecting yields, a trial was planted in a clay loam soil of Carimagua with four varieties planted with each of eight methods of soil preparation.

Table 6 shows that there were significant differences between varieties in their response to soil preparation treatment. In general, high yields were obtained only with an adequate loosening of the soil, either by plowing, discing and ridging, by discing and ridging alone, or by the use of the mechanical cassava harvester. Thus, if the previous cassava crop is harvested with the tractor-mounted blade, the soil will be sufficiently loosened to allow the next crop to be planted without further preparation, or with only additional ridging. This significantly reduces (by about 10%) the total cost of cassava production. It also leaves large clods at the soil surface, which facilitate the infiltration of water and reduce run-off and erosion. Reduced tillage with only a disc harrow, with chissels or by strip preparation significantly reduced yields in this rather compacted soil. Lowest yields of all varieties were obtained by planting without soil preparation. Since top growth was not significantly affected by reduced tillage it may be presumed that soil compaction in the zero and reduced tillage treatments did not allow sufficient root expansion, resulting in low root yields and harvest index. The latter decreased from 0.46 with adequate tillage to 0.23 with no tillage.

Erosion control

Cultural practices that reduce soil losses due to erosion in cassava grown on steep slopes were further investigated in four sites: one trial in each of the Las Pilas and Mondomito farms in the municipality of Mondomo, Cauca, and two in adjacent fields in CIAT-Popayan. Chemical and physical characteristics of these soils are shown in Table 1. Experimental techniques have been described in previous CIAT Cassava Program Annual Reports and consisted of monthly collections of eroded soil into plastic covered channels below each plot.

In Las Pilas, a previous erosion control trial (see CIAT Cassava Program Annual Report, 1985) was repeated using slight modifications in the treatments. Table 7 shows the effect of methods of soil preparation, live barriers and intercrops, weed control practices and fertilization on cassava yield and soil losses due to erosion. For cassava grown on a 40% slope, soil losses were slightly higher than

those of last year, but still very low (and within the acceptable level of 10 t/ha/year). Intensification of soil preparation from no tillage to plowing with oxen, slightly increased erosion, but markedly increased cassava yields. Strip preparation along the contour reduced erosion, but also reduced cassava yields compared with full preparation, mainly due to severe weed competition from the adjacent unprepared strips. To improve yields these unprepared strips should be gradually reduced in width during weeding.

The live barrier of Imperial grass reduced erosion but also reduced yields; a similar barrier of Elephants grass did not control erosion and caused a severe reduction of cassava yield due to competition from the very aggresive and superficial root system of this cut-and-carry grass. Intercropping with beans had no effect on erosion and decreased cassava yields only slightly.

Weed control with only pre-emergent herbicides and machete was expected to reduce erosion, but had the opposite effect. Throughout the growth cycle this treatment produced the greatest soil losses, although cassava growth was vigorous and yields were high. These results are contrary to those obtained last year and should be reconfirmed. Large soil losses by the use of herbicides in coffee have been reported by the Coffee Federation.

As in previous trials, application of fertilizers markedly reduced erosion by increasing plant growth and soil cover. Fertilization also increased yield at least 3-4 fold. Thus, in these highly infertile soils, fertilizer application is one of the most effective erosion control practices.

Six of the 12 treatments in Las Pilas were repeated on a 30% slope in Mondomito to see whether the results are repeatable in another site with a slightly different soil (see Table 1) but a very similar climate.

Table 8 shows that results were similar in terms of soil losses, these being highest in the unfertilized treatment, intermediate in the fertilized treatment with standard oxen preparation, and very low in the strip or the no-preparation treatment. The live barrier of Imperial was slightly less effective and the bean intercropping was more effective than in Las Pilas.

Unlike Las Pilas, where no tillage produced low yields, in Mondomito, highest yields were actually obtained with this treatment, probably because this soil had previously been plowed and cropped in cassava reducing soil compaction and weed competition. Lack of fertilization reduced yields, but not as dramatically as in Las Pilas; strip preparation had a similar detrimental effect on yield as in Las Pilas. From these two trials it was concluded that similar treatments had more or less the same effect in these two different sites, but there were some important differences due to differences in native soil fertility, soil texture, and cultivation history.

In Popayan, in a rather light textured and extremely erodable soil, two trials were conducted side by side. In collaboration with the Bean Program, cassava and beans were planted as the test crops. In one site with 30% slope, different methods of manual soil preparation were compared; in the other site with 15% slope alternative mechanical preparation techniques were used. Soil losses were determined in the same manner as described above, during a 17 month growth cycle of cassava. During this same time period, four consecutive bean crops were planted. The last bean crop, however, was lost due to drought and soil-borne diseases.

Table 9 shows the results for the manually prepared site. In both cassava and beans, soil losses were low without preparation or with strip preparation; however, strip preparation drastically reduced yields due to smaller area actually planted and more weed competition. Largest soil losses were obtained with the complete land preparation with hoe, but this treatment also resulted in highest yields in both crops. Imperial grass barriers reduced erosion, very significantly in the case of beans, but also reduced yields. Preparation of individual planting holes for cassava resulted in unusually high soil losses, which have not been observed before.

While cassava causes severe erosion, this trial showed that four crops of beans produced much greater soil losses than one crop of cassava grown in the same time span. Due to its slow rate of establishment, soil losses were initially greater in cassava than in beans. However, once the cassava was well established and covered the ground at 6 months, further soil losses were minimal. On the other hand, beans produce a rapid plant canopy, protecting soil from erosion, but this canopy is also lost very quickly due to leaf fall and harvest; the soil is exposed for at least two months until the next canopy is established. Moreover, during harvest and replanting the soil is disturbed, hand weeding is required frequently, resulting in the complete pulverization of the originally blocky soil structure. All these factors lead to much greater soil losses due to erosion in beans (and other short cycle crops) compared with a long-cycle crop like cassava.

This was corroborated in the second trial with tractor preparation (Table 10). Again soil losses in beans were about four times greater than in cassava, and reached an alarming level of 105 t/ha when the soil was plowed twice before the first planting. Although the slope was much less in this than in the previous trial, soil losses due to erosion were 2-3 times greater in both crops. This is because tractor preparation loosens the soil deeper and more intensively than hand preparation, resulting in a much more erodable soil surface. In both beans and cassava, plowing caused a much greater soil loss than either the use of rotatiller or chissels. Figure 9 shows that in both beans and cassava the plowed treatment initially caused little erosion due to the blocky structure of the soil surface. But once these clods were broken down by rainfall impact or hoe weeding, the loss of soil accelerated and continued due to the greater depth of preparation, reaching alarming rates every time the soil was unprotected by a plant canopy.

Strip preparation with a rotatiller mini-tractor, gave the lowest soil losses in both crops, but also produced the lowest yields. This treatment leads to the rapid formation of narrow terraces, which are very effective in decreasing run-off; however, during heavy rainfall drainage is impaired and crops can suffer from root rot problems. This, and heavy competition from the unprepared strip, resulted in low yields. Strip preparation along the contour, either by hand, by oxen or tractor, is probably the most effective method of erosion control on steep slopes, but care should be taken to prevent weed competition and excess water should be drained down-slope in especially protected waterways. With these precautions yields should not be affected by this method of land preparation, while both erosion and the cost of preparation are markedly reduced. Using these simple agronomic practices, cassava and other row crops can be grown on fairly steep slopes without causing severe erosion and without the need for expensive engineering projects. However, it is recommended that the planting of food crops be restricted to the flattest and most fertile areas of the farm, improving soil fertility through annual fertilizer applications and, when necessary, rotating among food crops. In this way crop yields increase and the area under cultivation could decrease, leaving the steeper slopes for permanent crops, pastures and trees.

TABLE 1. Chemical and physical characteristics of soils where experiments were conducted.

LOCATION	O.M. %	pH	P ppm	Al	Ca	Mg	K	Sand	Silt	Clay
				me $100\ g^{-1}$				%		
Quilichao, Cauca	7.1	4.3	1.8	2.8	1.80	0.70	0.18	13.2	24.7	62.1
Pescador, Cauca	7.7	4.7	2.5	3.0	0.62	0.32	0.12	16.2	21.0	62.8
Las Pilas: Mondomo, Cauca	11.0	5.5	6.0	0.5	0.53	0.16	0.16	31.7	39.3	29.0
Mondomito: Mondomo, Cauca	5.7	4.5	0.5	2.5	0.62	0.19	0.11	19.2	22.2	58.6
CIAT-Popayan, Cauca	28.2	5.4	2.0	2.2	0.53	0.17	0.18	45.5	33.0	21.5
Media Luna, Magdalena	0.6	5.3	5.3	-	0.76	0.25	0.07	79.6	5.5	14.9
Carimagua, Meta	3.4	4.1	1.3	3.6	0.22	0.11	0.07	13.8	49.9	36.3

TABLE 2.

Cassava varieties and hybrids adapted to low levels of soil P in CIAT-Quilichao

Variety	Adaptation index[a] to low P	Variety	Adaptation index[a] to low P
M Bra 13	2.42	M Col 2084	1.91
M Bra 36	2.10	M Col 2089	2.26
M Bra 41	3.57	M Cub 10	2.51
M Bra 44	2.45	M Cub 20	2.07
M Bra 50	2.68	M Cub 25	2.25
M Bra 54	2.44	M Cub 26	2.33
M Bra 97	3.47	M Ecu 68	1.84
M Bra 188	3.21	M Ecu 74	1.84
M Col 27	2.16	M Mex 9	1.74
M Col 149	2.90	M Per. 8	2.31
M Col 157	2.97	M Ven 143	2.60
M Col 213	2.16	M Ven 168	1.81
M Col 253	2.72	M Ven 205	2.08
M Col 346	3.32	M Ven 295	1.74
M Col 628	2.55	M Ven 310	1.66
M Col 679	2.82	M Ven 321	2.33
M Col 946	2.02	HMC 2	1.74
M Col 1047	2.28	CM 91-3	1.52
M Col 1185	3.11	CM 305-41	2.54
M Col 1513	2.85	CM 308-197	2.06
M Col 1514	2.99	CM 323-87	2.30
M Col 1654	2.75	CM 342-170	1.60
M Col 1684	1.66	CM 344-71	2.17
M Col 1778	2.73	CM 430-37	1.84
M Col 1894	1.86	CM 507-37	1.84
M Col 2061	1.65	CM 523-7	2.51
M Col 2067	1.90	CM 728-3	2.24
CM 849-1	2.76	CM 852-4	2.08
CM 942-14	1.75	CM 981-8	2.50

[a]Average of at least 3 evaluations in field screenings

$$\text{Low P adaptation index} = \frac{\text{Yield oP} \times \text{yield 75P}}{\bar{X}\ \text{Yield oP} \times \bar{X}\ \text{yield 75P}}$$

TABLE 3. Evaluation of cassava varieties and breeding lines for tolerance to low-soil P in Mondomo, Cauca

	Cassava Yield t/ha		Low P
	oP	100 P[1]	Adap.Index[2]
M Col 113	13.9	23.4	0.95
M Col 1522 (CMC 92)	10.8	26.0	0.82
M Col 2016	13.1	17.6	0.67
M Col 2019	13.2	18.2	0.70
M Col 2058 (Popayán)	14.7	13.8	0.59
M Col 2059 (Sata Dovio)	10.1	27.5	0.81
M Col 2060 (Regional Amarilla)	15.2	35.5	1.57
M Col 2257 (Americana)	18.5	21.6	1.16
M Col 2258 (Batata)	15.8	31.5	1.45
M Col 2259 (Selección 40)	15.7	22.4	1.02
M Col 2260 (Regional Negrita)	20.2	26.1	1.54
Bajuna Negra	16.9	33.0	1.62
HMC-1	11.4	21.3	0.71
HMC-2	12.5	36.2	1.32
CG 358-3	12.8	16.2	0.60
CG 401-3	15.1	21.9	0.96
CG 401-6	14.0	20.7	0.84
CG 406-5	12.6	18.7	0.69

1 100P = 100 kg P/ha, band applied as TSP

2 Low P adaptation index = $\frac{\text{Yield oP X yield 100 P}}{\bar{X}\text{ yield oP X }\bar{X}\text{ yield 100 P}}$

TABLE 4. Effect of different levels, sources, times and methods of applications of N on cassava fresh root yield in Media Luna

	Germination %		Root Yield t/ha	
	A	B	A	B
0N	92	98	23.0	44.3
25 kg N/ha, as urea, 100% at planting	81	98	24.4	45.5
50 kg N/ha, as urea, 100% at planting	78	84	38.0	33.8
75 kg N/ha, as urea, 100% at planting	55	87	17.0	47.2
100 kg N/ha,as urea, 100% at planting	48	67	15.8	40.8
50 kg N/ha, as urea, 100% at planting	78	84	38.0	33.8
50 kg N/ha, as $(NH_4)_2SO_4$, at planting	78	98	20.3	42.9
50 kg N/ha, as SCU , at planting	78	95	28.4	41.3
Foliar application with 1% urea at 60, 90, 120 days	83	100	27.9	36.3
Foliar application with 2% urea at 60, 90, 120 days	90	98	27.8	37.1
Foliar application with 4% urea at 60, 90, 120 days	94	98	24.1	42.5
50 kg N/ha, as urea + foliar application with 2% urea	63	90	27.8	37.8
50 kg N/ha, as urea + foliar application 4% urea	66	76	20.3	49.0
100 kg N/ha, as urea + foliar application 2% urea	47	58	17.3	31.2
100 kg N/ha, as urea + foliar application 4% urea	67	66	25.0	47.3
50 kg N/ha, as urea, 100% at planting	78	84	38.0	33.8
50 kg N/ha, as urea, 50% at 0, 50% at 60 days	79	90	38.7	39.2
50 kg N/ha, as urea, 50% at 0, 50% at 120 days	80	97	24.4	45.9
50 kg N/ha, as urea, 33% at 0, 60 and 120 days	88	95	35.6	46.9
50 kg N, 50 kg P, 50 kg K/ha at planting	75	95	28.9	52.3

A = Stakes of M Ven 25 from Media Luna

B = Stakes of M Ven 25 from CIAT-Palmira

TABLE 5.

Cassava forage and its nitrogen and crude protein content obtained in four cuts during 14 months in Quilichao. Root production corresponds with the final harvest of the whole plant.

Variety		Dry forage[a] t/ha	Fresh roots t/ha	In forage N kg/ha	In forage Crude protein t/ha
1	CMC 92	11.7	8.9	378	2.4
2	Regional Amarilla	12.3	18.8	345	2.1
3	Regional Negrita	11.5	28.3	366	2.3
4	Americana	10.6	13.8	338	2.1
5	Algodona	13.0	11.5	394	2.5
6	Selección 40	12.0	20.6	355	2.2
7	Batata	11.1	12.7	353	2.2
8	M Col 2016	9.8	20.6	326	2.0
9	M Col 2019	10.1	13.7	326	2.0
10	CG 358-3	13.9	13.1	351	2.2
11	HMC 1	8.4	28.4	298	1.9
12	CM 489-1	7.5	38.0	244	1.5
13	CM 430-37	9.4	17.5	269	1.7
14	M Ven 218	10.9	12.4	333	2.1
15	CM 507-37	7.6	27.7	260	1.6
16	CM 849-1	9.3	37.4	277	1.7
	$\bar{X}$ 1-10	11.6	16.2	353	2.2
	$\bar{X}$ 11-16	8.8	26.9	280	1.7

[a] Sum of 4 cuts during 14 months ; 1 t/ha of 10-20-20 applied at planting

NOTE; Varieties 1 to 10 are from the cold climate (ECZ5) while varieties 11 to 16 are from warmer climates (ECZ4)

TABLE 6. Effect of different methods of soil preparation on the yield of four cassava varieties grown in Carimagua

		CM 507-37	CM 523-7	CM 430-37	M Ven 77	$\bar{X}$
1	Disc harrow-plow-disc harrow-ridger	25.7	16.9	14.6	11.9	17.3
2	Disc harrow - ridger	23.6	18.6	17.3	6.2	16.4
3	Disc harrow	17.3	12.9	8.4	9.5	12.0
4	Cassava harvester - ridger	30.1	14.8	13.0	8.9	16.7
5	Cassava harvester	26.1	16.0	12.3	6.7	15.3
6	Chissels every 40 cm	21.0	14.8	8.4	7.5	12.9
7	One meter strips prepared with chissels alternated with one meter unprepared strips	14.9	11.9	5.9	8.6	10.3
8	Without preparation	11.4	6.5	3.6	6.2	6.9
		21.2	14.0	10.5	8.1	

LSD (5%) varieties = 1.80

LSD (5%) treatments = 2.53

LSD (5%) vxt = 5.08

TABLE 7.

Effect of agronomic practices on cassava yield and on soil losses due to erosion on 40% slope in Las Pilas farm, Mondomo, Cauca

	Agronomic practices	Cassava yield[a] t/ha	Dry soil loss[b] t/ha
A	Methods of soil preparation		
	1. Without preparation	13.5	0.82
	2. 1 meter strips plowed with oxen, alternated with 1 m unprepated strips	12.0	0.84
	3. Large planting holes (30x60cm) for 2 stakes	18.7	1.15
	4 1 pass with oxen drawn plow	31.7	1.82
B	Live barriers or intercrops		
	5. Without barriers or intercrops	31.7	1.82
	6. Live barrier of Imperial grass	23.3	1.28
	7. Live barrier of Elephants grass	7.3	2.52
	8. Double row cassava intercropped with beans	26.4	2.00
C	Weed control		
	9. Weed control with hoe	31.7	1.82
	10. Pre-emergent herbicides and machete	29.3	8.28
D.	Fertilization		
	11. With fertilizers, 1 pass with plow	31.7	1.82
	12. Without fertilizers, 1 pass with plow	10.5	6.45
	13. With fertilizers, preparation planting holes	18.7	1.15
	14. Without fertilizers, preparation planting holes	3.9	2.49

[a] Cassava fresh root yield, average two varieties, CMC 92 and Reg. Amarilla.

[b] Dry soil loss 12 months

TABLE 8.

Effect of agronomic practices on cassava yield and on soil losses due to erosion on 30% slope in Mondomito, Cauca

	Agronomic practices	Cassava yield[a] t/ha	Dry soil loss[b] t/ha
1	Without preparation	25.8	1.93
2	1 meter strips, plowed with oxen alternated with 1 m unprepared strips	9.7	1.02
3	1 pass with oxen-drawn plow	21.5	2.41
4	1 pass with oxen-drawn plow, no fertilization	16.9	3.82
5	1 pass with oxen-drawn plow, live barrier of Imperial	19.6	3.02
6	1 pass with oxen-drawn plow, iter-cropped with beans	16.9	1.86

[a] Fresh cassava roots, average of three varieties, CMC 92, Regional Amarilla, and Selección 40.

[b] Dry soil loss during 12 months.

TABLE 9.

Effect of manual land preparation methods on yields of cassava and beans, as well as on soil losses due to erosion on a 30% slope in Popayan, Cauca.

Crop	Method of soil preparation	Yield[a] t/ha	Dry soil loss[b] t/ha
Cassava	Without preparation	17.4	3.02
	Preparation of individual planting holes 30 x 30 cm	19.2	12.24
	1 meter strips prepared with hoe alternated with 1 meter without preparation	9.6	5.90
	Complete land preparation with hoe	24.4	6.27
	Complete land preparation with hoe live barriers of Imperial grass	16.1	5.79
Beans	1 meter strips prepared with hoe, alternated with 0,5 m without preparation	1.60	9.24
	Complete land preparation with hoe	3.11	44.68
	Complete land preparation with hoe, live barriers of Imperial grass	2.05	15.55

[a] Cassava fresh root yields after 17 months, average of two varieties CMC 92 and Regional Amarilla.

[b] Bean yield is sum of three consecutive harvests of BAT 1297, fourth bean crop was lost due to drought and diseases.

Total dry soil loss in 17 months.

TABLE 10.

Effect of mechanical land preparation methods on yields of cassava and beans, as well as on soil losses due to erosion on a 15% slope in Popayan, Cauca.

Crop	Method of land preparation	Yield[a] t/ha	Dry soil loss[b] t/ha
Cassava	1 pass with rotatiller	16.6	10.71
	1 pass with plow	21.4	26.50
	1 pass with chisels	17.5	16.21
	1 meter strips with rotatiller alternated with 1 m strips without preparation	12.3	7.50
Beans	1 pass with rotatiller	2.39	58.78
	2 passes with rotatiller	2.89	54.82
	2 passes with plow	2.15	104.68
	1 pass with chisels	2.20	51.18
	1 meter strips with rotatiller alternated with 1 m. strips without preparation	1.34	4.61

[a] Cassava fresh root yields after 17 months, average of two varieties
Bean yield is sum of three consecutive harvests of BAT 1297; fourth bean crop was lost due to drought and diseases.

[b] Total dry soil loss in 17 months.

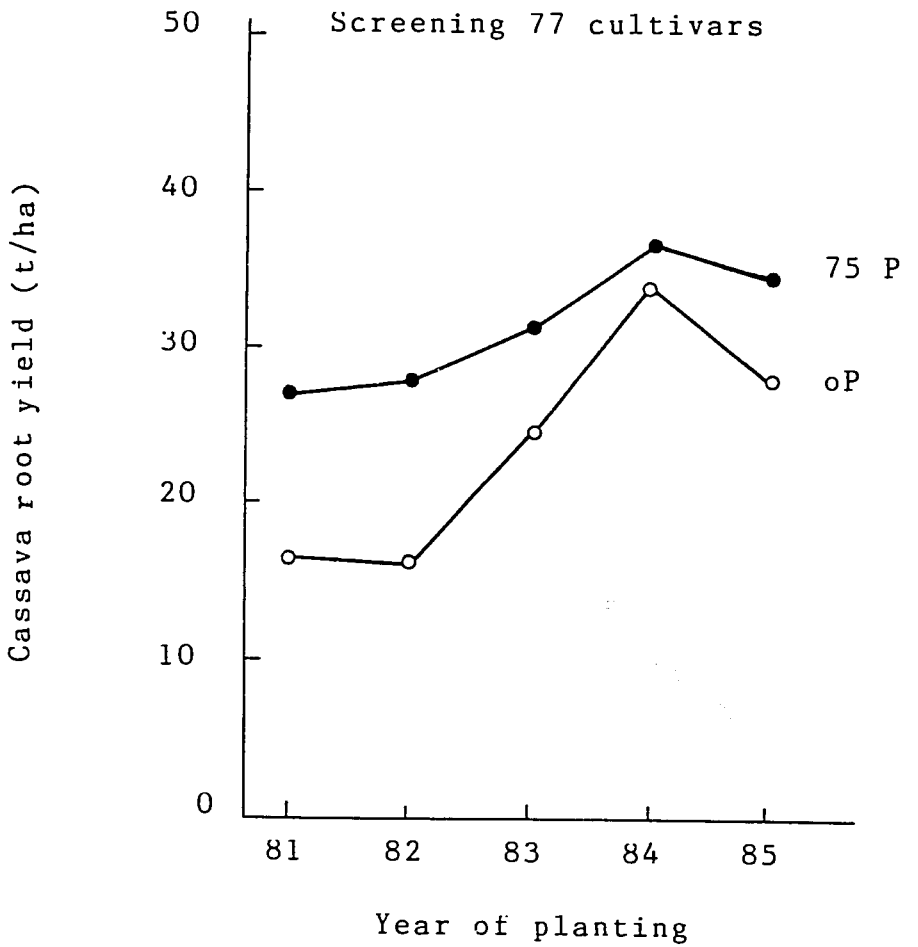


FIGURE 1. Average root yields of 77 cassava germplasm accessions and breeding lines grown with and without P application in five screenings for low-P adaptation in Quilichao.

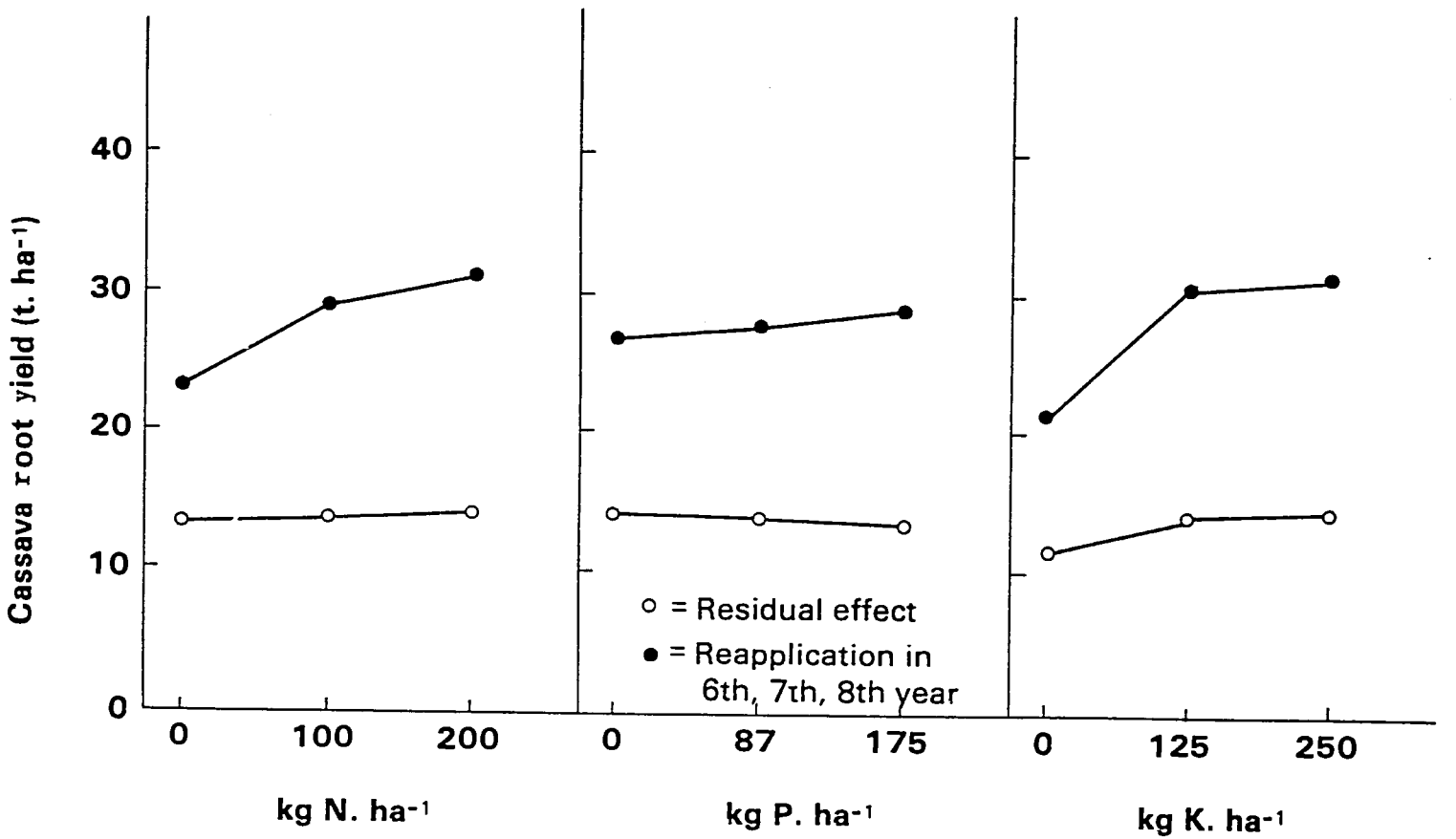


FIGURE 2. Response of the eighth consecutive cassava crop to three levels of N, P or K, applied either only with the first crop (residual effect) or annually starting with the sixth crop in CIAT-Quilichao.

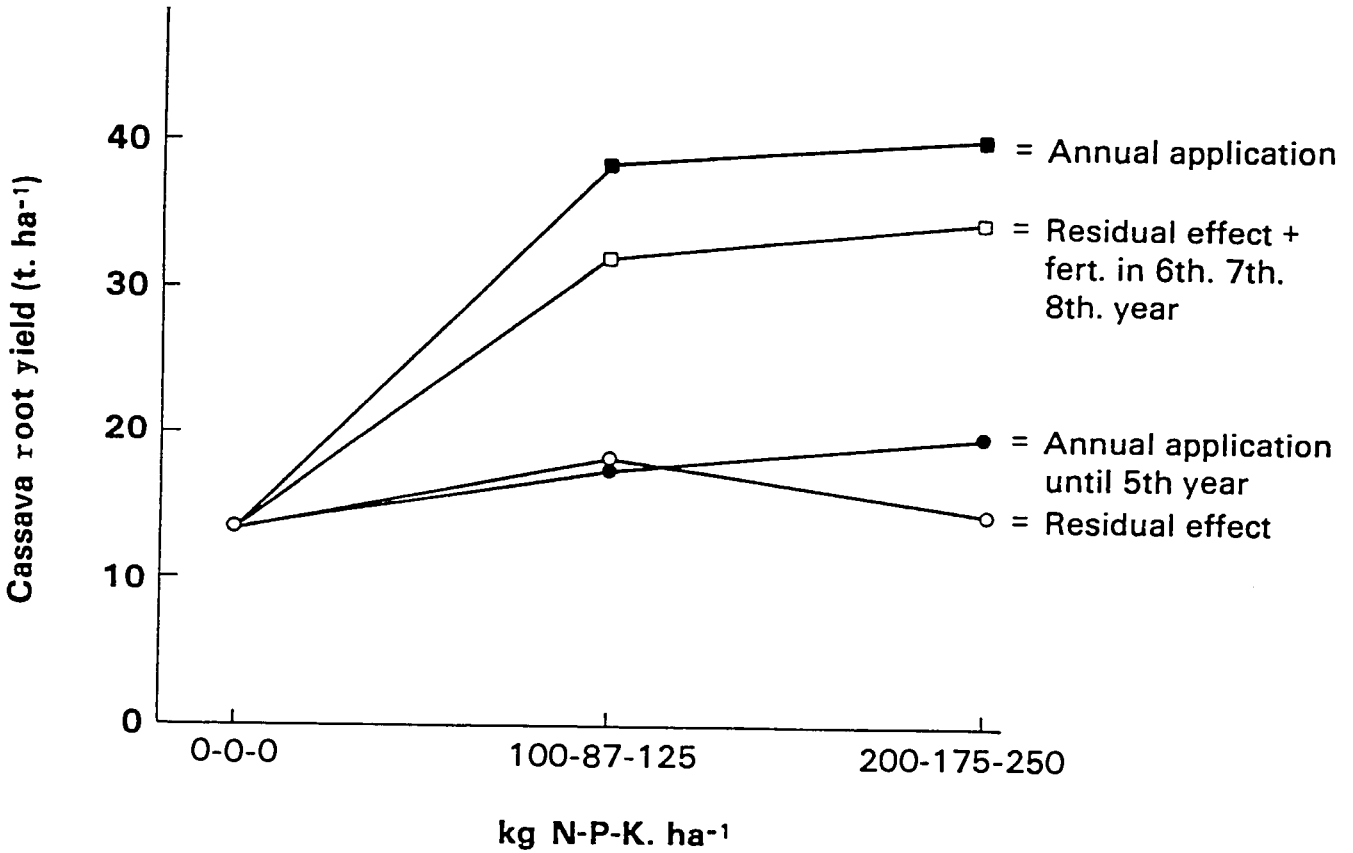


FIGURE 3. Response of the eighth consecutive cassava crop in Quilichao to intermediate or high applications of NPK, applied either annually with each crop, annually after the sixth crop, annually until the 5th crop or only in the first crop (residual effect).

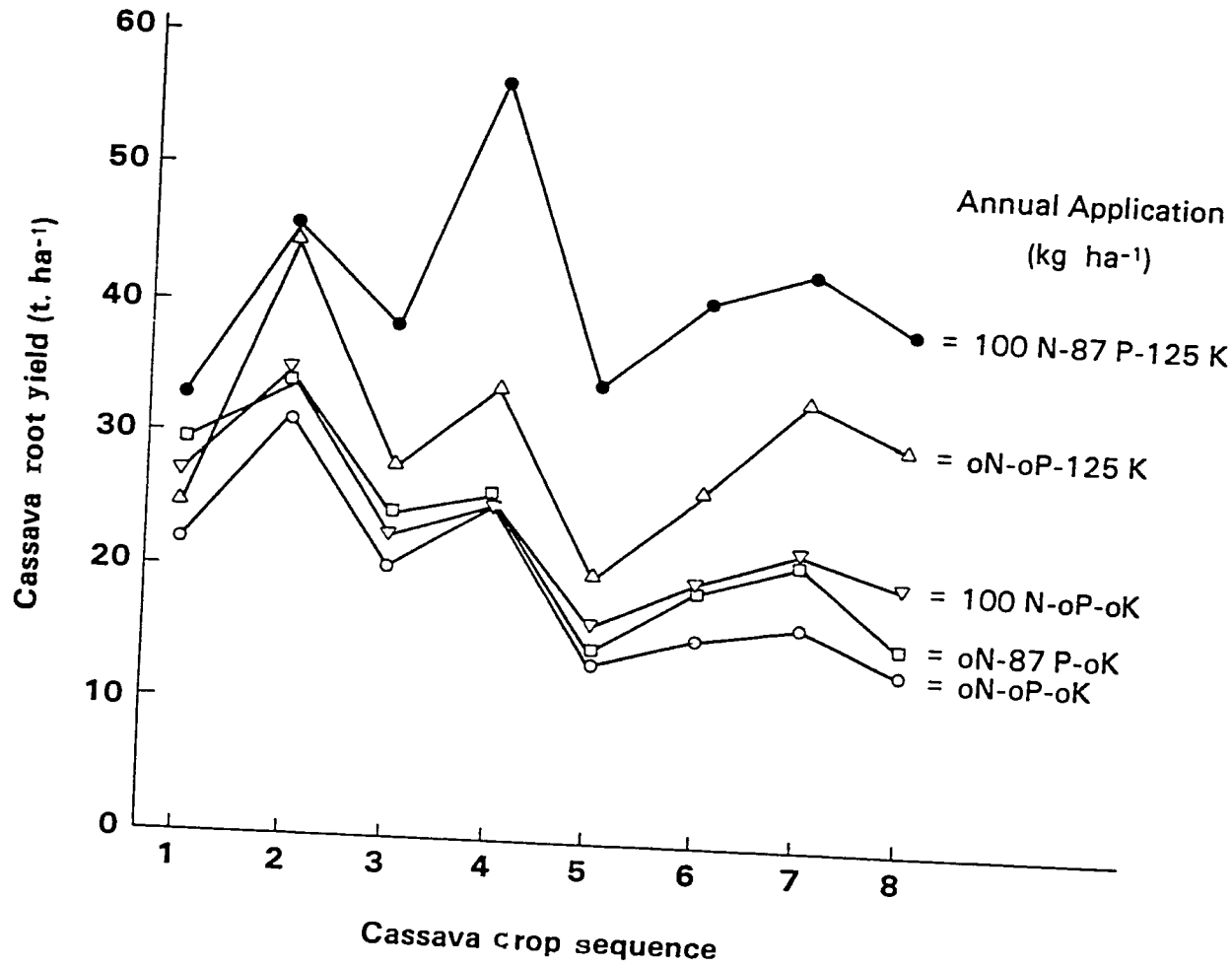


FIGURE 4. Yields of eight consecutive cassava crops grown in CIAT-Quilichao without fertilizers or with annual applications of N, P or K alone, or in combination.

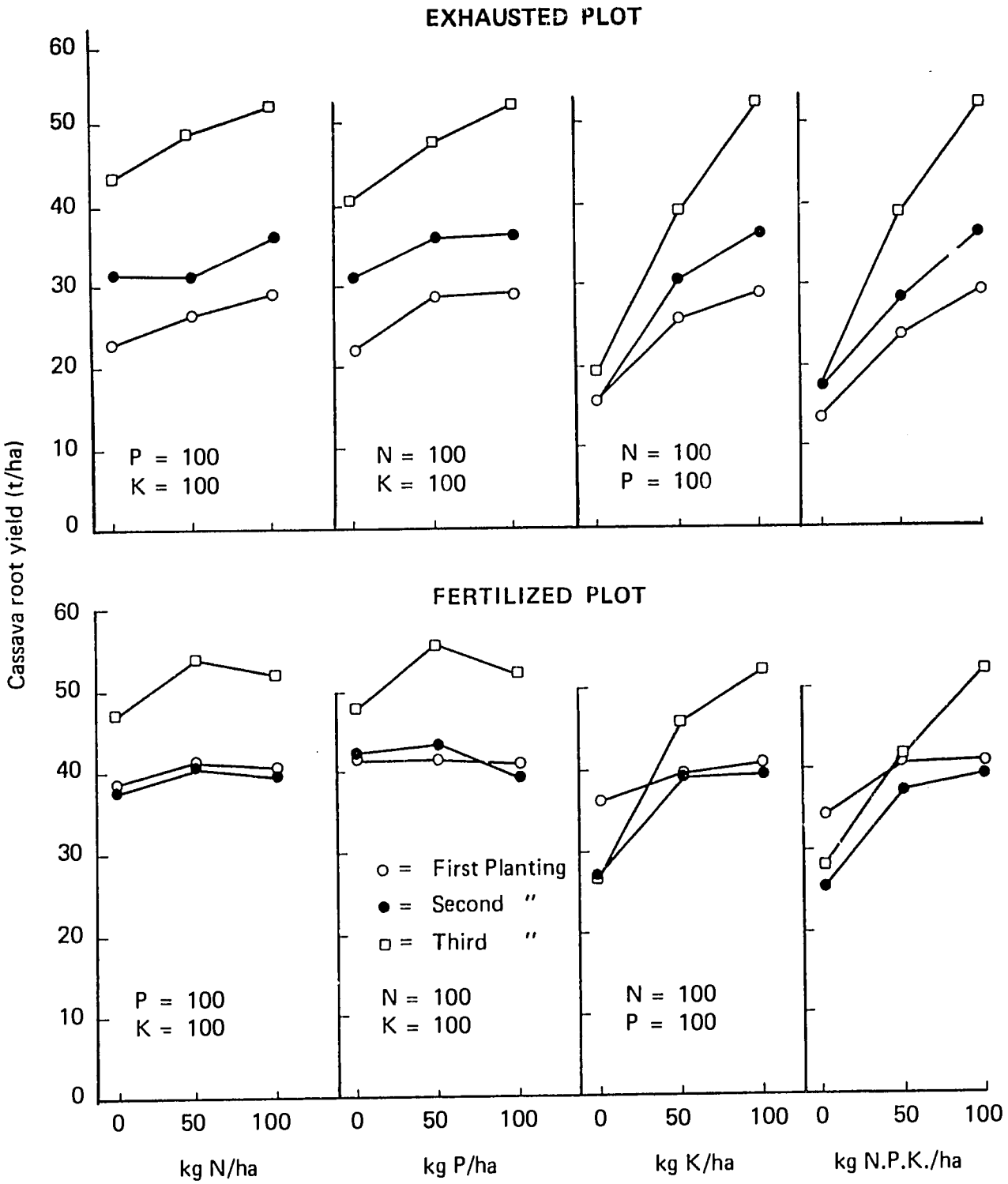


Figure 5. Response of three consecutive cassava crops to annual N, P and K applications in a previously exhausted plot (above) and an adjacent well-fertilized plot (below) in CIAT-Quilichao. Data are the average yields of M Col 1684 and CM 91-3.

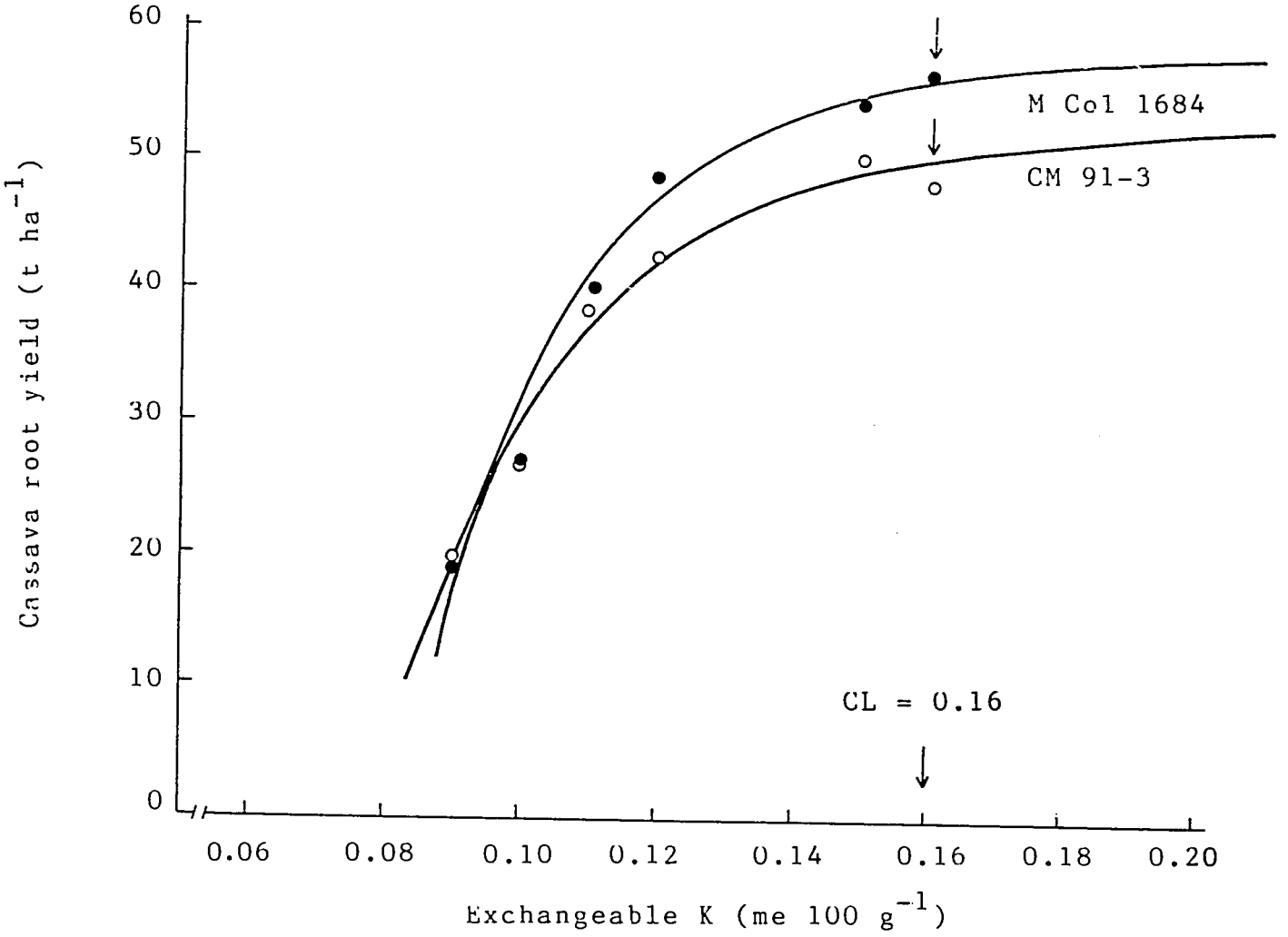


FIGURE 6. Relation between the yields of two cassava cultivars in Quilichao and the exchangeable K content of the soil, as determined by extraction with Bray II solution. Arrows indicate the critical level corresponding to 95% of maximum yield.

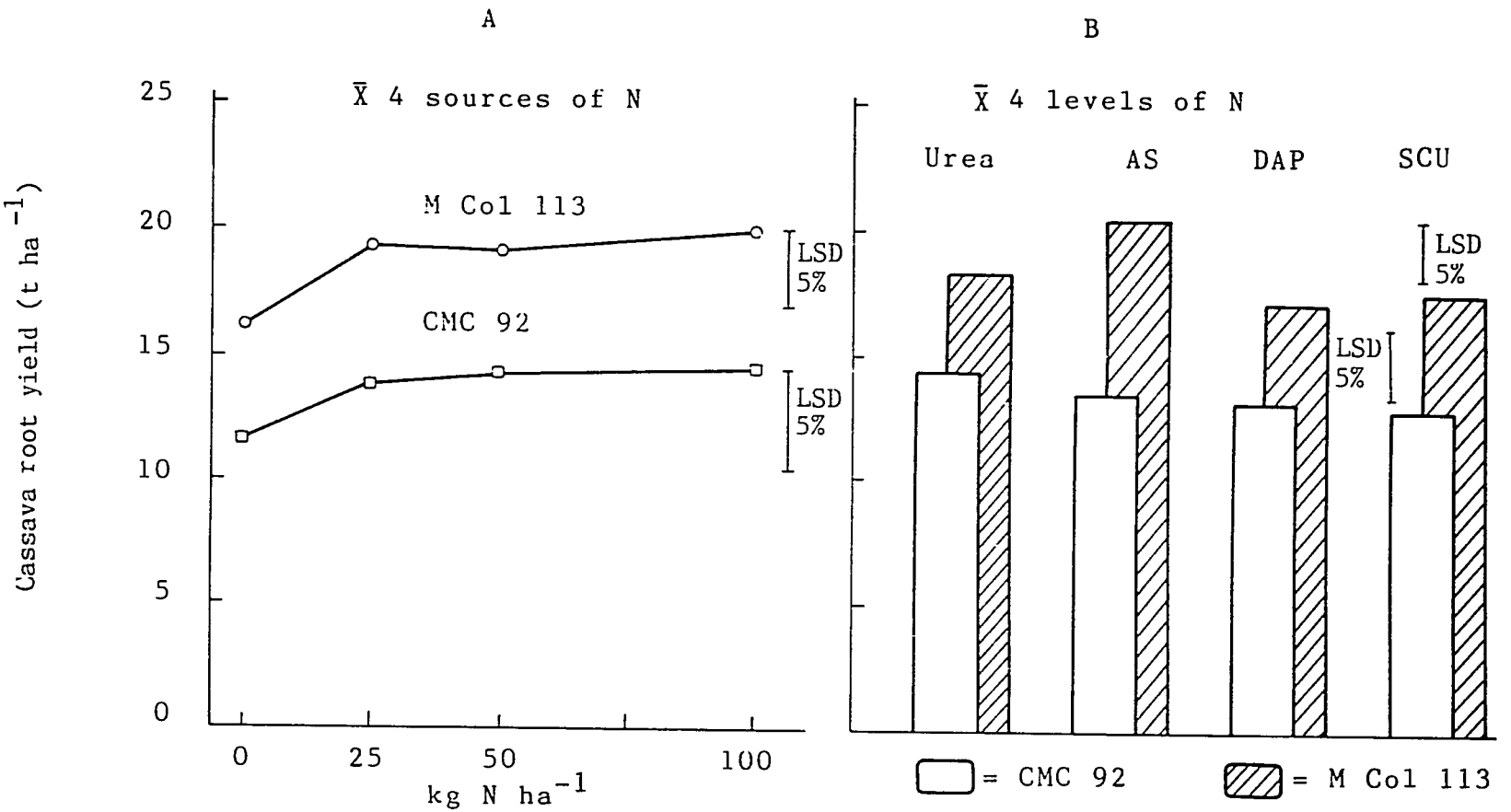


FIGURE 7. Effect of the application of four levels (A), and four sources (B) of N on the yield of two cassava cultivars in Pescador, Cauca. AS = ammonium sulfate, DAP = Diamonium phosphate, and SCU = sulfur coated urea.

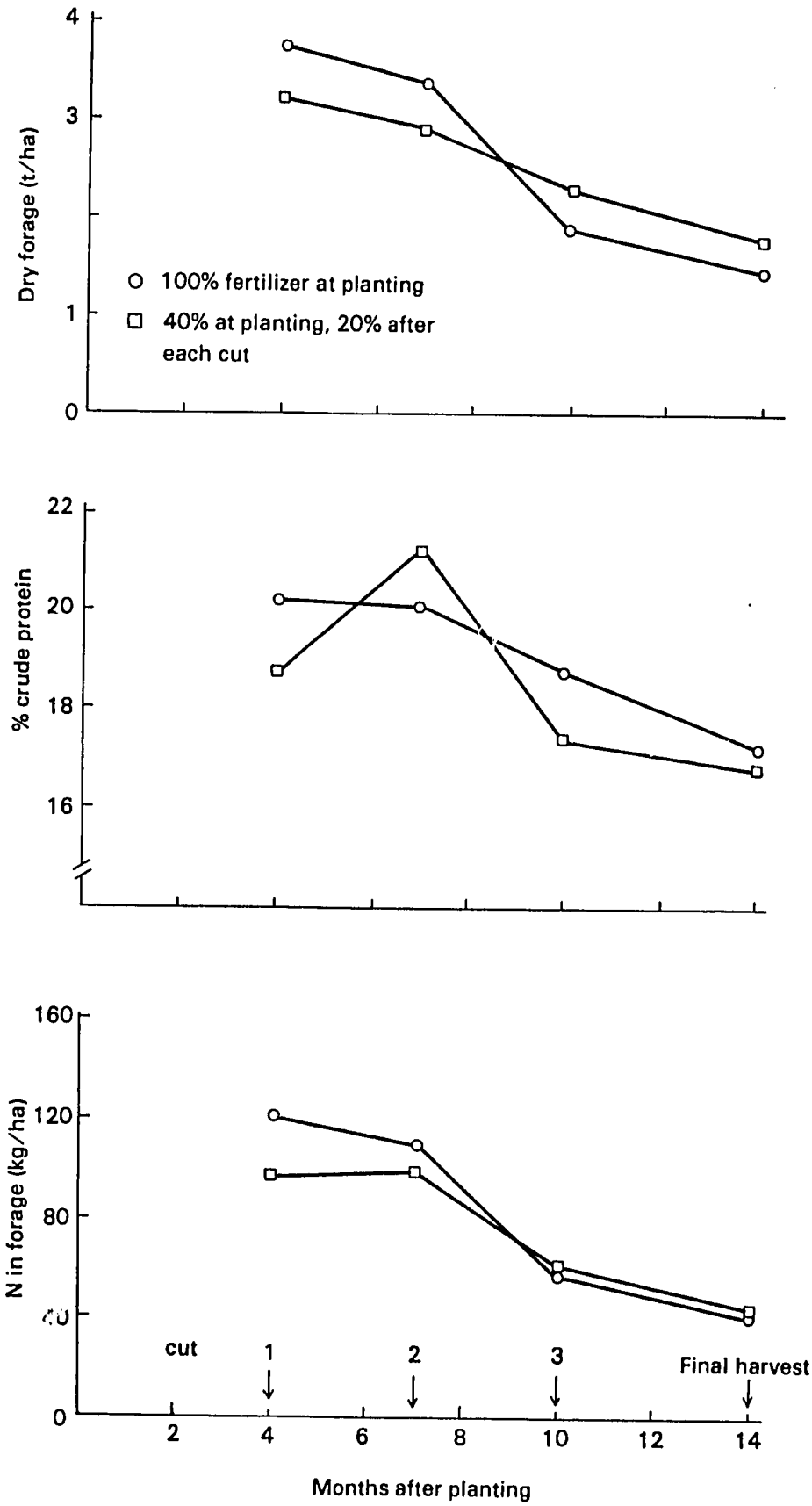


FIGURE 8. Effect of time of application of 1 t ha^{-1} of 10-20-20 on dry forage production, crude protein concentration and N content of four cuttings of cassava tops. Data are averages of 16 varieties grown in Quilichao.

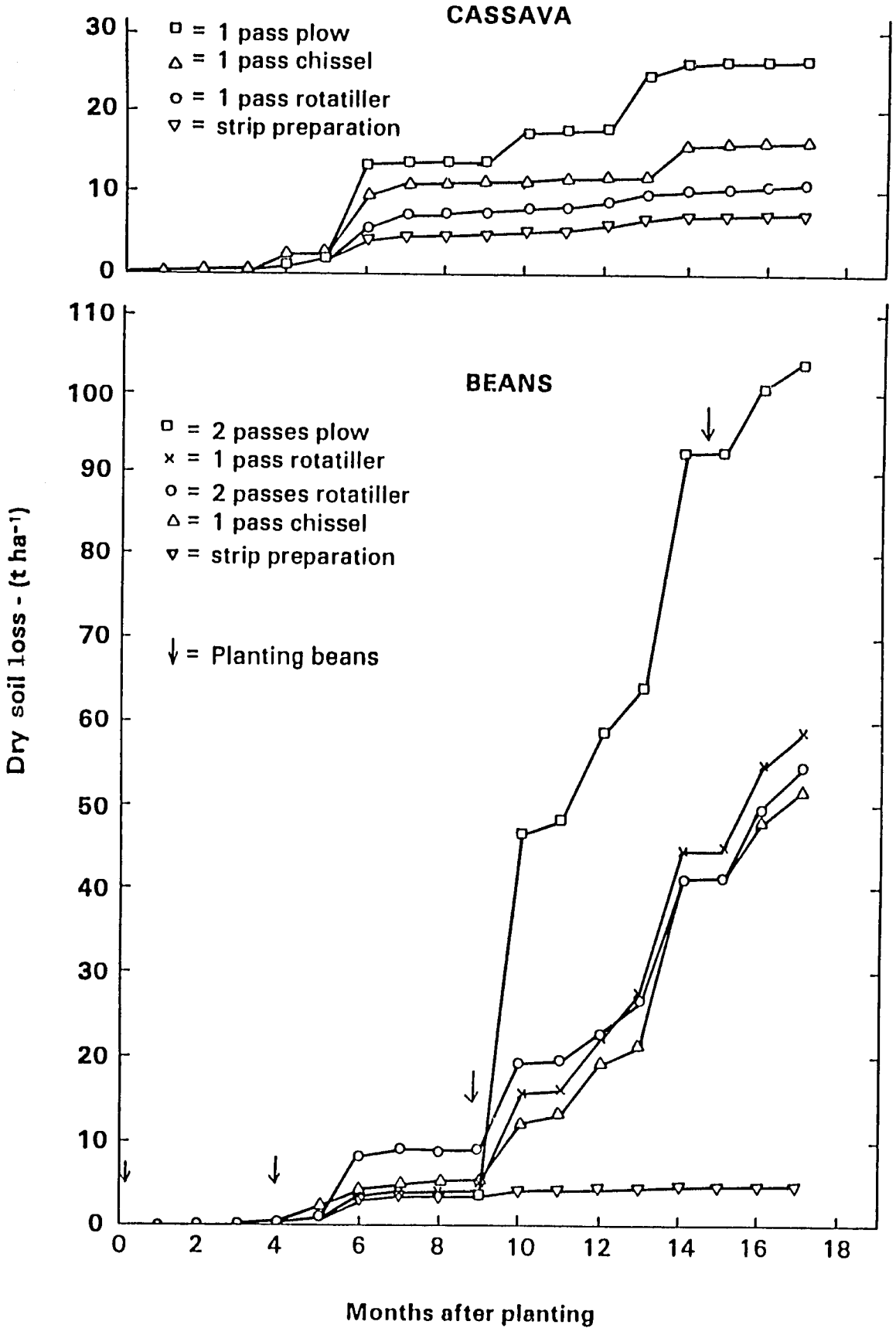


FIGURE 9. Cumulative soil loss due to erosion in one crop of cassava and four consecutive crops of beans, as effected by different methods of mechanical soil preparation on a 15% slope in Popayan.

ENTOMOLOGY

Mites

Cassava is attacked by more than 50 species of mites. Those most frequently reported on cassava are Mononychellus tanajoa, M. progresivus, M. caribbeanae, Tetranychus urticae, T. cinnabarinus, Oligonychus peruvianus and O. gossypii.

Given the widespread occurrence of mites, the frequency of a 2-5 month dry season in many cassava growing areas, and the potentially severe losses following mite attacks, several methods of control have been investigated (see previous CIAT Cassava Program Annual Reports); these include cultural, chemical, biological and host plant resistance. Due to the increased cassava losses on the African continent caused by green mites, efforts in biological control have received priority in recent years.

Past efforts in the biological control of cassava mites, included limited surveys by the Commonwealth Institute of Biological Control and CIAT of cassava mite predators in the neotropics, followed by the introduction into Africa of insect predators such as Oligota minuta. Current efforts involved the systematic surveying of major cassava growing regions throughout the neotropics. Emphasis is given to the phytoseiid or predator mite complex.

Predator/Prey Studies:

1) Chemical Exclusion Studies.

The traditional method to evaluate the importance of predation in population biology has been to compare the distribution and abundance of prey in plots with and without predators. Techniques used for predator removal or exclusion depend primarily upon the size and mobility of the predators and include trapping, manual removal, barriers such as field cages or clip cages and chemical elimination via selective pesticides. Because of the small size of the more important green mite predators such as the phytoseiid mite complex and Oligota minuta, manual removal and trapping are not practical methods. Plants grown in field cages often develop abnormally, and leaf clip cages interfere with normal prey movement.

A suitable pesticide for predator exclusion should kill a high proportion of the predators without killing the prey, should not be phytotoxic or phytostimulatory, and should not bring about hormoligosis in the prey. A study of the permethrin selectivity, with respect to the green mite and its predators was carried out, both in the laboratory and in the field. These results will be useful for future studies to evaluate the efficiency of cassava mite predators.

The mite species tested were Mononychellus progresivus and Tetranychus urticae; the predator species evaluated were Typhlodromalus limonicus and Oligota minuta. For the two mite species, laboratory bioassays were conducted with Ambush 50 (BASF), a commercial formulation of permethrin containing 500 g AI/L. Leaf discs (1.6 cm diameter) cut from mite-free greenhouse grown cassava plants of M Col 113 were dipped

for 5 seconds in a permethrin solution. The concentrations tested were 0.0, 1.875, 3.75, 7.5, 15.0, 30.0 and 60.0 g AI/100 L. Six discs per concentration were placed bottom side up in petri dishes lined with moist cotton. After drying for 3 hours at room temperature, five gravid female mites were transferred to each disc and were held in a growth chamber (27°C, 70% RH) for 24 hours (12 hour photoperiod) and mortality assessed.

T. limonicus was assayed by placing a leaf disc in a 2 cm plastic arena. O. minuta was tested by impregnating pieces of filter paper (6.5 X 4.0 cm) with a permethrin solution and inserting it in a plastic vial. Ten field collected beetles were introduced into each vial and mortality assessed after 24 hours.

Results show that O. minuta and T. limonicus are very susceptible to permethrin (Fig. 1). M. progresivus is 32-58 times more resistant to permethrin than T. limonicus and 12-21 times more resistant than O. minuta. The highest dose tested for T. urticae (60 g AI/100 L), killed only 30% of the exposed individuals, demonstrating an extreme resistance of T. urticae.

The difference in susceptibility to permethrin between predator and prey species is more than an order of magnitude, and 2 g AI/100 L would be expected to eliminate virtually all the predators, without killing significant numbers of the prey species. The results predict that at higher concentrations, about 8 g AI/100 L, some field mortality of M. progresivus might occur. Based on these conclusions 0, 2 and 8 g AI/100L were chosen for field testing.

The objective of field testing was to verify that permethrin could eliminate T. limonicus under field conditions. O. minuta was not encountered in significant numbers in the field to be evaluated . The clones M Col 22 (mite susceptible) and M Bra 12 (tolerant) were planted in a split plot design and treated with permethrin at a 0, 2 and 8 g AI/100 L. T. limonicus abundance was estimated by collecting 4 samples of leaves from the 15th node of randomly selected plants per subplot.

Mite damage was observed only in the experimental plots treated with 8 g AI/100 L. Mite density began to increase in the 8 g AI/100L plots immediately after permethin application (Table 1). It was only in these plots that M. progresivus showed the pattern typical of a mite outbreak. Mite numbers in the control plots and the 2 g AI/100 L plots, never reached outbreak levels. Throughout the period of biweekly permethrin applications, higher numbers of predators occurred in control plots than in treated plots (Table 2).

There are several hypothesis to explain the higher M. progresivus numbers in cassava field plots where T. limonicus was excluded with permethrin applications.

Phytostimulation, improved host nutritional quality or increased M. progresivus fecundity on permethrin treated plots, could have produced similar patterns of mite abundance as density-dependent predation by T. limonicus. Additional studies have shown that there is no evidence that

permethrin affects cassava growth or nutritional quality nor that it enhances M. progresivus population growth either through increased fecundity or improved egg viability. These results support the usefulness of permethrin as a predator exclusion agent in the studies of the cassava mite predator-prey complex.

2) Predator/Prey Population Fluctuations

Field studies were initiated to study the population fluctuations of phytophagous mites and their predators. The vertical distribution the plant of mites and their natural enemies was characterized, as well as the timing appearance of each species.

At CIAT, 1/2 hectare of the clone MCol 22 was divided into four equal blocks and seventeen plants were randomly sampled from each block by collecting a leaf from the lower, middle and apical portion of each plant. Sacrificed leaves were placed in plastic bags, brought to the laboratory, and mites and predators were removed with a mite brushing machine.

Results from the first year of the experiment reveal that a complex of phytophagous and predator species exist in CIAT cassava fields. M. progresivus, M. tanajoa, M. mcgregori, T. urticae, T. cinnabarinus, O. peruvianus, Tenuipalpidae and occasionally Calacarus guerreroi comprised the phytophagous complex. Predator species included Oligota minuta, Stethorus trudens, the phytoseiids T. limonicus, E. concordis and Neoseiulus anonymus and representatives of the family Ascidae. Phytoseiids were the most numerous predators, with T. limonicus comprising about 80% of the population (Fig. 2).

Mononychellus spp. were most numerous in the apical portion of the plant; however, relatively high numbers were found throughout the plant (Fig. 3). Tetranychus and Oligonychus spp. were also distributed at all levels, but at much lower densities. Tenuipalpid mites were found mainly on lower leaves. Predatory mites were distributed throughout the plant, with highest densities at the mid level.

Mononychellus and Tetranychus spp. can be detected soon after plant establishment and persist throughout the growth cycle although poplations decline to very low densities during the wet season.

Phytoseiids are also present from the initial stags of plant growth. T. limonicus is the most persistant species. Appearance of E. concordis and N. anonymus (Fig. 2) may be correlated with high densities of Mononychellus spp. populations of the Mononychellus mite.

T. limonicus is well adapted to survive rainy periods when phytophagus mite populations are lowest and, therefore, is present at the initiation of mite buildups at the onset of the dry season. Ability to survive the wet season is an important characteristic for successful biological control of Mononychellus spp.

Exploration for natural enemies

The prerequisite to the exploration phase of any clasical biological control program is the accurate identification of the pest

species, its geographic origin and distribution. The taxonomy of Mononychellus spp. in Africa and the Americas is still somewhat unclear. The validity of the two species M. tanajoa (Bondar) and M. progresivus Doreste, is being questioned. Morphological and ecological characteristics of both species are quite similar, suggesting a single species with considerable morphological variation. Until this conflict is resolved the cassava green mites (CGM) are often referred to as "Mononychellus tanajoa (Bondar) Complex".

An accurate geographic description of this complex is part of the exploration phase of the Cassava Mite Biological Control (CMBC) project. For exploration purposes this complex is treated as a single species.

Cassava green mites are found throughout many of the cassava growing regions of the Americas, especially where a 2 to 5 month dry season occurs. The observed association between Mononychellus and Manihot, with very few successful alternate hosts, suggests a coevolutionary relationship. The centers of diversity of Manihot species in the neotropics appear as a major center in northeastern Brasil and a secondary or minor center is southwestern Mexico. If we accept that Mononychellus and Manihot coevolved and therefore have similar centers of diversity, then the most successful natural enemies associated with Mononychellus may be found in the same regions. Temperature and rainfall pattern and intensity may have a major influence in defining the distribution of natural enemy species. The size of the phytoseiid complex suggests a diverse predator fauna whose distribution is influenced by climatic conditions and perhaps geographic barriers.

This reasoning has a possible influence on exploration for natural enemies. It suggests that:

1) All cassava growing areas where the green mites occur should be explored.
2) Northeastern Brazil and Southwestern Mexico should be emphasized for exploration.
3) Agroclimatological similarities between the cassava growing regions of Africa and the neotropics need to be defined.
4) Ecological homologues between Africa and Latin America will help to focus the search for natural enemies.

Cassava-growing regions of the neotropics matching African conditions will be sampled. These regions lie primarily between 25°N.L. and 25° S.L. which comprise the tropics, and run parallel to the African cassava belt. Based on climatological data such as dry season length, rainfall patterns and monthly precipitation averages, from hundreds of meteorological stations all over tropical America on a computer data base, the timing of explorations to cassava growing regions is being established.

Colombia has received priority status for exploration at this stage of the project due to the case of access from CIAT headquarters, its considerable cassava production, and its diverse ecological habitats where cassava is grown. Localities within Colombia already surveyed

include the North Coast Region (between 72-76° W.L. and 8-12° N.L.), the Cauca Valley, the Magdalena Valley and the Santanderes region.

Additional survey activity, although limited, has occured in the states of Tabasco and Veracruz in Mexico, some regions of the Brazilian Northeast and Southeast as well as regions of Cuba and Panama.

Taxonomic Inventory

Explorations in selected areas of Colombia have identified 46 phytoseiid species associated with cassava mites (Table 4). Six are new species. These 46 phytoseiidae species are represented by 15 genera: the most important genera, in terms of species represented are Amblyseius (7), Euseius (7), Neoseiulus 6), Proprioseiopsis (5), Typhlodromalus (4), Typhlodromips (4), and Galendromus (3). They were found feeding on several species of phytophagous mites; the species most frequently fed upon were Mononychellus progresivus, O. peruvianus, O. gossipii and Tetranychus spp. (Table 5).

The most important phytoseiids identified, in terms of the number of sampling sites where they were found were Typhlodromalus limonicus, Neosiulus anonymus, Galendromus helveolus and Euseius concordis (Figure 3). T. limonicus was found in 88% of the sites surveyed, N. anonymus, 36.5% G. heveolus 30.3 and E. concordis, 27%.

Many of the 46 species were only present in a few sites and, therefore, probably not very important in a cassava mite biological control program. A morphological description and distribution register has been developed for each of the species.

Rearing of Phytoseiidae

Selected species identified during the exploration phase are brought to CIAT for rearing and study. Suitable rearing procedures for small laboratory colonies have been developed for many photoseiid species. Two methods are currently being employed for phytoseiid colonization.

A. Mesa-Bellotti rearing method

The rearing unit is a rectangular transparent plastic tray (30 X 25 X 20 cm). In the lid of the tray a 10 cm diameter hole is sealed with filter paper, providing aeration and preventing mite escape. Two platforms, each consisting of an aluminum frame with nylon threads about 3 cm apart, are placed within the tray. The first platform is at 5 cm from the bottom and the second is 5 cm above the first. Initially, cassava leaves containing phytophagous mites are placed on the first (lower) frame and about 50 phytoseiid females are introduced to the system. After 3 days, (actual time may vary with species), when the prey has been consumed and the leaves start to deteriorate, new infested leaves are added to the upper frame allowing the predators to migrate upward in search of prey. Three days later, the leaves on the lower frame are removed and replaced by those from the upper frame, and new prey infested leaves are added to the upper frame. This process is repeated continually. Each tray can maintain a colony of about 500 to 800 individuals depending on the species. The trays are sealed with

masking tape and placed in a moat (a shallow tray with water) to prevent escape and migration to other colonies.

This method has been successful for rearing N. anonymous, N. ideaus, N. chilenesis, P. macropilis, G. annectens, and T. limonicus, at 25°C and 75% RH. With the exception of N. anonymus and P. persimilis, the other species developed best with a temperature fluctuation of ± 2°C. Introduction of 10 mealybug nymphs (Phenacoccus spp) per tray for improves development of T. limonicus.

B. McMurtry-Scriven Rearing Method

This method is based on that originally developed by McMurtry and Scriven (1965). Modifications include: (1) The use of castor bean (Ricinus comunis) pollen; (2) The replacement of the heavy construction paper originally used, by a square acrylic plate painted brown; and (3) the replacement of cellucotton with tissue paper. This method has been successfully used for rearing E. concordis, Clavidromus transvaalensis and Proprioseiopsis cannaensis.

Biological Studies

Basic studies including life cycles, host preference and consumption (choosing between M. progresivus and T. urticae) and life tables, are developed for the most promising phytoseiid species collected during the exploration phase. Some of these have been presented in previous CIAT Cassava Program Annual Reports (1984 and 1985). Three species were studied during 1986, Galendromus annectens, Neoseiulus ideaus and Phytoseiulus persimilis.

An experimental arena was designed for studies involving direct observation of individual mite predators.. A small plastic vial, 2 cm in diameter is cut to 1.2 cm in height. The bottom of the vial is covered with a moist filter paper disc to provide humidity; a cassava leaf disc containing prey is placed over the filter paper disc. One phytoseiid adult, usually a female, is introduced and the vial is covered with transparent plastic (Pro-Plastic Saran Wrap). The leaf disc is replaced as needed to provide new food for the predacious mite. This method is used for studies of prey consumption, life tables and developmental times of individual mites. All studies described in this report on the three aforementioned species, were done at constant temperatures of 25°C, 70-75% RH, and 12L:12D photoperiod.

Average development time, from egg to adult, for G. annectens, N. ideaus, and P. persimilis was 6.14, 4.22 and 4.8 days respectively when feeding on T. urticae, and 5.72, 4.19 and 4.02 days respectively when feeding on M. progresivus (Table 6). G. annectens has the longest development period regardless of the two prey species and is of longest duration feeding on T. urticae. N. ideaus shows no significant difference between the two prey species, while P. persimilis is significantly shorter when M. progresivus is the prey.

The duration of pre-oviposition, oviposition and post oviposition (adult longevity) was measured for the three species. None of the 3 species showed a significant difference in the pre-ovipositional period regardless of prey species. G. annectans had the longest

pre-oviposition period of the three species tested. (Table 7). There was no significant difference in the duration of the ovipositional period for G. annectens and N. ideaus, regardless of the prey species. However, P. persimilis had a significantly shorter ovipositional period when feeding on M. progresivus. Male/female copulation was obligatory for egg production with all 3 phytoseiid species.

The adult longevity of G. annectens and N. ideaus, was not significantly different with either prey species. P. persimilis post-ovipositonal period and adult longevity were shorter with M. progresivus prey (Figure 4).

Results of fecundity experiments reveal no significant difference when G. annectens and N. ideaus were offered either of the two prey species (Table 8). Fecundity of P. persimilis was significantly higher when feeding on T. urticae (31.3 eggs per female) compared to M. progresivus (22.6 eggs per female). These data show that T. urticae is superior to M. progresiuvs as prey for P. persimilis.

P. persimilis is an introduced species which probably originated in the Mediterranean and Chile is the only South American country that has reported this species. P. persimilis is one of the most studied phytoseiid species and probably one of the most utilized mite predators in biological control programs for phytophagous species of the genus Tetranychus. Its adaptation and preference for Tetranychus vs. Mononychellus species, is clear; however, P. persimilis displayed high reproductive potential feeding on M. progresivus when compared to the other two phytoseiid species (3.1 eggs per female per day vs. 1.9 and 2.2 for N. ideaus and G. annectens respectively). These data confirm previous reports that P. persimilis has one of the highest reproductive potentials of any of the studied phytoseiid species. The use of P. persimilis for control of Mononychellus is questionable if T. urticae is also present; however, N. ideaus and G. annectens may be suitable even if both genera are present.

Life Tables

Life tables were constructed according to the principles of Anderwarth and Birch (1954). The intrinsic rate of increase (Rm) for P. persimilis was 0.28 with either T. urticae and M. progresivus as prey (Tables 9 and 10). There was also no effect of prey species on the Rm of N. ideaus; however G. nnectens had a lower Rm with T. urticae (0.18) as prey (0.18) compared to M. progresivus (0.22).

The net reproductive rate (Ro) of P. persimilis was 26.6 female offspring per female when consuming T. urticae and decreased to 13.6 when offered M. progresivus. N. ideaus showed no effect of prey on Ro; however, G. annectens had a higher Ro (14.8) on M. progresivus than on T. urticae (12.9). The average generation time (T) was highest for G. annectens regardless of the prey species, and lowest for P. persimilis (9.3) when feeding on M. progresivus.

Survivorship curves (L_X), and age specific birth rates (M_X), are shown in Figures 5 and 6. Mortality was low for all three phytoseiids

until individuals reached adulthood. Birth rate was high during the early adult stage and decreased with age.

Promising Phytoseiidae Species

Several additional Phytoseiidae species have been selected for further study and possible introduction to Africa (Table 11).

Mealybugs

Cassava mealybugs continue to be a major pest problem in Africa (Phenacoccus manihoti) and parts of Brazil and Colombia (Phenacoccus herreni). Studies continue into the biology, ecology and natural enemies of P. herreni. Host plant resistance research on P. herreni is being given high priority. Additional studies are planned to characterize the severe plant damage symptoms of leaf and stem distortion.

Mealybug Sampling

Several studies have been done in past years to determine mealybug population fluctuation and dissemination within a field or on a single plant. A three year study in Carimagua has determined that field populations of mealybugs in the 1st and 2nd nymphal instars form small colonies, while 3rd instar nymphs and adults are observed as isolated individuals. From these data the sample size required at different confidence levels can be established. To estimate the population of 1st instar nymphs at the 15% level, 500, 3cm long terminals are the minimum number required. To estimate adult population at this level, 100 terminals would be required (Table 12).

Biology of P. herreni

The biology of P. herreni was measured in the growth chamber at four different temperatures, 20, 22, 25 and 30 with a constant RH of 70%. Generally, an increase in temperature resulted in a more rapid development for both males and females (Table 13). At 20C, female development time was 90 days, while at 25°C this was reduced to 38. For females, the optimal temperature appears to be between 25° and 30°C. At 30°C, female development time was 39 days, slightly higher than the results at 25°C. Males developed faster than females, approximately one half the development time. This difference in longevity is primarily in the adult stage. Male adults live for only few days, whereas females may live more than 3 weeks. At all temperatures evaluated, females were forming ovisacs and ovipositing eggs as the males reached adult stage (Figure 7).

Temperature effects on mortality of eggs, immature and adults of P. herreni. The egg stage showed a decrease in mortality as the temperature increased (Table 14). At 20°C there was a 31% egg mortality and this decreased to only 5% at 30°C. With immatures and adults mortality decreases with age, regardless of the temperature. For example at 25°C, first instar mortality was 43%, which decreased to 18% in the adult stage. In general, the greatest mortality due to temperature occurs in the first instar. In addition, the higher temperatures generally caused greater mortality. This is offset by the higher intrinsic rate of population increase at the higher temperatures.

The minimum temperature threshold for P. herreni was calculated at 17.5°C, with a 33°D and 193°D required for development by females and males respectively. (Table 13).

Biological Control

Several natural enemies of the mealybugs have been studied (See previous CIAT Cassava Program Annual Reports). Generally, parasites of P. herreni have received more attention than the predators in these studies. During 1986, the predator Cleothera notata (Coleoptera: Coccinellidae) was studied in detail. In this report, the biology of this predator will be presented.

A colony of C. notata was established in the laboratory in petri dishes at 25°C and 70±5% RH. The immature and adult stages of C. notata were fed mealybug egg masses and were able to complete their entire life cycle in the petri dishes.

Life cycle studies were done at three temperatures, 22, 25 and 30°C. The larval stage of C. notata passes through four instars, covered with a waxy coating, giving a cottony appearance which may cause them to be confused with the mealybug. The sex ratio is 1:1.

Development of C. notata was proportional to temperature. Developmental time of egg to adult was 42.3, 33.2 and 26.2 days for 22°, 25° and 30°C respectively (Table 15). The minimal temperature threshold was determined at 17.8°C, and the constant thermal temperature was 375 D° (day degrees) (Fig.8). These results, are similar to those of P. herreni (17.5°C and 330 D°).

The longevity of predator was longer than that of the prey at 22 and 25°C. Adult longevity of C. notata at 25°C, was more than 100 days (Figure 9).

Mealybug damage to cassava plants

A notable symptom of mealybug damage consists of leaf curling and deformation, resulting in a tight cabbage-like appearance of the apical growing points. The exact cause of these symptoms is not known. A preliminary experiment was done to evaluate the effect of the mealybug on Calcium (Ca) Phosphorous (P), Potassium (K) and Magnessium (Mg) extraction from the plant.

Three treatments using the variety CMC 40 were compared: (1) mealybug feeding; (2) mealybug feeding, but insects removed before the tissue analysis; (3) without mealybugs (control). Thirty day old plants (30 days after germination) were infested with one ovisac (250 to 300 eggs) per plant and the mealybug population was allowed to feed for 30 days. At this point, all mealybugs in treatment two were first removed from the plant, and then the terminals (10 cm) were removed and macerated. For treatment (1), terminal leaves were macerated with mealybugs and in treatment (3), the leaves, which never had mealybugs feeding on them, were macerated. Leaves were analyzed for percentage present of Ca, P, K and Mg. Ca is thought to be the most important element as it is basic for the formation of cell walls.

Results show that in treatment 2, when the mealybugs were removed, there was 32% less Ca than in the control and 30% less than in treatment 1, when mealybugs were macerated together with the leaves (Table 16). These results indicate that mealybugs are extracting considerable quantities of Ca from the leaves which may result in weakened, less rigid cell walls which manifests the curling characteristic of the damage. It is also possible that Ca influences hormonal activity as has recently been reported to be important in geotropism of roots. There were no such noticeable reductions in the other elements tested.

Resistance to mealybug

Screening of germplasm for resistance to the mealybug has continued. Of 900 accessions previously rated lower than 3 (0-5 scale) in field evaluations, 200 have been selected, based on this year's field evaluations at CIAT and Carimagua. These will be evaluated further in evaluation trials at both sites.

In evaluations at CIAT, a negative correlation (r=-0.59) was observed between initial vigor of accessions (0-5 scale) and subsequent mealybug damage (1-9 scale). Since $r^2 = 0.35$, only about one-third of the variability in damage symptom can be attributed to vigor as measured. This indicates that selection for more vigorous plants in the target environment (i.e. for good adaptation) might offer a degree of tolerance.

Thus, hybrids selected in the breeding program for adaptation and yield, might be expected to have increased tolerance over unimproved lines. This will be tested in yield trials with infested and protected treatments at Carimagua and CIAT. Other genetic factors influencing resistance will be investigated in field and greenhouse studies.

Cyrtomenus bergi

Previous research has shown that nymph and adult feeding by this insect, not only reduces the commercial value of the root for the fresh market consumption, but feeding damage can also reduce starch content by as much as 50%. Studies have also shown that high HCN varieties are "resistant", while the low HCN or sweet varieties are highly preferred. Research during this year evaluated the biology of C. bergi on low vs high HCN varieties.

Life Cycle

Previous studies have shown that C. bergi can complete its life cycle feeding on sweet or low HCN cassava varieties. A study was done comparing development time, oviposition and survival of C. bergi on low (CMC 40) vs. high (M Col 1684) HCN varieties. Eggs obtained from a laboratory colony were hatched and 1st instar nymphs were placed in a no choice situation at 25°C and 70±5% RH.

Development time of the five nymphal instars was twice as long on the high HCN variety (Table 17). Only 3 nymphs achieved adult status feeding on the bitter variety. The duration of the nymphal stage on the high HCN variety was 140 vs 71 days on the low HCN variety. Mortality in the first instar was high, regardless of HCN content, about 60%.

However, from the third through the fifth instars, mortality was considerably higher for those feeding on the high HCN variety.

Oviposition and adult mortality was tested by confining 20 pairs of C. bergi feeding on CMC 40 and M Col 1684, in the laboratory (25°C, 70 ± 5% RH). Prior to their confinement, adults had been feeding on low HCN or sweet varieties. Results show that over a period of 45 days, 234 eggs were oviposited on the sweet variety (CMC 40) compared to only 24 eggs oviposited on the bitter (M Col 1684) variety (Figure 10). During this same period, 13 of the 20 C. bergi adults survived on CMC 40 vs. only 5 survivors on M Col 1684 (Figure 10).

These results indicate that high HCN content in cassava roots is not only a feeding deterrant to C. bergi but also is detrimental to development and fecundity.

Chemical Control

Previous studies have shown that foliar systemic pesticide applications can reduce C. bergi damage to cassava roots. Present studies were designed to evaluate the application of soil applied pesticides on cassava root damage and adult presence of C. bergi.

Five plots of 25 plants each, were treated by incorporating aldrin (40 kg/ha) in the soil prior to planting. In five control plots no insecticide was applied. Two experiments were planted.

Results show that in both experiments aldrin was effective in controlling C. bergi and in reducing its damage to cassava roots. In the first experiment, an average of 5% of the roots were damaged in the aldrin treated plots vs. 44% in the untreated plots (Table 18). Results of the second experiment were similar; an average of 2% of the roots were damaged in the aldrin treated plots vs. 37% in the untreated plots. Evaluations were made by harvesting 10 plants from each block (2 plants per plot) each month for 9 months. C. bergi populations in the aldrin treated plots were 1.1 individuals per 10 plants in the first experiment and 0.2 per 10 plants in the second. C. bergi populations in the untreated plots were 6 per 10 plants in the first experiment, and 13 in the second.

In a separate experiment with treated (Aldrin) and untreated plots, C. bergi damage, root production and starch content were evaluated at the end of 9 month growth cycle. Root production was the same in the aldrin treated plots and the untreated plots (Table 18). Starch content was about 4% lower in the untreated plots in both the commercial and non-commercial roots.

The aldrin treatment resulted in a lower number of roots being damaged as well as a less severe damage grade for both commercial and non commercial roots (Table 18). In general, non commercial roots were more damaged than commercial roots for both the treated and untreated plots, indicating a preference by C. bergi for the smaller roots.

Population fluctuation

For the fourth consecutive crop cycle, the field dynamics of C. bergi populations were determined at CIAT-Quilichao from June 1985 to March 1986. Roots of the variety CMC 40 were periodically harvested and root damage and C bergi populations were evaluated.

Results are consistent with previous years; C. bergi feeding and root damage is initiated during the first month of the crop growth cycle and continues throughout the cycle (Fig.11). Insect population and root damage were low to moderate during the first 6 months of the crop cycle and then began to increase dramatically from months 7 through 10. This is also consistant with previous results.

Intercropping Crotalaria

Crotalaria sp. (Sunne hemp), intercropped with cassava has shown to be an effective means of control of C. bergi (CIAT Cassava Program Annual Report, 1984). The plant insecticidal qualities appear to be a repellent to the presence or the feeding of C. bergi. In the original studies, crotalaria was intercropped every row between the cassava rows. Additional studies were designed to evaluate different spacing patterns with crotalaria as a means of control. Crotalaria was planted between every two, six, ten, 15 and 20 rows of cassava and around the cassava plots. Each plot was 20 x 20 (400 plants) with three replications. Cassava was planted at 1 x 1 meter, and crotalaria was planted at 40 kg/ha 20 days after the cassava had germinated. Seven months after the cassava was planted, a second crotalaria planting was made. Intercropping and rotation experiments were done in collaboration with the Department of Entomology, University of Caldas.

Results show that none of the new planting patterns tested gave satisfactory results in controlling C. bergi attack and damage (Table 20). The percentage of roots damaged ranged from a low of 65%, when crotalaria was planted around the field, to a high of 92% when crotalaria was planted every 20 rows of cassava. In the control, those plots with no crotalaria, 90% of the roots were damaged. Damage ratings were highest in the control plots and significantly lower in the crotalaria intercropped plots. The lowest damage ratings occured when crotalaria was planted around the cassava plots. However, the damage was sufficiently high to render the roots unacceptable for the fresh market. Those roots with damage ratings above 2, would probably also be refused by the industrial starch market. There were no differences in crop yield.

In plots where crotalaria was intercropped between every cassava row, only 5% of the plants were damaged, with a damage rating of 0.45. These results, and those of previous experiments, indicate that the optimal system for obtaining damage free roots is by planting rotalaria between each row of cassava.

Rotation with Crotalaria

Experiments were designed to evaluate the effect of cassava rotation with crotalaria to control C. bergi damage. The experiment had the following treatments:

1) Cassava (variety Chiroza) planted continually for two consecutive years

2) Cassava intercropped with crotalaria between each cassava row
3) Cassava planted for one year followed by crotalaria
4) Crotalaria planted for one year followed by a cassava crop

Results show that rotating cassava with crotalaria will not effectively control or reduce root damage by C. bergi (Table 21). Cassava that was rotated with crotalaria actually had similar root damage (76%) to cassava harvested after two cycles of cassava (68%). The control plots, those planted with a row of crotalaria between every two rows of cassava resulted in only 5% of the roots being damaged. Damage severity was also considerably lower in the control plots.

These results indicate, that a cassava/crotalaria rotation will not give adequate C. bergi control, and support previous research by showing that a cassava/crotalaria intercrop will effectively reduce C. bergi damage.

Cassava Hornworm

Baculovirus erinnyis has previously been studied and found to be an effective control of Erynnis ello. The "virus" can be applied directly by collecting infected hornworm larvae, liquefying these in a blender and mixing with water and spraying on the cassava crop. The infected larvae may also be frozen and stored for a period of time, or through a liquification, separation, filtration, centrifuging and vacuum drying process, the virus is converted to a powered form.

A field experiment was conducted to evaluate a two year old powdered virus, infected hornworm larvae that had been held frozen for four years and recently collected virus infected hornworms. The following solutions were used:

1) Powder: Stock solution of 0.26% (0.13 grams in 50 cc distilled water).
2) 4 year frozen larvae: Stock solution of 6% (30 grams of infected larvae in 500 cc of distilled water).
3) Recently collected larva: stock solution of 6% (3 grams in 50 cc distilled water).

Fifteen plant plots separated by 20 rows of cassava were selected for treatment. The number of hornworm eggs and larvae were evaluated in each plot prior to application. A 10% solution of the previously described stock solutions was applied to the plots. Evaluations were made at 41, 89, 113 and 161 hours after the virus application.

Results indicate that recently collected virus infected hornworm were most successful in hornworm control, resulting in 100% mortality within 161 hours after application (Fig. 12). The virus from 4 year frozen hornworms resulted in a 67% control, indicating that the virus can be stored in infected hornworms for a considerable period. The powder form of the virus gave only a 20% mortality, indicating that this may not be an efficient way of storing the virus.

The hornworm virus, Baculovirus erinnyis, has been found naturally infesting cassava hornworms in Brazil, especially in the Santa Catarinha

area. By using the frozen hornworm/virus technique, the virus is available on a semi commercial basis (EPASE, the Santa Catarinha State Research Institute, prepares and stores the frozen virus and makes it available on request from other state research institutes or farmers). Through printed material, newspapers, audiotutorial units, radio and television, farmers are instructed on the collection, preparation, storage, and application of diseased hornworm larvae. The hornworm virus is being used effectively by farmers in numerous areas of Brazil.

Cassava Pest Complex

An evaluation of the insect and mite complex at CIAT has been carried out for the sixth consecutive crop cycle. Four 36 plant plots of four cassava varieties (CMC-40, M Col 113, M Col 22 and M Col 1684), received insecticide treatment (dimethoate 2 cc PC/E water, applied every 15 days); four plots of each variety received no insecticide treatment. Monthly evaluations of insect and mite populations and plant damage were done, and root yield was recorded.

Insect populations and damage, in general, were about the same as the previous year. The major pests attacking these varieties were mite (*Mononychellus* sp. and *Oligonychus* sp.), trips, lacebugs (*Vatiga manihotae*), mealybugs (*Phenacoccus Herreni*) and whiteflies (*Aleurotrachelus socialis* and *Trialeurodes variabilis*). Mite populations were high throughout the drier months (January to April) and there was considerable thrips damage throughout the growing cycle (Figures 13 and 14).

Yield reduction was greater than in previous years (Table 22); CMC 40, M Col 22 and M Col 1684 suffered a 50, 50 and 58% yield loss respectively. M Col 113 suffered no yield loss, and in fact, showed a slight (9%) increase in the non-treated over the treated plots. Thrips and mite damage were high on CMC 40 and M Col 1684, and probably accounted for their high yield loss. M Col 113 is resistant to thrips and suffered only low levels of mite damage. M Col 22 has intermediate resistance to thrips; however it is susceptible to mite and mealybugs and has a low leaf area index, often making it very sensitive to insect attack in terms of yield loss. M Col 113 is a farmer selected, traditional variety, grown in the Cauca Valley. It is well adapted to local edapho-climatic conditions and consistantly shows the lowest or least percentage of yield loss in these annual trials.

The disadvantages of M Col 1684 are clearly defined in both yield reduction (57%) and in the loss of planting material, a 60% reduction. Since planting material for the following trial is supplied by the harvest of the previous trial, M Col 1684 may be slowly degrading.

Table 1. Relative abundance of *M. progresivus* in cassava field plots treated with permethrin for predator exclusion.

Sampling date	Proportion infested[a]		
	Permethrin dose		
	0 g AI/100 L	2 g AI/100 L	8 g AI/100 L
31 Jan. [b]	0.314 A	0.331 A	0.392 A
13 Feb. [b]	0.322 A	0.331 A	0.386 A
14 Mar.	0.489 B	0.447 B	0.758 A
3 Apr.	0.600 B	0.547 B	0.906 A
7 May	0.025 A	0.067 A	0.106 A
29 May	0.019 B	0.081 AB	0.158 A

[a] Proportion of infested leaves in a sample of 45 leaves from the fifteenth node.
Proportions followed by the same letter are not significantly different at = .05 based on Scheffe's test.

[b] Before initiation of permethrin applications.

Table 2. Efficacy of permethrin in exclusion of *A. limonicus* from cassava field plots.

Sampling date	Mean *A. limonicus* per 15 leaves[b]		
	Permethrin dose		
	0 g AI/100 L	2 g AI/100 L	8 g AI/100 L
1 Feb.[a]	3.0 A	3.0 A	2.8 A
15 Feb.[a]	3.6 A	3.4 A	3.1 A
8 Mar.	28.3 A	2.8 B	2.5 B
29 Mar.	16.3 A	2.2 B	1.6 B
10 Apr.	31.8 A	3.3 B	3.1 B
12 May	31.9 A	2.8 B	1.5 B
28 May	33.1 A	1.8 B	1.2 B

a Before initiation of permethrin applications.

b Means followed by the same letter are not significantly different at = .05 based on Scheffe's test.

Table 3. The vertical, within plant distribution of phytophagous and phytoseiid mites at CIAT.

Plant Level	Phytophagous				Beneficial
	Mononych.	Tetranych.	Oligonych.	Tenuipalpidae	Phytoseiidae
Apical	120.1[a]	2.0	1.6	0.03	1.4
Mid	91.9	2.7	1.6	1.1	3.0
Lower	72.9	3.7	0.8	4.2	2.4

[a] Average of 15 samples (each sample consists of 68 leaves taken from 17 plants from four replications. All figures should be multiplied by a factor of 3.57 to obtain actual populations).

Table 4. Species of Phytoseiidae identified as associated with cassava mites in Colombia.

Amblyseius aerialis	Proprioseiopsis cannaensis
A. chiapensis	P. mexicanus
A. herbicolus	Proprioseiopsis sp.
A. largoensis	Proprioseiopsis sp aff. neotropicus
Amblyseius sp	Proprioseiopsis sp nov.
Amblyseius sp aff. coffeae	Quadromalus colombiensis
Amblyseius sp aff. curiosus	Typhlodromalus aripo
Clavidromus transvaalensis	T. limonicus
Diadromus sp aff. pritchardi[a]	T. peregrinus
Euseius alatus	Typhlodromalus sp nov.
E. casearіae	Typhlodromina subtripica
E. concordis	T. tropica aristidesi
E. hibisci [a]	Typhlodromips neotunus
E. naindaimei	Typhlodromips sp
E. sibelius	Typhlodromips sp aff. dentilis
Euseius sp [a]	Typhlodromips sp nov.
Galendromus annectens	
G. helveolus	
Galendromus sp	
Iphiseiodes zuluagai	
Neoseiulus anonymus	
N. californicus	
N. chilenensis	
N. idaeus	
N. paraibensis	
Neoseiulus sp[a]	
Paraphytoseius multidentatus[a]	
Phytoseiulus macropilis	
Phytoseius pennaseius purseglovei	
Phytoseius pennaseius rhabdifer [a]	

[a] Not found on Cassava

Table 5. Phytoseiid species and associated prey mites found through explorations in Colombia through 1986.

Phytoseiidae														
T. limonicus	X	X	X		X	X	X	X				X		
G. annectens	X	X			X	X	X	X				X		
G. helveolus	X	X		X	X	X	X	X				X		
N. anonymus	X	X	X		X	X	X	X	X			X		
E. concordis	X	X			X		X					X		
T. peregrinus		X			X		X					X		
T. aripo	X	X			X	X	X	X				X		
A. aerialis						X	X	X				X		
A. chiapensis		X			X	X	X	X		X	X	X	X	X
I. zuluagai						X	X			X	X		X	X
A. herbicolus		X				X	X			X	X		X	X
E. sibelius	X		X				X	X		X	X		X	X
Typhlodromina T. aristidesi							X			X	X		X	X
T. aff. *dentilis*						X	X							
Typhlodromips sp nov.						X								
P. macropilis	X					X	X	X						
Amblyseius sp.	X						X	X						
N. idaeus	X			X		X	X	X	X					
Proprioseiopsis sp.						X	X	X						
P. cannaensis		X					X							
E. naindaimei		X				X								
C. transvaalensis	X					X		X						
N. chilenensis					X									

TABLE 6. The duration (days) of the development stages of *Galendromus annectens*, *Neoseiulus idaeus* and *Phytoseialus persimilis* (Acarina, Phytoseiidae) feeding on two Tetranychidae species.

	Tetranychus urticae					*Mononychellus progresivus*				
	Egg	Larvae	Protonymph	Deutonymph	Total	Egg	Larvae	Protonymph	Deutonymph	Total
G. annectens	2.5A[a]	1.3A	1.2A	1.2A	6.1A	2.5A	0.9B	1.0B	1.2A	5.7B
N. idaeus	1.9C	0.5CD	0.8C	0.9B	4.2D	1.9C	0.5D	1.0B	0.9B	4.2D
P. persimilis	2.0B	0.6C	1.0B	1.1A	4.8C	2.0B	0.6C	0.8C	0.8C	4.0E

[a] Duncan P = 0.05

Table 7. Duration (days) of the reproduction period of three Phytoseiidas species (*Galendromus annectens*, *Neoseialus idaeus* and *Phytoseiulus persimilis*) feeding on *Mononychellus progresivus* and *Tetranychus articae* at 25°C.

Prey species	*G. annectens*	*N. idaeus*	*P. persimilis*
	Preoviposition		
T. urticae	2.3 A	1.4 A	1.6 A [a]
M. progresivus	2.1 A	1.4 A	1.4 A
	Oviposition		
T. urticae	11.7 A	10.6 A	10.0 A
M. progresivus	10.7 A	10.8 A	7.2 B
	Post-oviposition		
T. urticae	3.7 B	3.9 B	9.2 A
M. progresivus	4.4 B	4.7 B	1.6 B
	Longevity		
T. urticae	17.6 B	15.9 B	20.9 A
M. progresivus	17.2 B	16.9 B	10.3 C

[a] Duncan P = 0.05

TABLE 8. Fecundity of three species of Phytoseiidae feeding on *Mononychellus progresivus* and *Tetranychus articae* at 25°C.

Prey species	*G. annectens*	*N. idaeus*	*P. persimilis*
M. progresivus	22.4	20.9	22.6
T. urticae	18.0	17.8	31.3

TABLE 9. Life table parameters of three Phytoseiidae species (*Galendromus annectens*, *Neoseiulus idaeus* and *Phytoseilus persimilis*) feeding on *Tetranychus urticae* at 25°C.

Parameter Measured	*G. Annectens*	*N. idaeus*	*P. persimilis*
Developmental time (egg-egg) (days)	8.4	5.6	6.4
Ovipositional period (days)	11.7	10.6	10.0
Total fecundity (X)	18.0	18.0	31.3
Eggs/female/day (X)	1.5	1.7	3.1
Sex ratio (♀/♂)	3.81	3.71	4.41
50% mortality (days)	19.9	18.2	21.7
Net reproductive rate (R_o)	12.9	14.0	26.6
Average generation time (T) (days)	13.9	10.4	11.6
Intrinsic rate of increase (R_M)	0.18	0.25	0.28
Finite rate of increase (λ)	1.2	1.3	1.3
Population duplication (days)	3.8	2.8	2.5

TABLE 10. Life table parameters of three Phytoseiidae species (*Galendromus annectens*, *Neoseiulus idaeus* and *Phytoseilus persimilis*) feeding on *Mononychellus progresivus* at 25°C.

Parameter Measured	*G. Annectens*	*N. idaeus*	*P. persimilis*
Developmental time (egg-egg) (days)	7.9	5.6	5.5
Ovipositional period (days)	10.7	10.8	7.2
Total fecundity (X)	22.5	20.8	22.6
Eggs/female/day (X)	2.2	1.9	3.1
Sex ratio (♀/♂)	3.81	3.71	4.41
50% mortality (days)	18.5	19.3	10.8
Net reproductive rate (R_o)	14.8	14.5	13.6
Average generation time (T) (days)	12.3	10.3	9.3
Intrinsic rate of increase (R_M)	0.22	0.2	0.28
Finite rate of increase (λ)	1.2	1.3	1.3
Population duplication (days)	3.2	2.7	2.5

TABLE 11. Promising CGM natural enemies for shipment to IITA, Nigeria and possible release in African cassava fields.

Phytoseiidae	Prey consumed Mononychellus	Tetranychus	Oligonychus
Amblyseius aerialis	X	X	X
A. chiapensis		X	X
A. herbicolus		X	
Euseius sibelius	X	X	X
E. naindaimei		X	
Galendromus helveolus	X	X	X
Iphiseiodes zuluagai	X	X	X
Typhlodromalus aripo	X	X	X
T. peregrinus	X	X	X
Typhlodromalus sp nov.	X		X
Phytoseiulus macropilis	X		X

TABLE 12. Minimal sample size required to estimate the field density of *Phenacoccus herreni* at different confidence levels.

Mealybug Stage (Instar)	Precision		
	30 %	25 %	15 %
Nymph I	178 [a]	277	492
Nymph II	40	62	109
Nymph III	57	88	157
Adult females	33	52	92

[a] Minimal number of 3 cm long cassava terminals.

TABLE 13. The effect of temperature on the developmental time of *Phenacoccus herreni*.

Temperature °C	Average days	
	Female	Male
20	90	52
22	68	33
25	38	22
30	39	20
Minimum temperatures threshold	17.5°C	
Constant thermal temperature	330° D	193° D

TABLE 14. The effect of temperature on the mortality of *Phenacoccus herreni*.

STAGE	Mortality %			
	20°C	22°C	25°C	30°C
Egg	31	26	15	5
I Instar	21	54	43	62
II Instar	34	1	26	23
III Instar/cocoon	11	3	21	36
Adult	11	12	18	12

TABLE 15. The life cycle of *Cleothera notata* (Coleoptera: Coccinellidae) at 22°, 25° and 30°, feeding on *Phenacoccus herreni*.

	Temperature		
	22°C	25°C	30°C
	X	X	X
Egg	8.8	5.9	4.0
Larvae 1	3.2	2.0	1.4
Larvae 2	3.1	1.8	1.9
Larvae 3	3.3	2.4	2.3
Larvae 4	11.6	9.0	7.4
Pupa	9.7	8.8	6.7
Pre-adult	2.6	3.3	2.5
Total	42.3	33.2	26.2

TABLE 16. Leaf tissue analysis of the cassava variety CMC 40 with and without mealybug (*Phenacoccus herreni*) attack.

Treatment	% Nutrients			
	Ca	P	K	Mg
With mealybugs	1.10	0.44	1.96	0.48
With mealybug (removed)	0.77	0.36	2.16	0.43
Without mealybugs (control)	1.14	0.33	2.26	0.46

TABLE 17. The life cycle of Cyrtomenus bergi Froeshner feeding on a high HCN variety (M Col 1684) and a low HCN variety (CMC-40) in the laboratory (25°C, 70 ± 5% RH).

Instar	MCol 1684 (High HCN)		CMC 40 (Low HCN)		Difference in life cycle/days
	Duration in days	Mortality %	Duration in days	Mortality %	
I	28	62	12	60	16
II	20	2	18	2	2
III	22	4	15	0	7
IV	28	20	13	2	15
V	39	6	12	0	27
Total	140		70.9		69.1
Adult	41.3	6%	106.4 [a]	16%	

[a] 20% of population still survive.

TABLE 18. The effect of Aldrin treatment on population and cassava root damage caused by Cyrtomenus bergi at Santander de Quilichao.

Plant age (months)	Aldrin application [a]		No chemical treatment	
	% roots damaged	No. of C. bergi in soil	% roots damaged	No. of C. bergi in soil
1	0	1+	2	4
2	6	3+	45	1
3	0	0	41	4
4	15	1	45	11
5	5	0	28	2
6	0	0	53	11
7	1	3+	56	5
8	5	0	71	11
9	9	2	51	5
X Total	4.8	1.1	44.2	6

[a] Aldrin 2.5% Dust applied at dosis of 40 kg/ha.

+ Number of dead C. bergi found

TABLE 19. The effect of Aldrin treatment on Cyrtomenus bergi damage to cassava roots, root production and starch content.

		Treatments			
		Aldrin application		No chemical treatment	
Damage & grade	% root surface damaged	Commercial roots %	Non commercial roots %	Commercial roots %	Non commercial roots %
1	0	9	90	48	26
2	1-25	3	5	38	29
3	26-50	0	3	11	22
4	51-75	0	0	0	9
5	76-100	0	0	0	12
Yield t/ha		29.1	5.1	30.0	5.4
% Starch content		30.5	28.5	26.4	24.9

TABLE 20. The effect of planting patterns of cassava with crotalaria on cassava yield and root damage caused by *Cyrtomenus bergi*.

Treatment	Yield t/ha	% Root damage	Damage grade
Cassava monoculture	40 A [a]	90 AB	3.7 A
Cassava + Crotalaria (15) [b]	39 A	87 AB	2.0 BC
Cassava + Crotalaria (2)	38 A	82 AB	1.5 BC
Cassava + Crotalaria (6)	37 A	75 AB	1.2 C
Cassava + Crotalaria (10)	36 A	87 AB	2.1 BC
Cassava + Crotalaria (20)	33 A	92 A	2.3 B
Cassava + Crotalaria (encircling plot)	36 A	65 C	1.1 C

[a] Numbers with the same letter are not significantly different at the 0.05 level.

[b] Numbers in parenthesis ( ) indicate rows of cassava between *Crotalaria juncea* planting.

TABLE 21. The effect of a cassava/Crotalaria rotation and a cassava Crotalaria intercropping on root damage caused by *Cyrtomenus bergi*.

Treatments	Yield t/ha	% Roots damaged	Damage grade
Cassava/Crotalaria rotation	40.6	76	3.5
Cassava + cassava	36.3	67	3.6
Cassava/Crotalaria intercrop[a]	29.9	5	0.5

[a] One row of cassava between every 2 rows of Crotalaria.

TABLE 22. The effect of the CIAT cassava pest complex on the root yield and production of planting material of four cassava varieties.

Variety	Treatment	Root yield total production t/ha	% difference yield	Starch content %	No. of cuttings/plant	% difference
CMC 40	with insecticide [a]	63.2	50.3	33.18	8.7	-
	without insecticide	31.4		31.77	9.2	+ 5.4
M Col 113	with insecticide [a]	32.9	+ 9.3	28.56	7.0	-
	without insecticide	36.3		29.25	8.0	+12.5
M Col 22	with insecticide [a]	59.9	50.3	36.12	8.0	-
	without insecticide	29.8		32.99	5.0	37.5
M Col 1684	with insecticide [a]	57.6	57.8	31.54	10.0	-
	without insecticide	24.3		30.09	4.0	60.0

[a] Dimethoate 2cc Pc/liter of water , applied every 15 days.

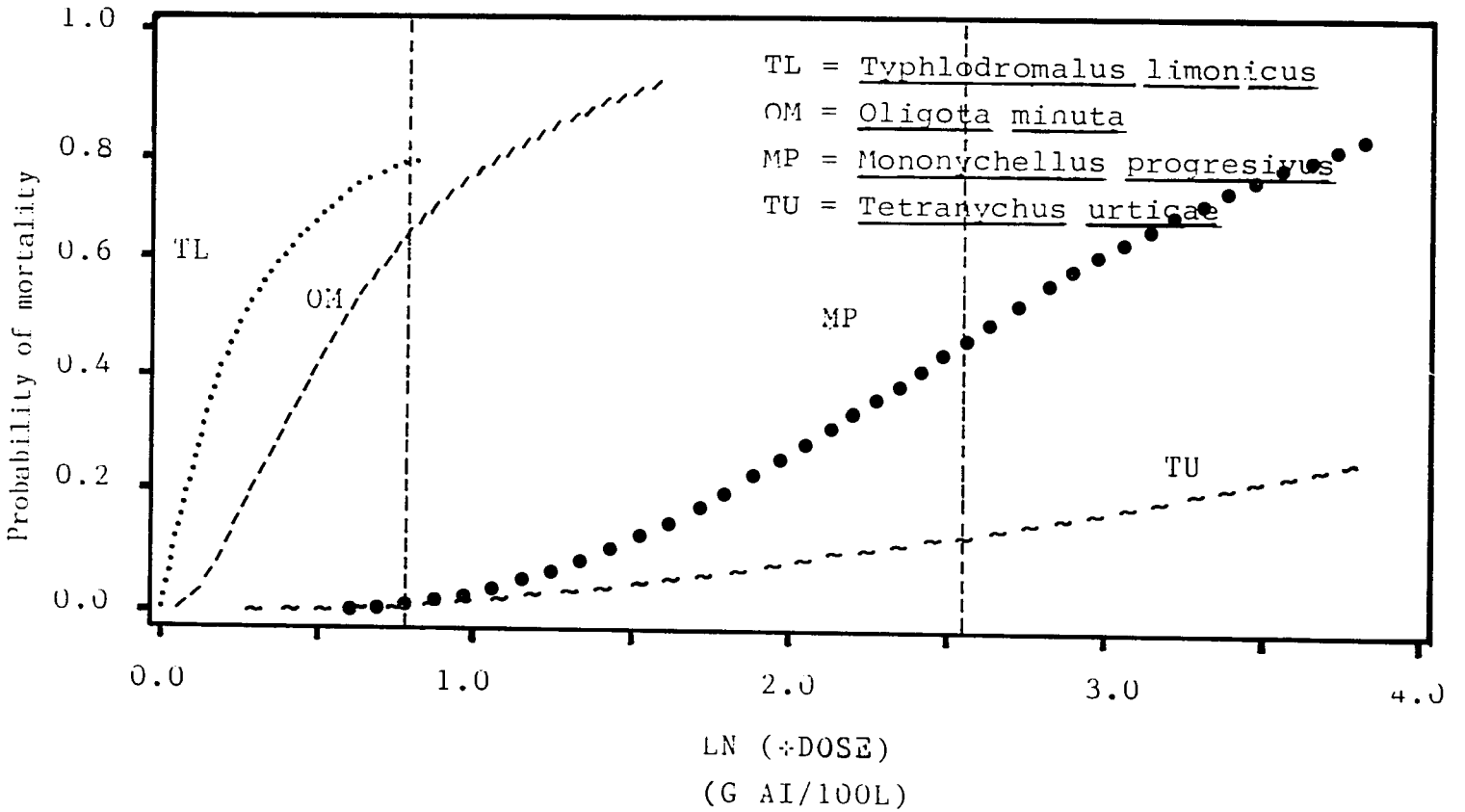


FIGURE 1. The effect of permethrin on tetranychid pests of cassava and their predators.

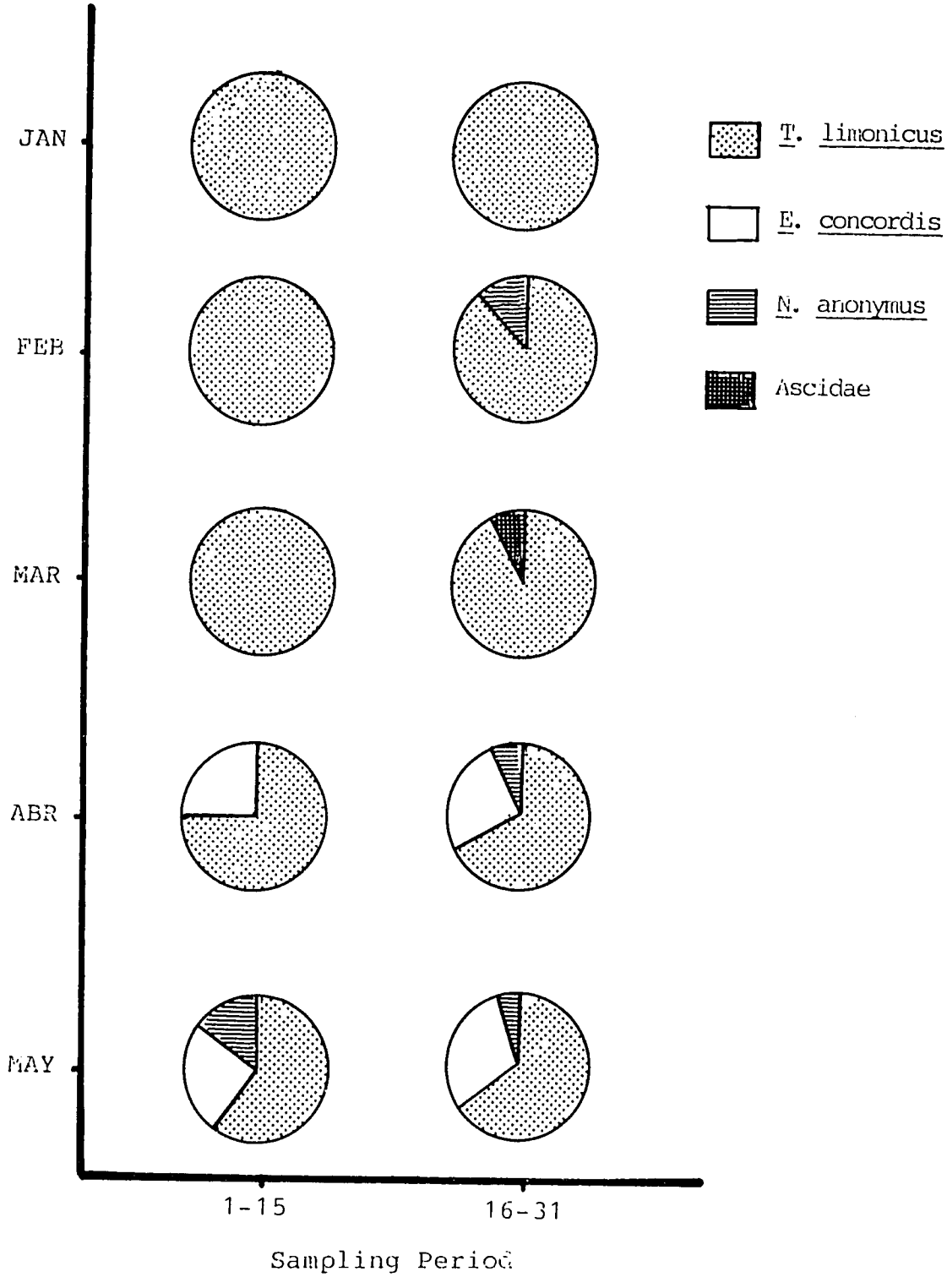


FIGURE 2. Species composition of predatory mite complex CIAT, Cali, Colombia, 1986

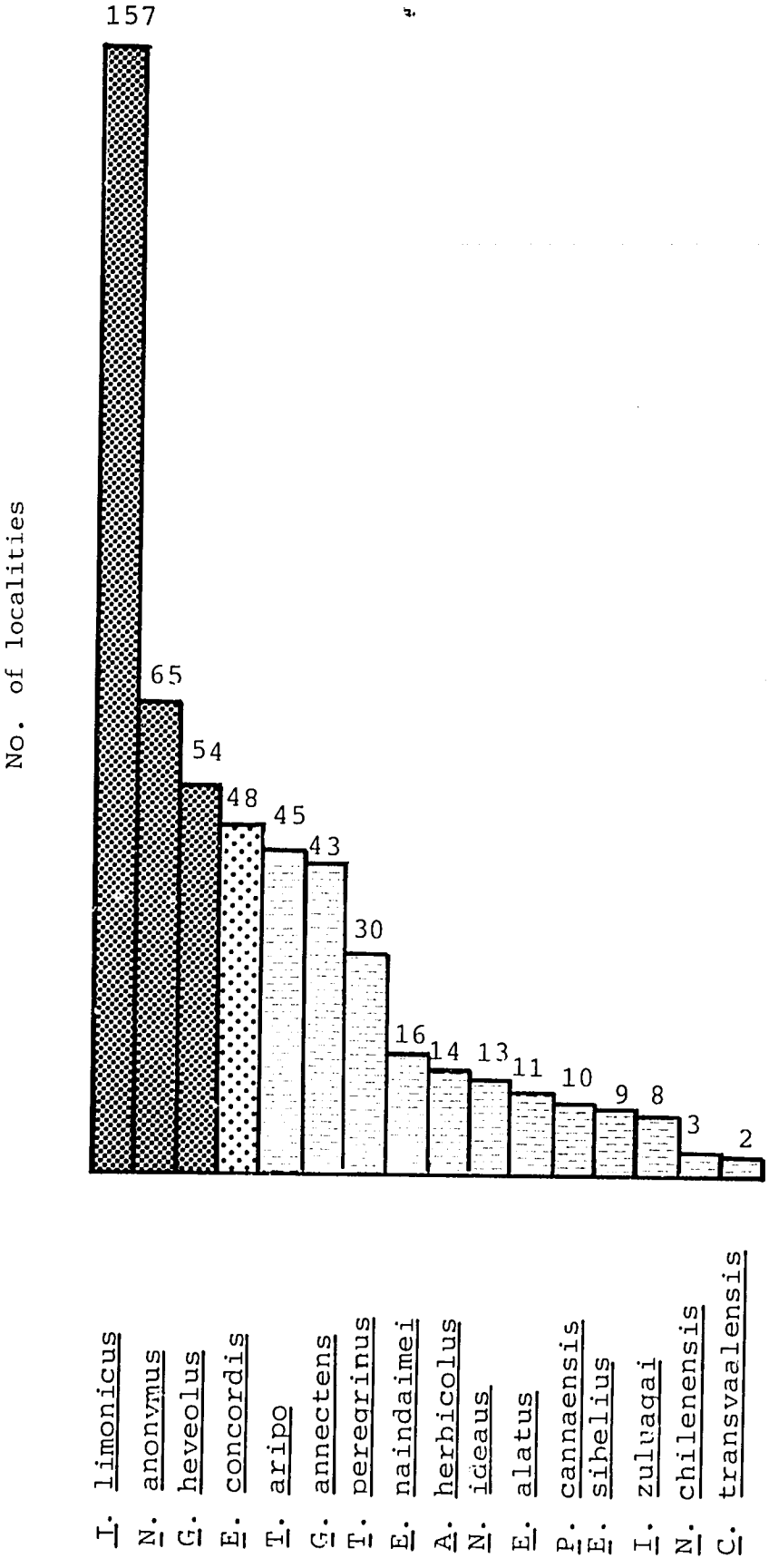


FIGURE 3. Phytoseiidae species frequency distribution found through survey activity (178 localities sampled)

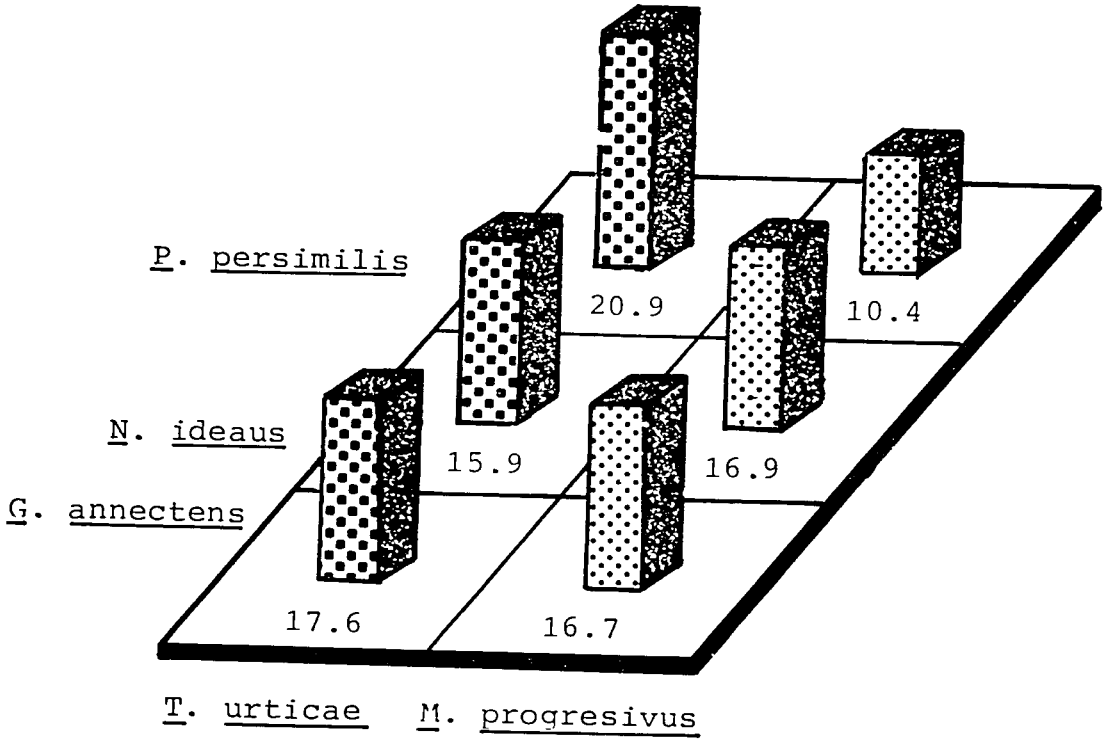


FIGURE 4. Female longevity of *Galendromus annectens*, *Neoseiulus ideaus* and *Phytoseiulus persimilis* feeding on *Tetranychus urticae* and *Mononychellus progresivus* at 25°C

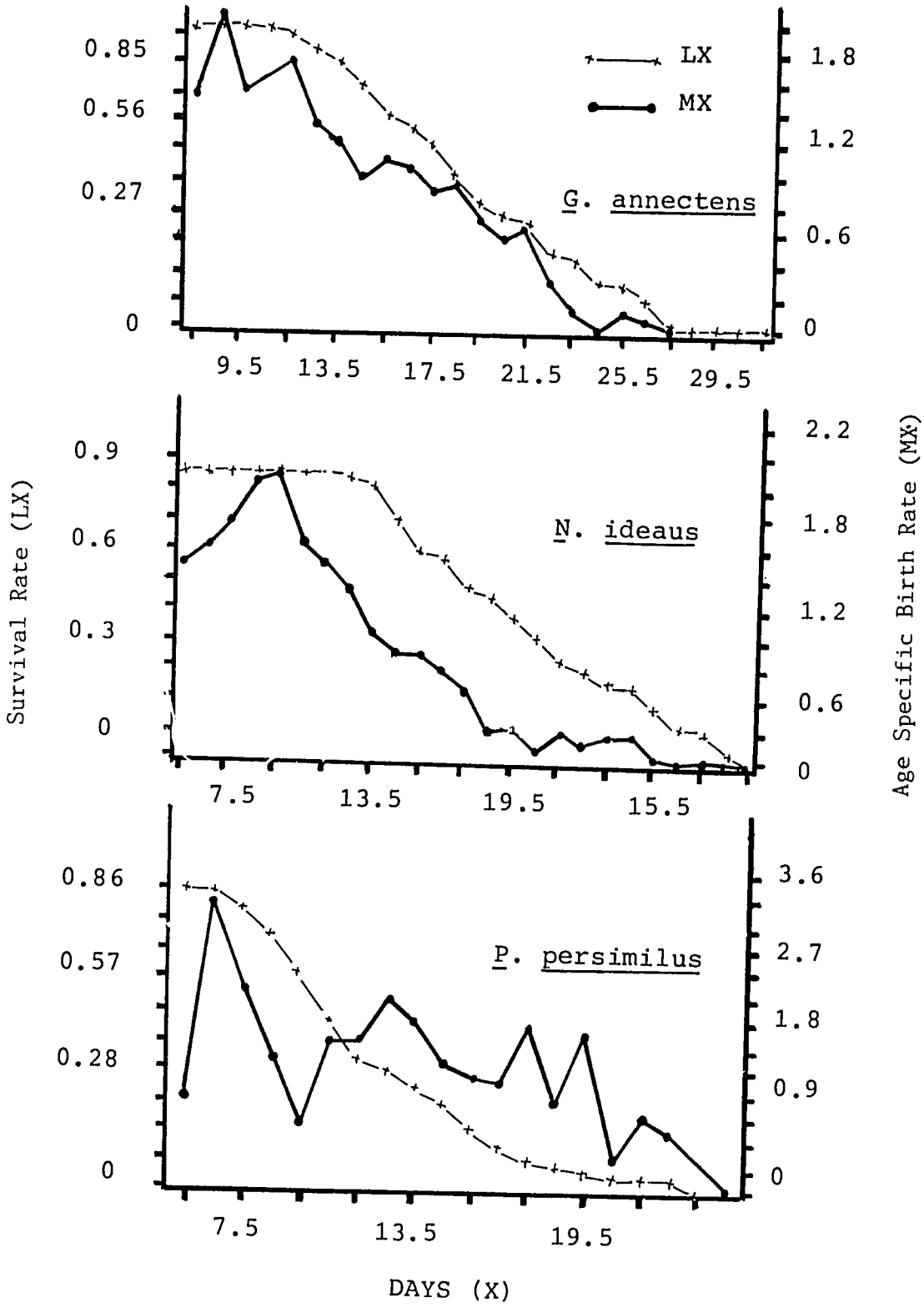


FIGURE 5. Survival rate and offspring per female of three species of Phytoseiidae feeding on Mononychellus progresivus (25°C and 70+5% RH)

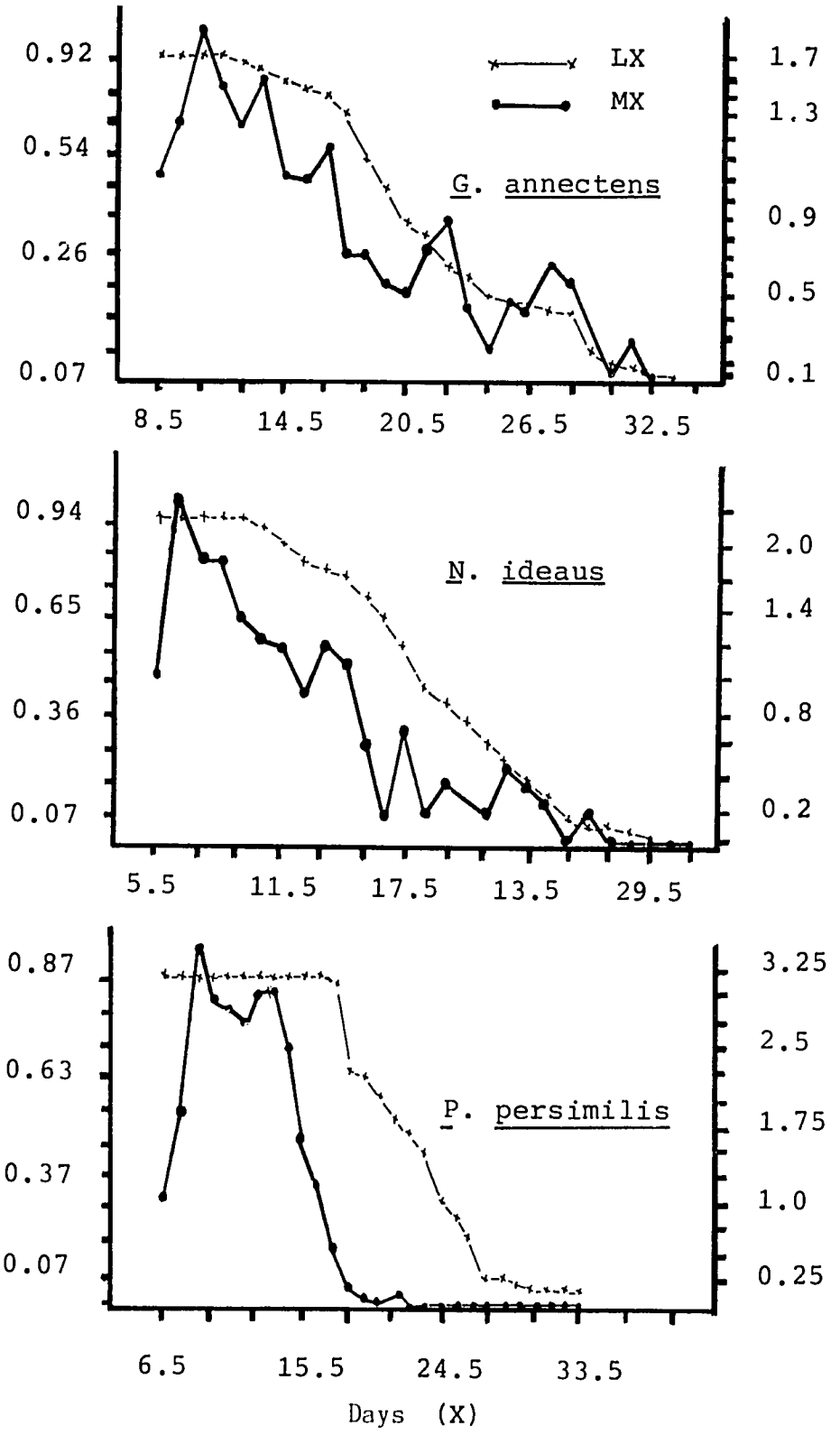


FIGURE 6. Survival rate and offspring per female of Phytoseiidae feeding on Mononychellus progresivus (25°C and 70+5% RH)

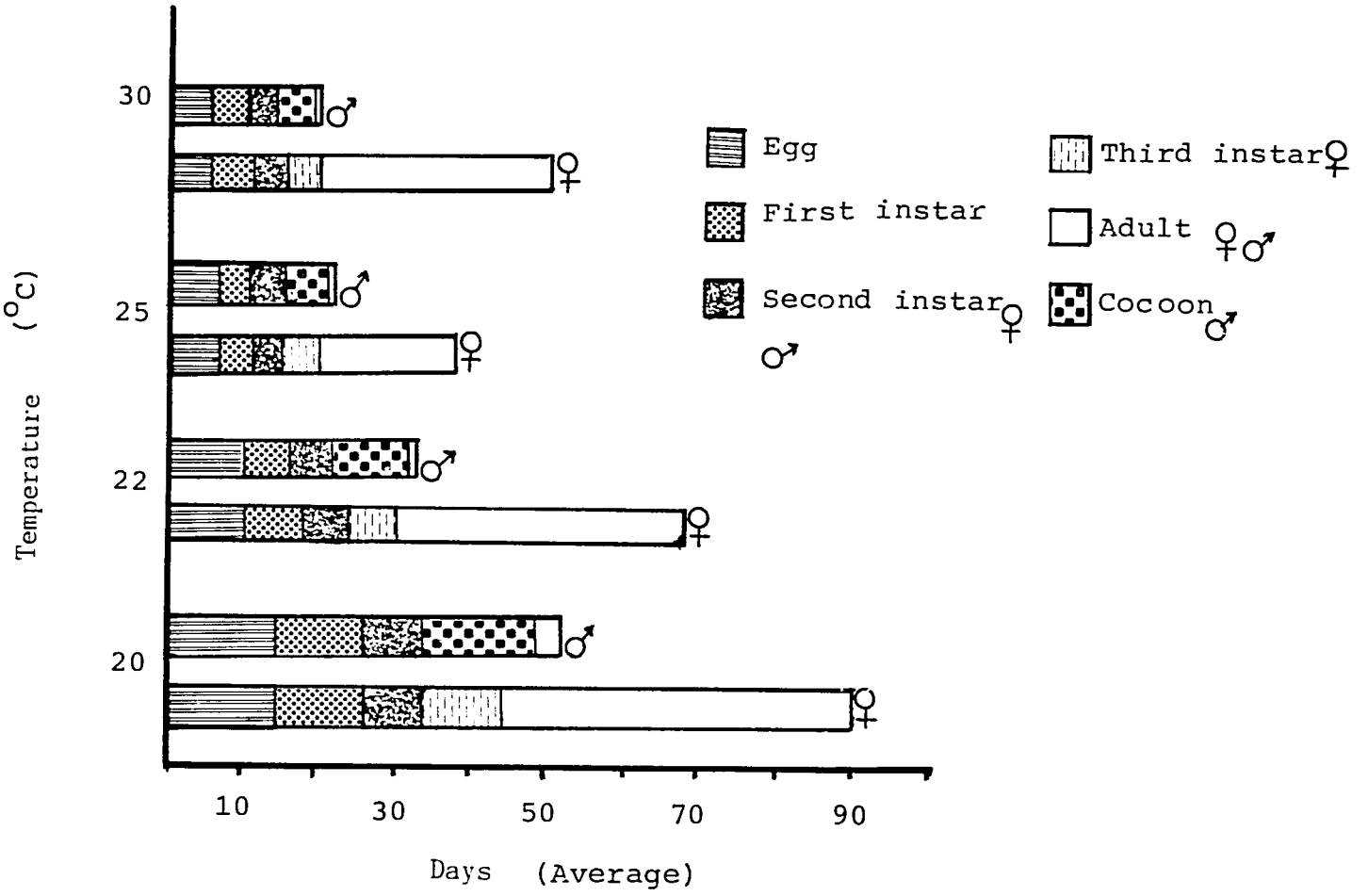


FIGURE 7. The effect of temperature on the development of Phenacoccus herreni

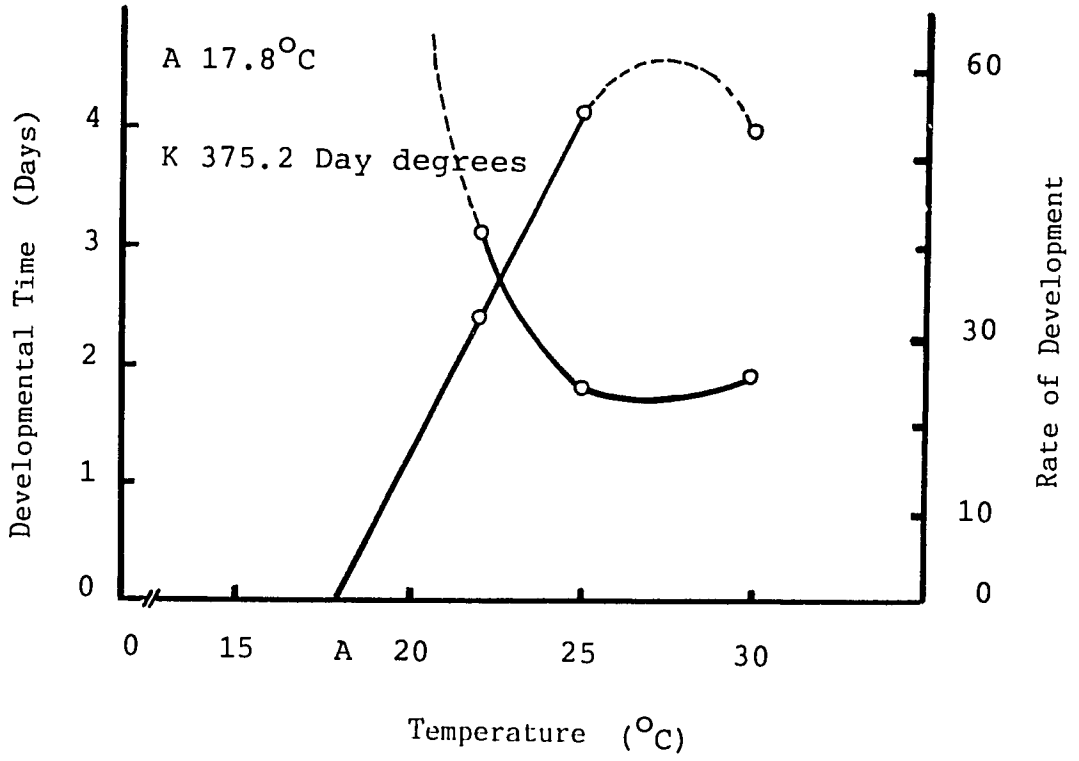


FIGURE 8. The development curve of the second instar of Cleothera notata

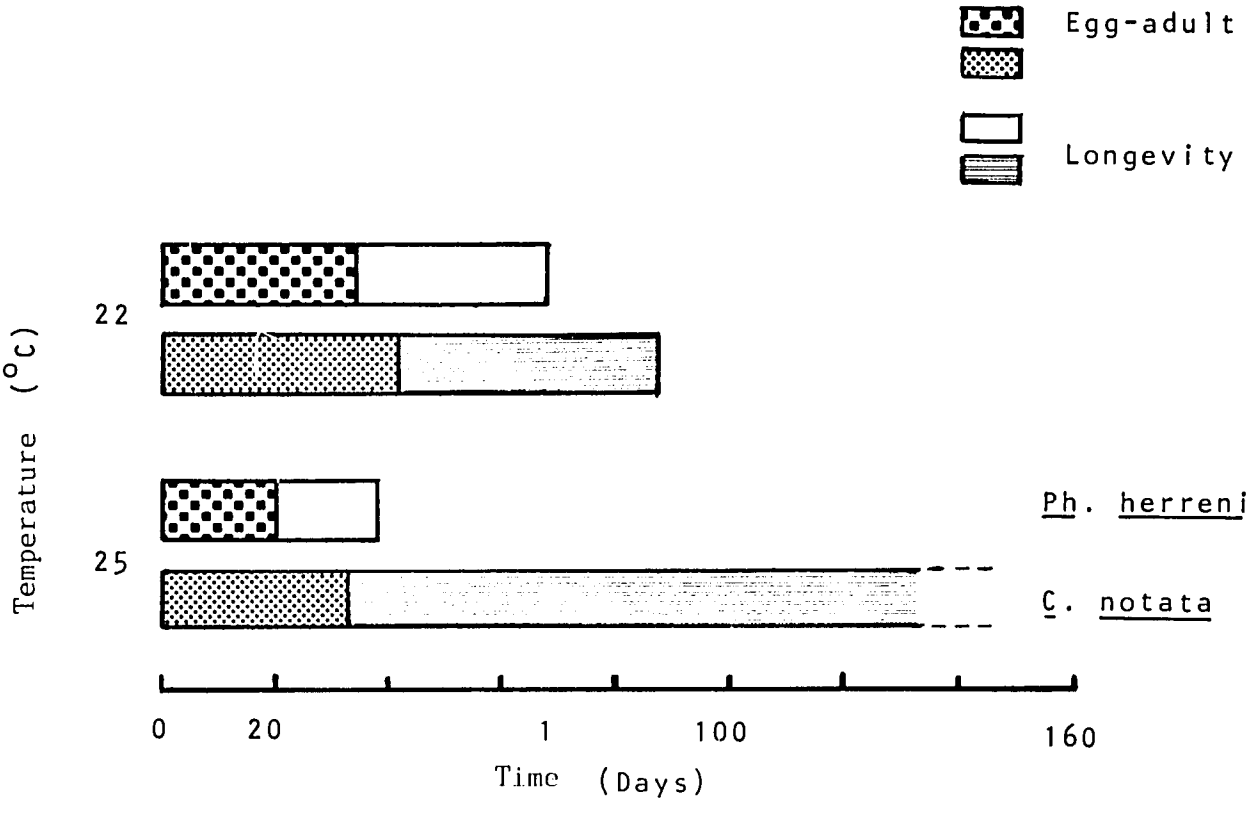


FIGURE 9. Development and longevity of Cleothera notata at 22 and 25°C feeding on Phenacoccus herreni

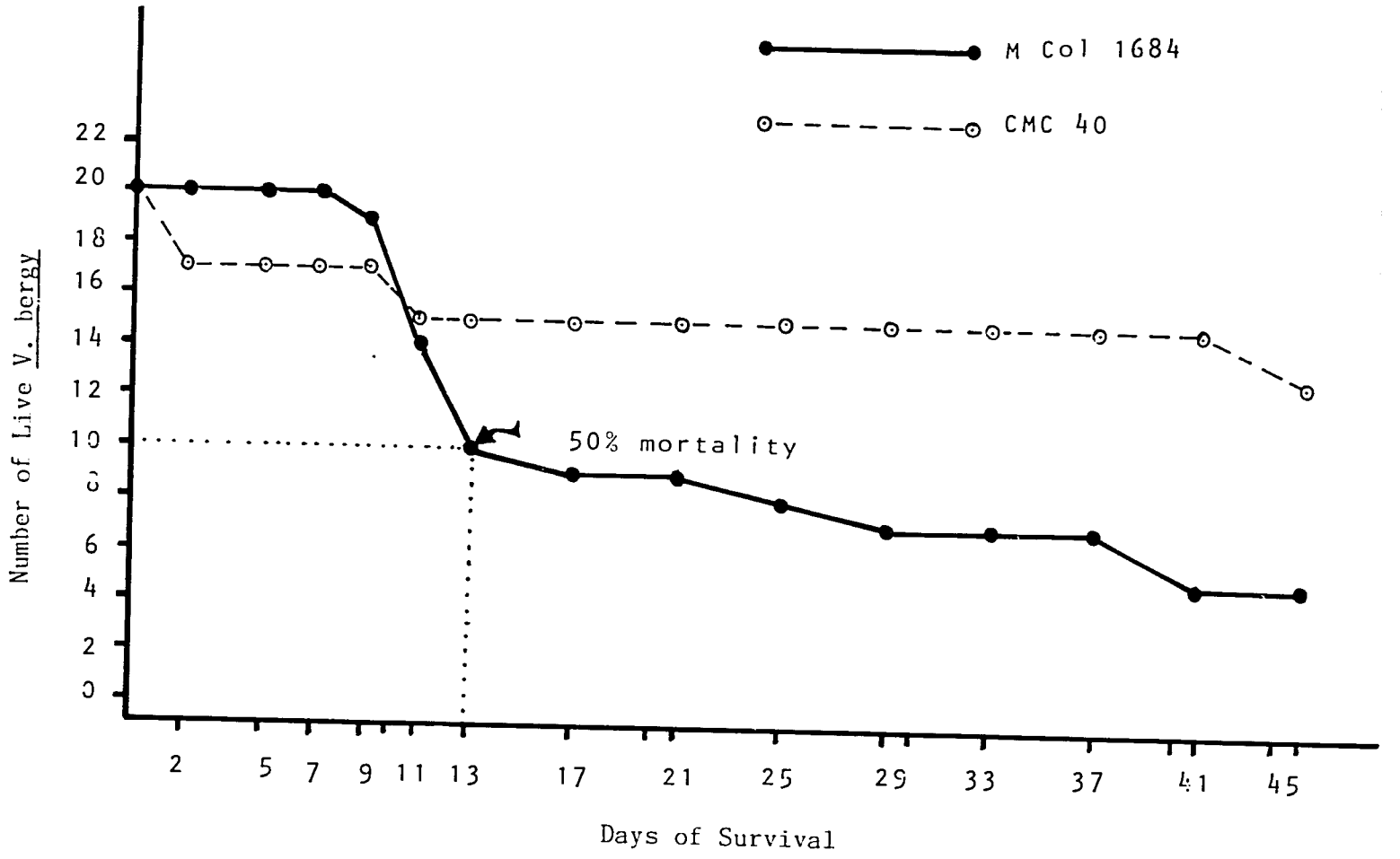


FIGURE 10: Survival rates of Cyrtomenus bergi adults feeding on a high HCN (M Col 1684) and a low (CMC 40) HCN Cassava variety

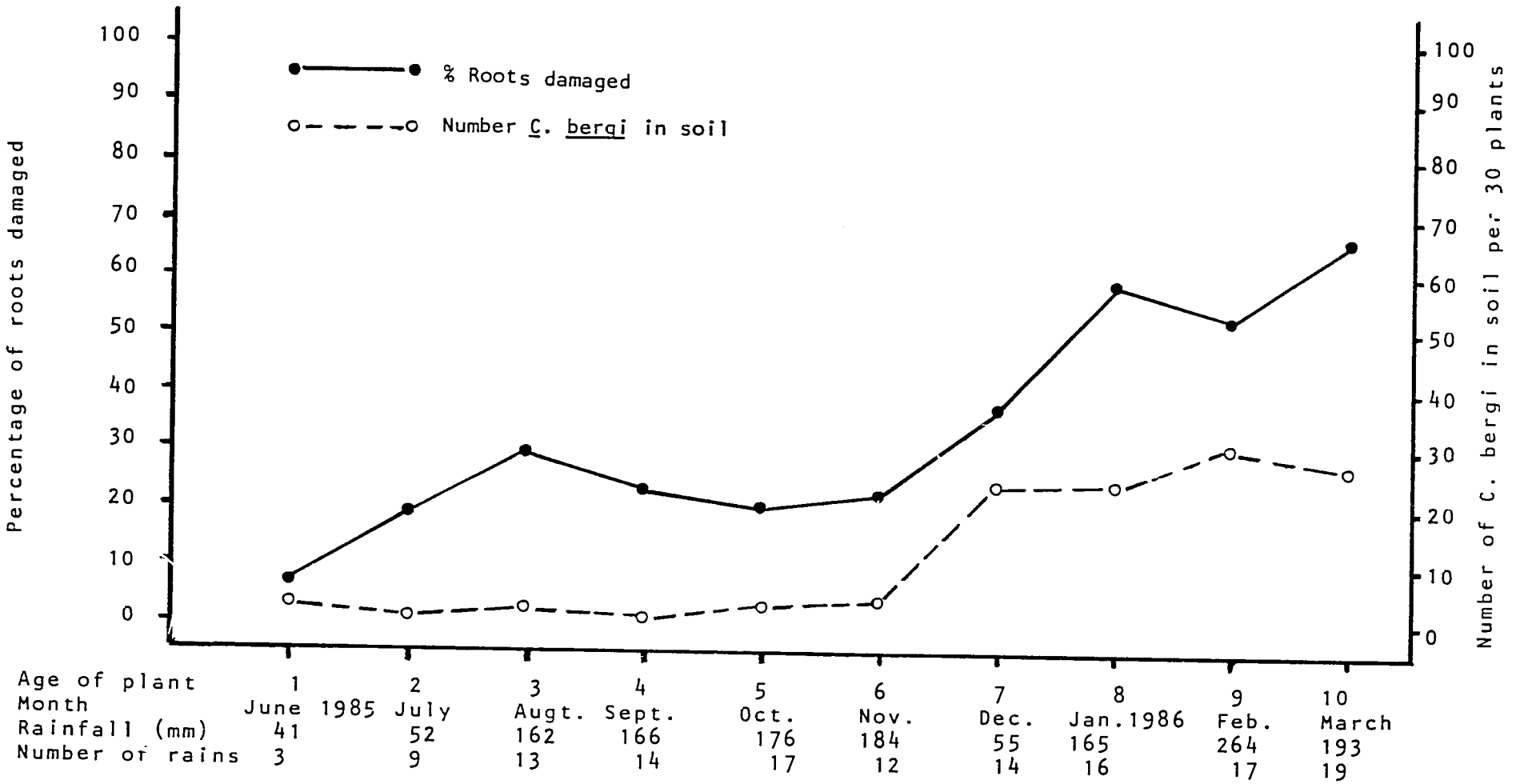


FIGURE 11: Cyrtomenus bergi populations and percentage of cassava roots damaged during a 10 month crop cycle (June 1985 to March 1986) at Santander de Quilichao.

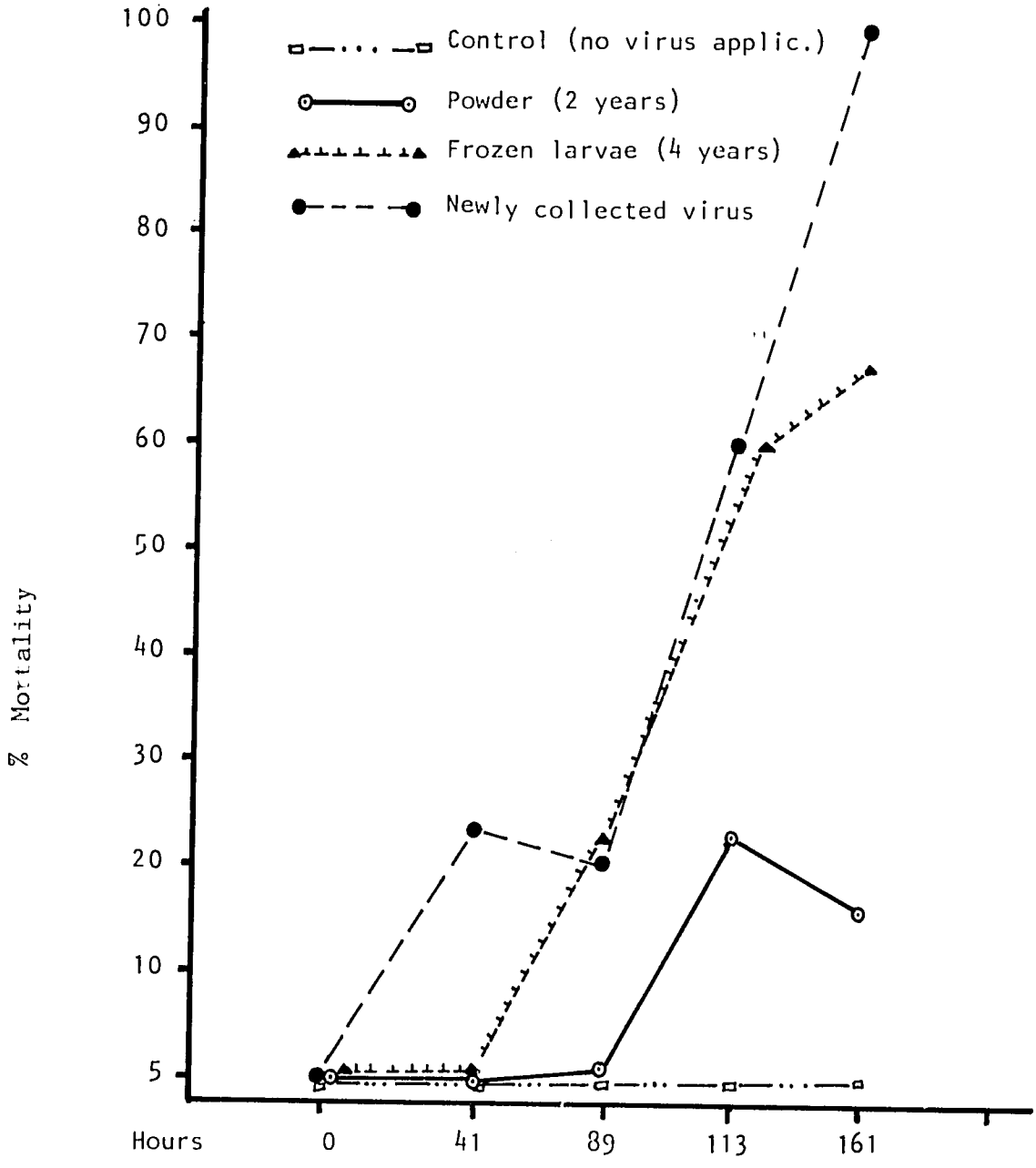
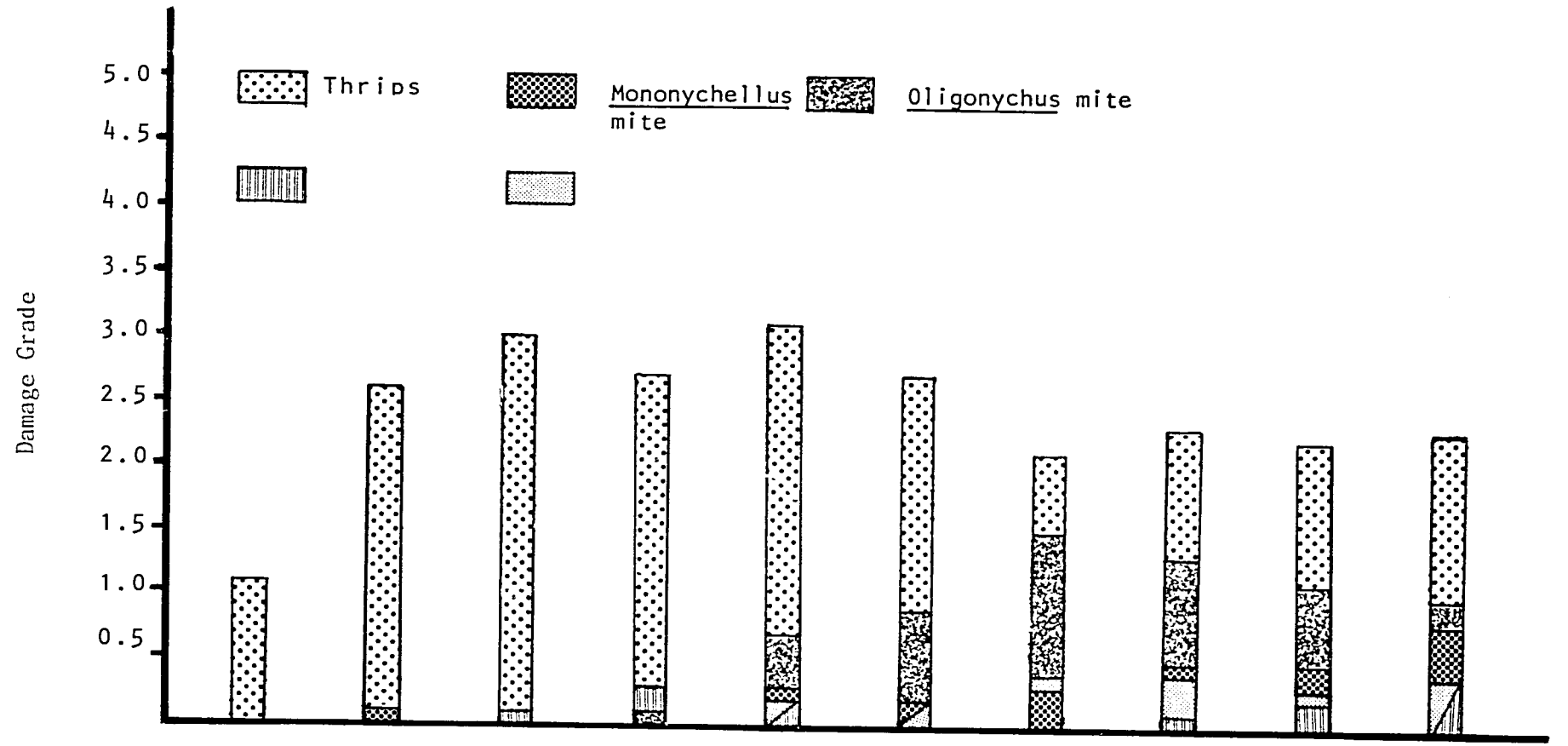


FIGURE 1?. Mortality of Erinnyis ello larvae due to Baculovirus erinnyis stored as powder for 2 years of frozen within larvae for four years and compared to newly collected virus.



Plant age	1	2	3	4	5	6	7	8	9	10
Month	Sept 1985	Oct.	Nov.	Dec.	Jan.1986	Feb.	March	April	May	June
Rainfall (mm)	120.7	63.7	64.7	50.5	72.0	94.3	70.4	160.2	104.0	54.1
Number of rains	13	15	12	7	6	10	13	14	11	11

FIGURE 13. Plant damage caused by insects and mites feeding on cassava variety M Col 1684, at CIAT, Palmira

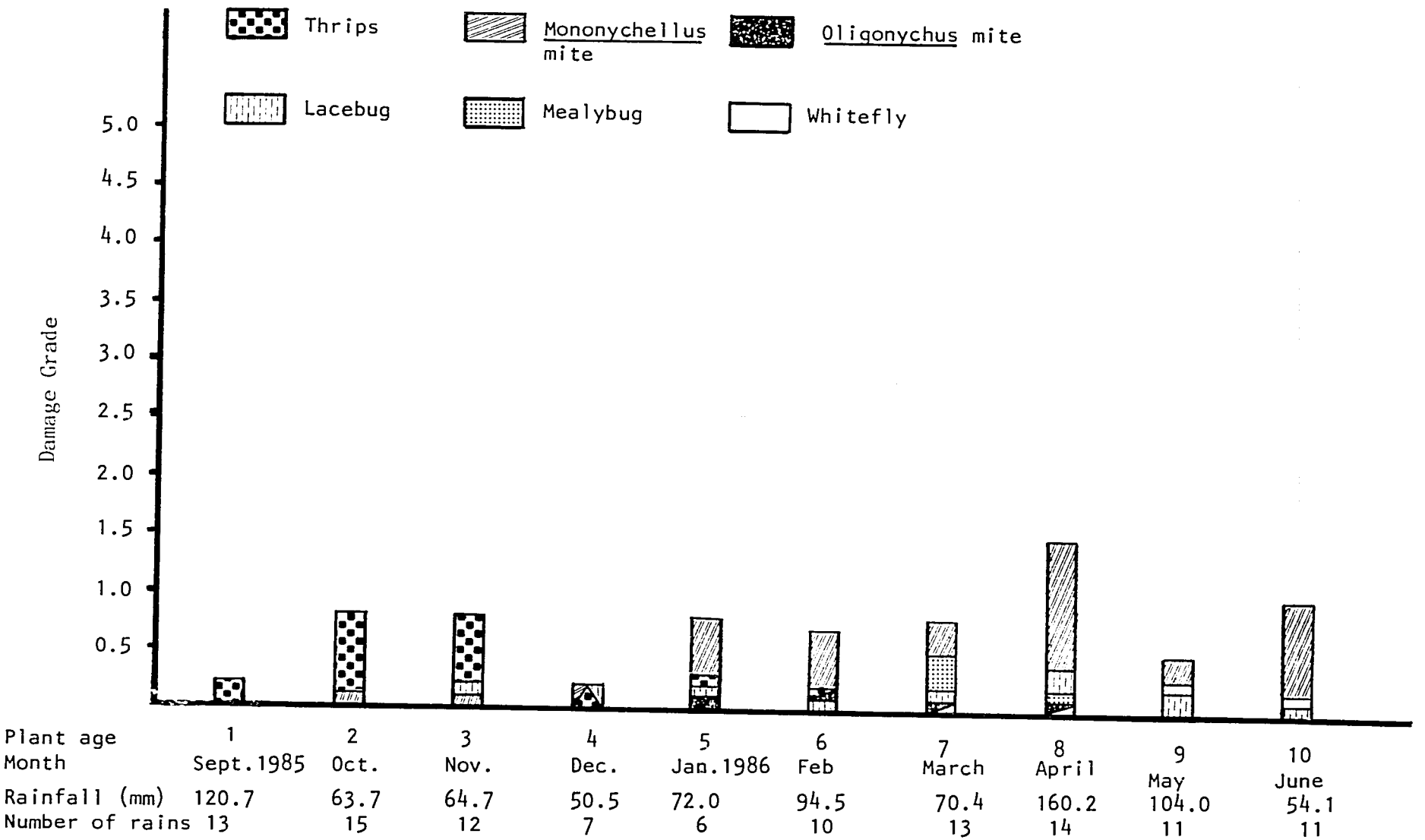


FIGURE 14. Plant damage caused by insect and mites feeding on cassava variety M Col 113, at CIAT-Palmira.

PATHOLOGY

Emphasis was given this year to the development of methods for screening for resistance to Diplodia and Fusarium stem and root rots, Anthracnose and Cercospora leaf spots. A method for evaluating varietal differences in cutting perishability during their storage was also developed. Investigations on factors affecting quality of cassava planting material also continued.

Diplodia stem and root rot

Diplodia stem and root rot is one of the most important factors affecting the quality of cuttings in different edapho-climatic zones (ECZ). It has been found inducing losses in Thailand, Mexico, Brasil and Colombia. For example, this year the incidence of cutting infection by D. manihotis ranged from 30 to 98% in Media Luna (ECZ1), from 5 to 30% in Carimagua (ECZ 2), from 5 to 80% in CIAT headquarters (ECZ 4), from 5 to 100% in Santander de Quilichao (ECZ 4) and from 5 to 10% in Popayan (ECZ 5). Consequently, intensive research is being carried out to develop methods for the control of this disease.

1. Survival

Diplodia manihotis was able to survive for more than a year in infected debris (stem and branches) stored under shade or in the sun. The viability of the pycniospores produced under the above conditions, was as high (more than 80% germination) as that produced on acid-PDA in Petri dishes. Similarly, this fungus was able to survive for more than a year in infested soils with 10% of organic matter (pH=6.8). The above results suggest the great ability of this pathogen to survive on debris and in soils and maintain a high inoculum potential during fallow periods. The pathogen was also found affecting Crotalaria spectabilis, an introduced legume which commonly grows in Media Luna as a green manure crop during the rotation cycle. Crotalaria may be responsible for the very high disease severity in Media Luna at the onset of the rainy season. The fungus first penetrates the stem inducing cankers, dieback and then plant death. During this period, a high number of pycniocarps are formed on the bark of affected plants; these pycniocarps maintain the inoculum during the dry season until their release at the beginning of the next rainy period.

Trials are underway to evaluate the effect of eliminating both plant debris and the alternate host on pathogen survival. Care should always be taken when introducing a plant species as a green manure to consider its pathological relationship with the crop(s) growing in the area where the species is introduced.

2. Chemical control on cuttings

Thirteen different fungicides were tested as eradicants of D. manihotis affecting cassava cuttings. Benlate 50% (Benomyl) and Banrot 40% (5-ethoxy-trichloromethyl) eradicated the pathogen from cuttings at concentrations above 200 ppm of active ingredient. Most protectant fungicides asserted slight control of D. manihotis affecting cassava cuttings at concentrations higher than 1800 ppm. In vitro tests with the same fungicides showed that both Benlate and Banrot were the best.

3. Resistance

The control of Diplodia stem and root rot by fungicidal treatments is, however, partial (CIAT Cassava Program Annual Reports, 1984, 1985) and costly; genetic control is more appropriate. An inoculation method was developed by dipping 10cm-cuttings into a conidial suspension of 4 X 10^4 pycniospores/ml for 20 minutes. The most consistent results were obtained by inoculating cuttings from the middle stem portions of 10 to 12 month old plants. The pycniospore inoculum was harvested from 12-day old cultures growing on acid-PDA under continuous fluorescent light. Inoculated cuttings were planted in pots and covered with plastic bags for 4 days, in order to maintain a high relative humidity for fungal establishment. Cuttings were then uncovered and maintained in a greenhouse at 25°C (±8°C), 80% RH and 2,000 foot candles, approximately. The symptoms that developed on susceptible clones, 20 days after inoculation, were characterized by the presence of blackish stomata beneath the epidermis, each containing around 4 pycnidia. Bud germination was inhibited, stem tissues were necrosed and black mycelia grew on the cut surface of the cuttings. On the other hand, buds on cuttings from resistant clones germinated, and cuttings rooted without signs of infection.

However, a group of inoculated clones showed variable results under replicated inoculations. They were susceptible when sterilized with Na-hypochloride (3%), but resistant or partially resistant when not sterilized (Table 1). Apparently, the microflora growing on the epidermis of the stem of these clones offered protection against D. manihotis. Indeed, most most of the isolated epyphitic bacteria were antagonistic to D. manihotis in vitro (CIAT Cassava Program Annual Report, 1985) causing strong growth inhibition of the pathogen.

After screening 140 clones by the above method, 12% were resistant, 10% were resistant in the presence of microflora bacteria, and 78% were susceptible. Resistant clones were selected in successive evaluations in Media Luna. Resistance did not change when they were inoculated with 15 different strains collected from five different edapho-climatic zones.

The above results demonstrate the existence of stable genetic and acquired resistance to D. manihotis in cassava. As field screening requires several years of evaluation to this pathogen, greenhouse screening facilitates the identification of resistant clones producing results within 2 months. Genetic resistance can be separated from acquired resistance by sterilizing the cuttings before inoculation with D. manihotis.

Fusarium root rot

1. Survival

Fusarium oxysporum was found affecting Crotalaria spectabilis in Media Luna. The pathogen induces first leaf blight, and then stem rot, dieback and plant death. It is thought that the high incidence of Fusarium root rot in this area is due to the survival ability of this causal agent on Crotalaria.

2. Resistance

Fusarium oxysporum and F. solani, were reported inducing root and stem rot in Brasil, Mexico and Colombia. Several cultural practices to control the diseases induced were reported last year, as well as a system to screen for resistance to these pathogens (CIAT Cassava Program Annual Reports, 1984, 1985). After screening several clones for resistance to both organisms, it was found that the resistance to these two pathogens is independent (Table 2). Consequently, it will be necessary to integrate both types of resistance for control of these pathogens in areas where both are present. Clones resistant to only one Fusarium species must only be introduced into areas where the resistance is effective.

After screening several cassava clones for resistance to F. oxysporum, four groups of clones were clearly distinguished on their reaction to strains collected at CIAT headquarters, Carimagua and Media Luna (Table 3). Apparently, a specific host-pathogen interaction has evolved independently in each ecosystem. Therefore, there is a need for strict quarantinery precautions to avoid the dissemination of races of this pathogen to non-endemic areas. The integration of resistance to different races of F. oxysporium affecting cassava requires investigations on the nature of the genetic control.

Anthracnose

1. Etiology

Three species of Colletotrichum, C. gloeosporioides, C. gloeosporioides f. sp. manihotis and C. graminicola, were reported inducing anthracnose on cassava (CIAT, 1985). The sexual stage of these pathogens (Glomerella cingulata), has only been reported on decayed woody stems of cassava debris. However, isolates of G. cingulata, collected in an infested plantation located in the "pie de monte" region of the eastern plains of Colombia, were able to cause leaf anthracnose and stem rot on cassava. Collected strains reverted to C. gloeosporioides in vitro only when incubation temperatures were higher than 27°C.

The disease induced by G. cingulata on cassava leaves is similar to the anthracnose induced by C. gloeosporioides, but lesions are darker with lighter chlorotic halos than those induced by the asexual stage. Fifteen days after infection abundant perithecia are born on the upper leaf surface; they are dark-brown and round (200 to 300 diameter), containing several hyaline cylindrical asci each, with 8 cylindrical and hyaline ascospores.

A foliar inoculation of 18 different cassava clones, using both the sexual and asexual stages of the pathogen, yielded similar rates of disease reactions indicating at least pathogenic stability. Further studies with single cell cultures might elucidate cultural and pathogenic stability. Knowledge of the amount of pathogen variability in nature is necessary for the design of a breeding program for genetic control.

2. Resistance

Two methods of inoculation were developed to screen for resistance

to C. gloeosporioides:

1. The stems of one-month old plantlets are punctured with an infested needle (inoculum concentration of 4 X 10^6 conidia/ml) at the base of 5 leaf petioles. Inoculated plantlets are maintained in a greenhouse (25°C ± 8°C) under constant mist for 10 to 12 days. Resistant clones show only a light necrosis at the inoculation point, while susceptible clones exhibit die-back and die. Acervuli are noticeable on the epidermis of infected stems 20 days after inoculation.

2. Healthy leaves of intermediate age, taken from 4 to 8 month-old plantations, are desinfested with sodio hypochloride (3%) for 3 minutes and then rinsed with sterile distilled water. Desinfested leaves are then placed on a glass triangle in a Petri dish with sterile filter paper; a wet cotton ball should be placed at the cut petiole base to reduce dehydration. Leaf lobes are then inoculated with an infested needle at the middle of each midrib. Petri dishes are then covered and maintained at room temperature (approximately 24°C) for 4 to 5 days before evaluation. Resistant clones show up to 25% of the leaf area affected, while susceptible clones show more than 50% of the leaf lobes invaded by the pathogen.

   The reaction of 85 clones screened by the above inoculation methods, was correlated. Field evaluation of 9 clones during several years for resistance to anthracnose gave similar results to those obtained under con .olled conditions.

Consequently, the above described inoculation methods to evaluate resistance to anthracnose induced by C. gloeosporioides are reliable; the leaf inoculation method is however, simpler, and results can be obtained in a shorter period of time than with the stem puncturing method.

Results so far have shown that the frequency resistance to C. gloeosporioides is relatively high in cassava (Table 4). However, it will be necessary to investigate whether this resistance is also effective to C. gloeosporioides f. sp. manihotis, C. graminicola and G. cingulata, species that induce the same anthracnose syndrome.

Cercospora leaf spots

Screening for resistance

Cercospora leaf spots, induced by Cercosporidium henningsii (brown leaf spot) and Cercospora henningsii (leaf blight), are the most widely distributed diseases of cassava. They are found in almost all cassava plantations of Africa, Asia and the Americas, inducing reduction in total yield of fresh roots, and reducing the carbohydrate concentration of affected plants (CIAT Cassava Program Annual Reports, 1978, 1979). Genetic control is most appropriate, however, due to a slow growth habit and low spore production in vitro, the best method for screening for resistance is field evaluation.

One hundred and fifteen clones were planted at Santander de Quilichao and Media Luna, two locations where Cercospora leaf spots are endemic. According to clonal reaction the following conclusions can be drawn:

1. The severity of each disease was ecosystem specific: C. henningsii was much more severe in Media Luna than in Santander de Quilichao, while C. vicosae was more severe in Santander de Quilichao than in Media Luna (Fig. 1).

2. Resistance was found to each causal agent and each was independent; however, combined resistance to both pathogens exists in M. esculenta (Table 5). Resistance to C. henningsii was more frequent than resistance to C. vicosae among the evaluated clones (Fig. 2).

Sanitary quality of planting material

In any cassava production system, the following problems are always observed: (a) plant population is not equal to the number of cuttings planted; (b) differences occur in plant vigor between plants in the same cassava plantation; (c) yield varies between plants of same clone; and (d) root rot problems are related to the sanitary condition of the planted cuttings. Cultural characteristics of the cuttings (maturity, size, number of nodes, etc.) used for planting, are important in the cyclic occurrence of the above problems; however, the sanitary quality of the cuttings is also crucial. For example, plots of selected cuttings from traditional susceptible (to biotic constraints) clones, taken from disease-free plants obtained from meristem cultures, yielded considerably more than plots planted with "uncleaned" selected cuttings (Table 6). However, in Carimagua the yield of the resistant clone M Ven 77 was not modified by the cleaning methodology used (Table 6). These results demonstrate the important effect the sanitary condition of the cutting has on yield potential, and the importance of varietal resistance to biotic constraints on yield.

The following methods to improve the quality of the planting material were investigated with effective results:

1. Disease eradication by meristem culture

Increased yields over controls have always been obtained during the first cycle in plots planted with cuttings from plants derived from meristem culture (Table 6). However, yields have constantly decreased after two cycles of successive planting (Table 7). This instability limits the usefulness of a massive meristem culture cleaning program for cleaning many commercial clones, considering the cost and time involved in producing large amounts of planting material on a commercial-scale.

Searching for reasons for such instability, it was found that cuttings from plants obtained from meristem culture are much more susceptible to certain pathogens than those obtained from farmer's field (Table 8). The population of beneficial bacteria was found to be higher on cuttings from farmer's fields than on plants derived from meristem culture (Table 9). The above is an important indication of the role of native beneficial microflora in protecting cassava plants against

pathogens. Preliminary results indicate that inoculation of cuttings obtained from plants arisen from meristem culture, with beneficial bacteria, gives stable yields during the first two cycles of evaluation.

2. Visual selection of cuttings

Yields of traditional clones increased (Table 10) when cuttings were taken from vigorous, apparently disease-free plants of cassava fields, selected by eliminating those with signs of infection. However, the above system was not effective when cuttings of new hybrids were used (Table 10). Traditional clones, which have been cultivated for many years, have suffered abiotic and biotic stresses which have decreased the quality of cuttings; this has not yet happened to new hybrids. By selecting apparently healthy cuttings from the best looking plants in a plantation, many sanitary problems can be avoided.

3. Selection of cuttings according to yield/plant

The use of selected cuttings from the highest yielding plants in a plantation has been shown to be highly successful (CIAT, 1984, 1985; Table 11). The advantage of this selection method is that it is more effective for clones that are susceptible to various production constraints than for clones that appear to have stable resistance (Table 11).

4. Selection of cuttings from plants growing on the best plots of a farm

The disease severity of plants is, to a certain point related to their nutritional status (i.e. poor nutrition increases susceptibility to weak pathogens). Reserving the best plots of the farm for cutting production has increased the quality of planting material with a consequent yield increase (Table 12). Supplying the best cultural practices to plots exclusively chosen for planting material production (i.e. fertilization, pest control, improved drainage, etc.), can improve the quality of planting material considerably.

5. Cutting treatments

Visually selected cuttings could be infested or infected by pathogens which can induce losses during the growing cycle and reduce yields. Similarly, soils infested by soil-borne pathogens may affect unprotected cuttings after planting. In order to desinfest and eradicate pathogens from selected cuttings, as well as to protect them against soil-borne pathogens during establishment, it is necessary to treat cuttings with fungicide-insecticide mixtures.

Considerable yield increases (Table 13) and reduction of root rots (Table 14) have been obtained when selected cuttings were treated with mixtures of systemic and protectant fungicides (i.e. Benomyl and Maneb) plus a broad spectrum pesticide (i.e. Malathion). Effective protection was also obtained when cuttings were treated with *Pseudomonas putida* (Strain No.88) (Tables 13 and 14). This opens the possibility for a better approach to control biological root rots of cassava.

Summarizing the above, it is concluded that the sanitary condition of the planting material directly influences final yields. Planting material of good sanitary quality can be produced by taking cuttings

from the most fertile plots on the farm, by selecting cuttings, or by treatment with a fungicide- insecticide mixture or an improved strain of a beneficial epyphitic bacterial species. Cuttings should be selected from visually healthy and high yielding 10 to 12 month-old plants. Basic clean stocks of native clones should be produced by cleaning the clones with meristem culture technique; however, to assure the stability of stocks,they should be treated with beneficial bacteria to initiate natural acquired resistence.

Effect of fluorescent Pseudomonads on cassava

The protective effect of strains of *P. putida* and *P. fluorescens* to inhibit cassava pathogens (i.e. root rots and cassava bacterial blight), was reported previously (CIAT Cassava Program Annual Report, 1984, 1985).

By using 119 strains collected in 8 different ecological zones of Colombia to inoculate cuttings (1×10^9 cfu/ml) of 5 clones of cassava the following general groups of fluorescent pseudomonads were distinguished:

Group 1

No antagonistic reaction *in vitro* to cassava pathogens, but increased the root system of cassava clones (Table 15 and Fig. 3). This result, which has previously been reported on other crop species, suggests the production of root promoting regulators. Inoculations of plantlets, obtained by the shoot rooting system in water (CIAT, 1974) under sterile conditions using the Leonard jar system, corroborated previous findings (Table 16). The root system of sterile plants was significantly increased by various strains of *P. fluorescens*.

Group 2

Strains belonging to this group showed a high inhibitory effect *in vitro* to pathogens of cassava (both fungi and bacteria), but did not promote an increase in foliage or root system of inoculated clones. As reported for other crop species, secondary metabolities may have fitotoxic or antibiotic activity.

Group 3

Strains of this group inhibited cassava pathogens and increased both the foliage and root systems of inoculated clones (Fig. 3). It is possible that antagonistic interactions with pathogens (nutrient competion or antibiotic effectc) resulted in the exclusion of these from the rhizosphere. Healthy roots promote better total plant growth.

Group 4

Strains of this group induced a strong inhibitory effect on cassava pathogens and a significant increase in the aerial parts of inoculated clones (Table 17 and Fig. 3). This has also been reported for other crop species, which were affected by Gibberellic acid applications, compounds also found to be produced by some strains of fluorescent pseudomonads.

Further investigations on the above topics will continue by using strains of each of these established groups.

Survival

High bacterial populations were found in the rhizosphere of inoculated plants of 5 clones, two months after inoculations with 1.4 X 10^8 cfu/ml. Even though there were variations in bacterial populations among clones and between strains, a clone/strain interaction was not found. This indicates negative specificity with the host, at least among the strains used. It has been reported that survival of this group of bacteria is probably dependent on nutrient availability, space and cellular migration to new sites, or a combination of these factors. Similarly, quality of exudates (production and quantity of specific amino-acids or toxic compounds) may influence the survival of this bacterial species. Further investigations will include specific clones selected for their HCN-acid content and starch production.

Treatment of cuttings with beneficial bacteria is a promising method to increase production of cassava (CIAT 1984, 1985). But cuttings should also be treated with fungicidal mixtures to eradicate and protect against pathogens. Strains of fluorescent pseudomonads were tested against the most commonly used fungicides for cassava cutting treatments. Results (Table 18) showed that only Manzate (Maneb) induced a significant deleterious effect on bacterial populations of tested strains. This indicates the possibility of using both bacterial and fungicidal treatments simultaneously.

Storage of planting material

Planting material of cassava must be stored in many cassava growing areas for several reasons: unsuitable conditions for planting, lack of prepared land at time of planting, excessive demand for cassava roots before the planting season, etc. The storage of planting material reduces cutting quality considerably; the reduction in plant establishment commonly found, is related to the storage conditions and the length of storage.

The following factors were reported (CIAT 1976, 1977) as reducing the quality of planting material during storage: (a) dehydration: related to availability of nutrients; (b) sanitary conditions: pathogens and insects can affect and spread among cuttings during the storage time; and (c) early bud germination which directly depletes nutrient reserves in the cuttings.

In order to develop a reliable and practical system for storing cassava planting material, cuttings 1.20 m in length from three clones were stored at two locations, CIAT and Media Luna. They were stored in bundles of 10 cuttings/treatment/clone, under four different light regimes of approximately 86 foot candles (in a hut), 4.800 (in a screen house), 10.200 (under a tree) and 13.400 (plain sun light). Light measurements were taken at 10cm above ground at noon. All bundles were stored vertically. One replication was stored with the base of the cuttings in a container containing 5 cm of water, another replication was stored on a dry base and the third replication was buried in soil to a depth of 5 cm. The periods of storage/treatment/clone were of 1, 2, 3, and 4 months plus control.

Results after four months of storing long cuttings (1m or more) of two cassava clones in Media Luna and CIAT, are presented in Figs. 4 and 5.

General results from these investigations and previous experiments carried out at CIAT (1977, 1981 and 1982) lead to the following conclusions:

1. Long cuttings (1.0 to 1.30m) are more resistant to storage than short cuttings (20cm) (CIAT, 1976). Consequently, only cuttings longer than 1.0 m should be stored.

2. The quality of stored cuttings decreases over prolonged periods (CIAT, 1976 and 1983). Consequently, to maintain high quality the storage period should be as short as possible.

3. There are varietal differences in storage quality of planting material. Consequently, it is advisable to select for this important factor especially in areas where storage is required. A storage system for screening could be the following: store bundles (10 cuttings/clone) of 1.20m cuttings under the shade of a tree (10,000 f.c. at midday, approximately) for a period of three months. Cut stored cuttings to 20cm long cuttings, eliminating the first 5cm from each extreme, and plant under greenhouse or field conditions. Observe the germination percentage two months after planting.

4. Plant type is correlated with the observed varietal difference in storage of planting material. Unbranched or late branching clones (Venezolana 1 and CMC 40, Figs. 4 and 5) stored well, while early branching types (Secundina, and M Col 1684, Figs. 4 and 5) did not.

5. It is essential to treat cuttings with a fungicidal-insecticidal mixture in order to eradicate and protect cuttings from fungi, insects and mites during the storage period (CIAT, 1976).

6. The quality of cuttings during the storage time is related with the light intensity during storage. More plants were obtained from cuttings stored under plain sun light than at lower light intensities (Figs. 4 and 5). This appears to be related with the carbohydrate levels inside the cuttings as suggested previously (CIAT, 1985). Sprouts from cuttings stored under plain sun light restore the carbohydrates lost during storage more efficiently than those from cuttings stored under deficient light.

7. Water excess or high relative humidity in the storage environment, decreases quality of storaged planting material. This is a consequence of increased pest damage favored by the environment (Figs. 4 and 5).

Future projections

1. Basic etiological studies on unreported diseases affecting cassava plantations of Asia and the Americas. These studies will include taxonomy of the causal agents and determination of environmental factors required for growth *in vitro*, for establishment on other hosts and for disease development in the field.

2. Epidemiological studies to determine reasons for recent outbreaks in several regions of the Americas and Asia, i.e. in the northeast-Brasil, root rots are inducing losses of more than 70%.

3. Studies on the control of cassava diseases will focus on the following topics:

   a. Cultural practices
   These studies will include both monoclonal and multiclonal plantings as well as mixed and mono-cropping systems. Suggested agronomic practices will be evaluated in order to determine the advantages or disadvantages offered for controlling diseases of cassava: i.e. determination of the effect of hand, mechanical and herbicidal weeding on the incidence of root rots.

   b. Biological control
   Studies on the effect of increasing populations of beneficial bacteria on the severity and incidence of stem and root rots as well as on the promotion of plant root growth with the consequent yield increase. The interactions (biological and physical) of beneficial organisms with cassava clones will also be investigated, as well as practical means for their isolation, culture, storage and inoculation under commercial systems.

   c. Varietal resistance
   New systems for evaluating for resistance to most important diseases will be developed or improved. Mass screening evaluations for resistance to the most important rotting fungi (*Diplodia*, *Fusarium*, *Phytophthora* species) will be conducted. Studies on the nature of resistance, genetic control and linkage with resistance mechanisms to other pathogens are planned.

   d. Sanitary measures
   The existing methods for the production of high quality planting material will be improved, and methods will be developed to facilitate the interchange of cassava planting material (sexual and asexual) among countries and regions within countries. Recommendations based on research results will be implemented to reduce risks of introducing cassava pathogens during the interchange of cassava planting material.

Table 1. Reaction of 9 clones to *Diplodia manihotis* 20 days after dip inoculation in a conidial suspension of 4 X 10^4 conidia/ml.

Clone	Disease reaction[a]	
	Unsterile cuttings	Sterile cuttings
M Bra 12	S	S
M Col 22	S	S
M Pan 70	S	S
M Col 1684	S	S
M Col 458A	S	I or R
M Col 2063	S	I or R
M Col 2032	S	I or R
M Col 2057	R	R
M Bra 174	R	R
M Mal 2	R	R

[a] Disease reaction: S=bud germination ranging from 0 to 30%; R=bud germination ranging from 76 to 100%; and I=intermediate germination (bud germination ranging from 30% to 75%). Average results of 10 cuttings per inoculation replicated 3 times.

Table 2. Reaction of three clones to *F. oxysporum* and *F. solani* 20 days after dip inoculation of cuttings in a suspension of 6.8×10^4 conidia/ml.

Pathogen	Clonal reaction		
	M Col 1684	M Col 113	CMC 40
F. oxysporum #CIAT 5	R[a]	S	IR
F. solani #CIAT 7	S	S	S

[a] Data taken after inoculating 20 cuttings/clone/pathogen species. Disease reaction: R=resistant; IR=intermediate resistant; and S=susceptible.

Table 3. Reaction of different clones of cassava to different strains of *F. oxysporum* collected at CIAT-Palmira, Carimagua and Media Luna.

Group of clones	Fungal strain location		
	CIAT-Palmira	Carimagua	Media Luna
A	S[a]	S	S
B	S	R	S
C	S	S	R
D	R	S	S/I

[a] Reaction to *F. oxysporum*: R=resistant; I=intermediate resistant; and S= susceptible. Results of 20 cuttings/clone inoculated/strain.

Table 4. Reaction of 85 clones to anthracnose, induced by *C. gloeosporioides*, by both stem and leaf puncturing inoculation methods.

Number of evaluated clones	Disease reaction	Percentage leaf area affected
20	R[a]	24
28	I	32
37	S	44

[a] Results after inoculating 20 plantlets or leaves/inoculation method/clone by using an inoculum concentration of 4×10^6 conidia per ml. R=resistant; and S=susceptible.

Table 5. Group of cassava clones in relation to their reaction to *Cercosporidium henningsii* (C.h.) and *Cercospora vicosae* (C.v.) under field conditions.

Clone number	Disease reaction	
	C. h.	C. v.
M Ven 23	R[a]	R
M Ven 185	R	S
SG 104-57	R	S
SG 106-59	R	S
CM 1305-3	S	R
CT 26-12	S	R
CM 2512-11	S	R
CM 1022-4	S	S
CG 1-17	S	S
SG 105-11	S	S

[a] Reaction of 20 plants/clone, 7 months after planting: R= resistant (1 to 2=up to 20% of leaf area affected); S= susceptible (3.6 to 5=more than 60% of the leaf area affected).

Table 6. First cycle yields (ton of fresh roots/h) of cleaned (cutting source=plants obtained from meristem culture) and uncleaned traditional clones planted in the site of origin.

	Site of evaluation and source of cuttings							
	Quilcace		Media Luna		Carimagua		CIAT	
Clone	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned
Quilcace	7.5[a]	17.4	-		-	-	-	-
M Col 113	4.6	16.5	-	-	-	-	-	-
Secundina	-	-	17.6	32.8	-	-	17.2	36.1
Llanera	-	-	-	-	4.1	14.8	-	-
M Col 1684	-	-	-	-	-	-	26.8	29.6
M Col 72	-	-	-	-	-	-	16.0	19.4
CMC 40	-	-	-	-	8.4	16.7	17.2	26.8
M Ven 77	-	-	-	-	13.0	13.9	-	-

[a] Results of 4 plots with 30 plants each per clone obtained 11 to 12 months after planting.

Table 7. Yields (ton/ha) of four native clones during several cycles after being cleaned by the meristem culture system.

Cycle of planting	Clone			
	Secundina	Llanera	Quilcace	M Col 113
I	30[a]	15	17	17
II	26	11	13	7
III	21	6	-	-
Control	17	4	8	5

[a] Results of 4 plots with 30 plants each per clone obtained at 11 to 12 months after planting. Border plants were eliminated.

Table 8. Percentage of bud germination of cuttings of five cassava clones from farmers' fields and from plants derived from meristem culture 30 days after inoculation with *Diplodia manihotis*.

Clone	Source of cuttings	
	Farmers' fields	Meristem cultures
M Col 113	95[a]	0
CMC 40	60	0
M Col 72	50	0
M Col 1684	10	0
M Ven 77	0	0

[a] Data taken from approximately 40 cuttings/clone/source.

Table 9. Bacterial population on Secundina cassava cuttings from 6 month old plants from farmer's fields and from plants obtained from meristem culture.

Cutting source	Media for isolation		
	PDA[a]	NA	KB
Farmers' fields	3×10^5 [b]	3×10^7	2×10^7
Meristem cultures	3×10^4	5×10^4	6×10^4

[a] PDA= potato-dextrose-agar; NA=nutrient agar; KB=King's B medium.

[b] Data taken by dilution plante of washed suspensions of 10cm long cuttings. Most bacteria belonged to Bacillus and Pseudomonas genera and were antagonistic to several bacterial and fungal pathogens of cassava

Table 10. Yield of two traditional clones and two new hybrids using visually selected cuttings from the healthiest plants of a plantation.

Clones	Visual selection	
	Unsel -ted	Selected
Cultivars		
M Col 22	18[1]	24[b]
CMC 40	9[a]	13[b]
Hybrids		
CM 523-7	26[a]	27[a]
CM 342-170	21[a]	23[a]

Results of 4 plots with 30 plants each per clone and treatment obtained at 11 - 12 months after planting. Border plants were eliminated. Yields followed by the same letter are not significantly different at the 0.05 level of the Duncan Multiple Range Test.

Table 11. Effect of cutting selection (according to yield/plant) in three different locations and during two year in relation to clonal resistance/susceptibility to production constraints in each location.

		Yield (ton/ha)					
		Media Luna		CIAT		Carimagua	
Cultivar	Source of cuttings	1985	1986	1985	1986	1985	1986
Venezolana 2 (Verdecita M Col)	H[b]	7.1a	20.8a				
	L	7.0a(1)[c]	18.1b (15)				
Venezolana 1[a] (Coñito M Col)	H	10.3a	24.1a				
	L	6.8b(52)	16.3b (48)				
Secundina[a] (M Col)	H	10.2a	25.4				
	L	6.0b(70)	19.6(30)				
M Col 113	H			18.7a	-		
	L			17.7a(6)	-		
M Col 22	H			38.9a	-		
	L			33.3b(17)	-		
CMC 40[a]	H			29.5a	-	9.6a	16.6a
	L			18.6b(58)	-	5.8b(66)	9.2b (80)
M Pan 19	H					9.0a	20.3a
	L					7.5a(21)	16.1b (26)
M Ven 77	H					13.5a	25.1a
	L					12.2a(11)	22.1b (14)

[a] Clones which were evaluated as susceptible to production constraints in the respective locations.

[b] H=percentage of plants with higher yield than the plot average; L=percentage plants with lower yield than the plot average.

[c] Data taken from four replicates plots of 30 plants each. In parentheses is the percentage of yield increase obtained by using cuttings from high yielding plants. The figures on the same column are not significantly different at 0.05 level of the Duncan Multiple Range Test.

Table 12. Effect of cutting source on yield of two cassava clones with resistance (R) and intermediate resistance (IR) to pathological problems at Carimagua.

Cutting source	Fresh root yield (ton/ha)	
	M Ecu 82 (R)	CMC 40 (IR)
Agronomia[a]	19.2 a	7.4 a
Reserva	10.0 b	4.0 b

[a] "Agronomia" is an area with better soil nutrition than the "Reserva" but both areas are on the Carimagua station.

Table 13. Yield of 6 clones when selected cuttings were treated with a fungicidal-pesticidal mixture or a bacterial suspension of *Pseudomonas putida*, Strain 88 (1×10^9 cfu/ml) before planting at CIAT-Palmira.

M Ven 77	Yield (ton/ha) per treatment		
	Bacterization	Fungicide	Controls
M Ven 77	16[a] (45)[b]	16 (45)	11
Secundina	23 (77)	24 (84)	13
Venezolana 1	26 (30)	24 (20)	20
M Col 113	14 (40)	13 (30)	10
CM 342-170	27 (50)	30 (67)	18
CM 523-7	30 (100)	22 (47)	15

[a] Results of 4 plots with 30 plants each; border plants were eliminated. Cuttings were chemically treated by immersion in a mixed solution of Benomyl (3g/l of a.i.), Maneb (3g/l of i.a.), and Malathion 57 (2ml/l) during 5 minutes. Bactericidal treatment: immersion in a bacterial suspension for 20 minutes.

[b] Percentage of yield increase in relation to controls.

Table 14. Percentage of root rot decrease by treating cuttings with a mixture of fungicide-insecticide or with a bacterial suspension of *P. putida*, strain 88 (1×10^9 cfu/ml) before planting at CIAT-Palmira.

Clone	Percentage of root rots at harvest/treatment		
	Bacterial inoculation	Fungicide	Controls
M Col 113	7[a]	18	41
CM 342-170	1	0	12
CM 523-7	0	0	5

[a] Results of 4 plots with 30 plants each; border plants were eliminated. Cuttings were bactericidal treated by immersion in the bacterial suspension for 20min; they were chemical treated by immersion in a mixed solution of Benomyl (3g/l a.i.), Maneb (3g/l a.i.), and Malathion 57 (2ml/l) for 5 min.

Table 15. Effect of some strains of P. putida and P. fluorescens on cassava clones two months after planting. Increase percentage in relation to root weight of untreated controls.

Duncan	Average	Strain
A**	320.06	60
A		
B A	317.50	23
B A		
B A C	295.67	3
B A C		
B A C	293.49	11
B A C		
B D A C	281.87	65
B D A C		
B D A C	278.88	90
B D A C		
B D A C	278.05	35
B D A C		
E B D A C	272.67	44
E B D A C		
E B D A C F	268.81	88
E B D A C F		
E B D A G C F	255.71	64
E B D G C F		
E B D H G C F	245.04	148
E D H G C F		
E I D H G C F	241.01	13
E I D H G C F		
E I D J H G C F	224.12	58
E I D J H G C F		
E I D J H G C F	223.32	59
E I D J H G F		
E I D J H G K F	216.97	91
E I D J H G K F		
E I L D J H G K F	212.23	147
E I L D J H G K F		
E I L D J H G K F	208.91	39
E I L D J H G K F		
E I L D J H G K F	208.17	262
E I L D J H G K F		
E I L D J H G K F	206.95	77
E I L J H G K F		
E I L M J H G K F	197.30	10
I L M J H G K F		
I L M J H G K F	195.88	154
I L M J H G K		
N I L M J H G K	188.78	252
N I L M J H G K		
N I L M J H G K O	183.07	259
N I L M J H G K O		
N I L M J H G K O	179.98	28
N I L M J H K O		
N I L M J H K O	178.82	140
N I L M J H K O		
N I L M J H P K C	175.91	85
N I L M J H P K O		
N I L M J H P K O	175.84	12
N I L M J H P K O		
N Q I L M J H P K O	173.53	263
N Q I L M J P K O		
N Q I L M J R P K O	166.47	45
N Q S L M J R P K O		
N Q S L M J R P K O	161.82	251
N Q S L M J R P K O		
T N Q S L M J R P K O	147.32	81
T N Q S L M R P K O		
T N Q S L M R P K O	144.70	48
T N Q S L M R P O		
T N Q S L M R P O	137.66	238
T N Q S L M R P O		
T N Q S L M R P O	136.17	67
T N Q S M R P O		
T N Q S M R P O	122.74	189
T N Q S R P O		
T N Q S R P O	116.50	208
T Q S R P O		
T Q S R P O	112.00	188
T Q S R P		
T Q S R P	101.52	204
T Q S R P		
T Q S R P	101.38	250
T Q S R		
T Q S R	98.09	200
T S R		
T S R	95.57	217
T S R		
T S R	92.35	49
T S R		
T S R	92.24	192
T S R		
T S R	91.55	206
T S R		
T S R	90.03	25
T S		
T S	87.48	210
T		
T	75.12	233

* Results of 10 cuttings/clone/ each cutting was inoculated by dip immersion for 20 min in a bacterial suspension of 1 X 10^9 cfu/ml, and 15 and 30 days after by pouring 10cm of an inoculum with the same bacterial concentration, approximately.

** Readings with the same letter did not differ significantly (Duncan Multiple Range Test)

Table 16. Effect of *P. fluorescens* (strain 88) on the root system of cassava (clone M Ven 77) two months after inoculation and incubation under sterile conditions.

Treatment	root weight (g)	increase (%)
P. fluorescens plus nitrogen	4.5[a]	164
uninoculated control plus nitrogen	1.7	-

[a] Results of 10 plantlets which were immersed for 20min in a bacterial suspension of 1×10^9 cfu/ml. Leonard jar contained sterile Morri's medium plus washed quartz.

Table 17. Effect of some strains of P. putida and P. fluorescens on 5 cassava clones two months after planting. Increase percentage in relation to above ground weight of untreated controls.

Duncan	Average	Strain
A**	284.60	58
B	198.79	154
B	194.30	147
B	168.85	60
B	162.85	59
B	161.72	140
B	160.13	65
B	159.37	3
B	156.08	23
B	155.02	259
B	153.16	64
B	149.02	11
B	147.35	262
B	145.18	77
B	143.91	252
B	140.68	28
B	134.33	48
B	134.29	35
B	132.92	45
B	132.58	90
B	132.38	238
B	129.54	44
B	127.22	12
B	125.57	13
B	123.38	88
B	121.95	39
B	119.09	251
B	118.07	85
B	117.52	263
B	112.63	250
B	112.21	189
B	109.75	67
B	104.75	91
B	103.79	25
B	101.18	10
B	100.79	49
B	100.18	188
B	94.45	192
B	94.19	200
B	91.45	208
B	90.99	81
B	84.07	204
B	83.31	217
B	78.04	210
B	78.01	233
B	65.81	206

** Results of 10 cuttings/clone; each cutting was inoculated by dip immersion for 20 min in a bacterial suspension of 1 X 10^9 cfu/ml, and 15 and 30 days after by pouring 10cm of an inoculum with the same bacterial concentration approximately.

** Readings with the same letter did not differ significantly (Duncan Multiple Range Test).

Table 18.. Populations of three strains of *P. putida* (P.p.) and *P. fluorescens* (P.f.) 36 h after the inoculation of nutrient broth (NB) with several fungicides.

Fungicide added to medium	cfu/per strain inoculated		
	P.p. F-44	P.f. C-88	P.f. C-5a
Benomyl	1.5×10^7	1×10^7	2.5×10^6
Maneb	0	0	0
Captan	1.5×10^5	1.5×10^4	2.8×10^3
Thiabendazole	1.0×10^8	3×10^8	1.0×10^8
Captafol	1.9×10^7	1.8×10^7	3.5×10^7
Benomyl+ Captan	1.8×10^5	1.0×10^6	1.5×10^6
Control	1.0×10^8	2.0×10^8	1.1×10^9

[a] Bacterial population in 100 ml of nutrient agar plus fungicide (concentration of 3,800 ppm) inoculated with 10 ml of a bacterial suspension of 1×10^9 cfu/ml; 36h after flasks were incubated in a shaker at 25°C.

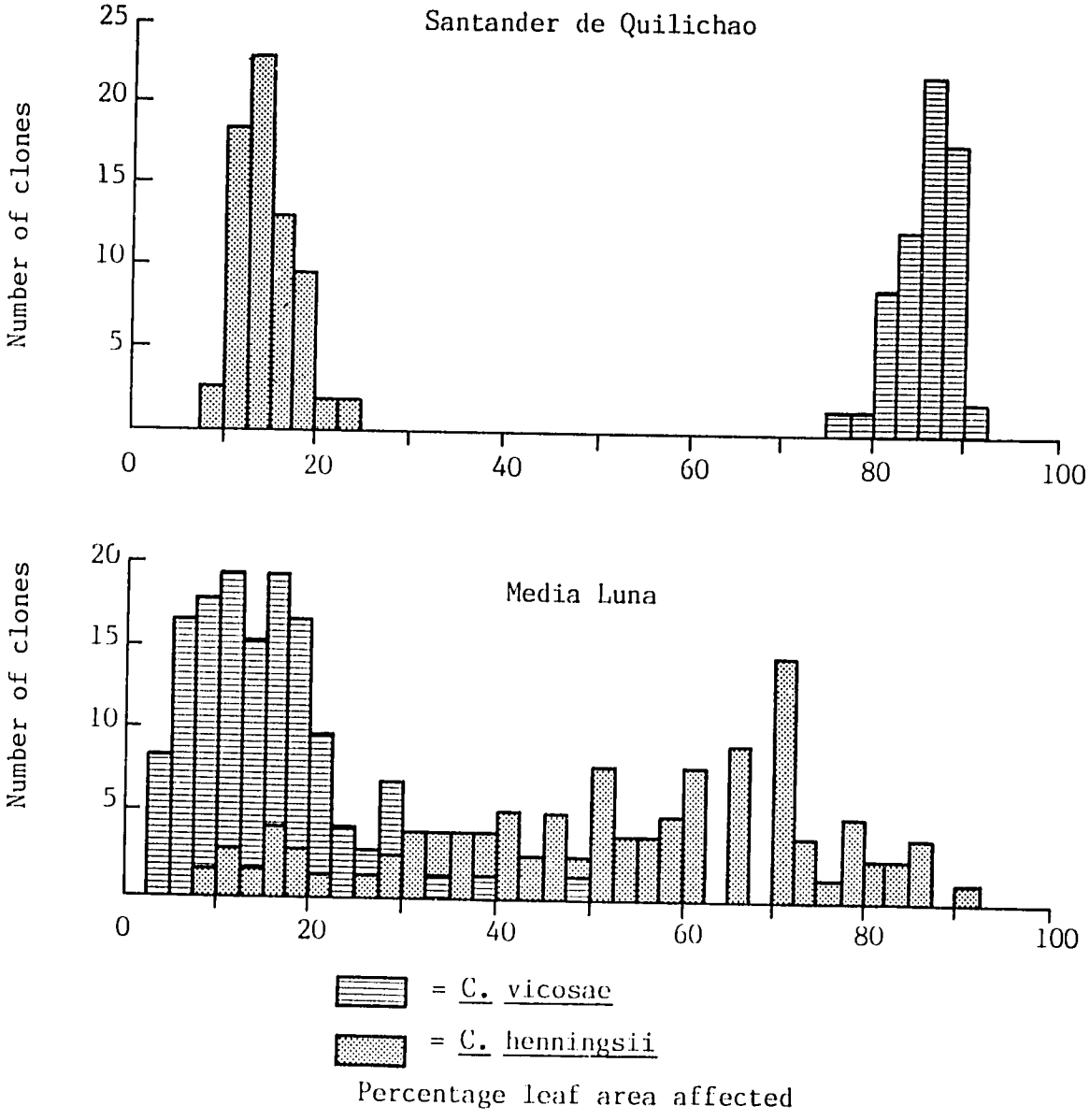
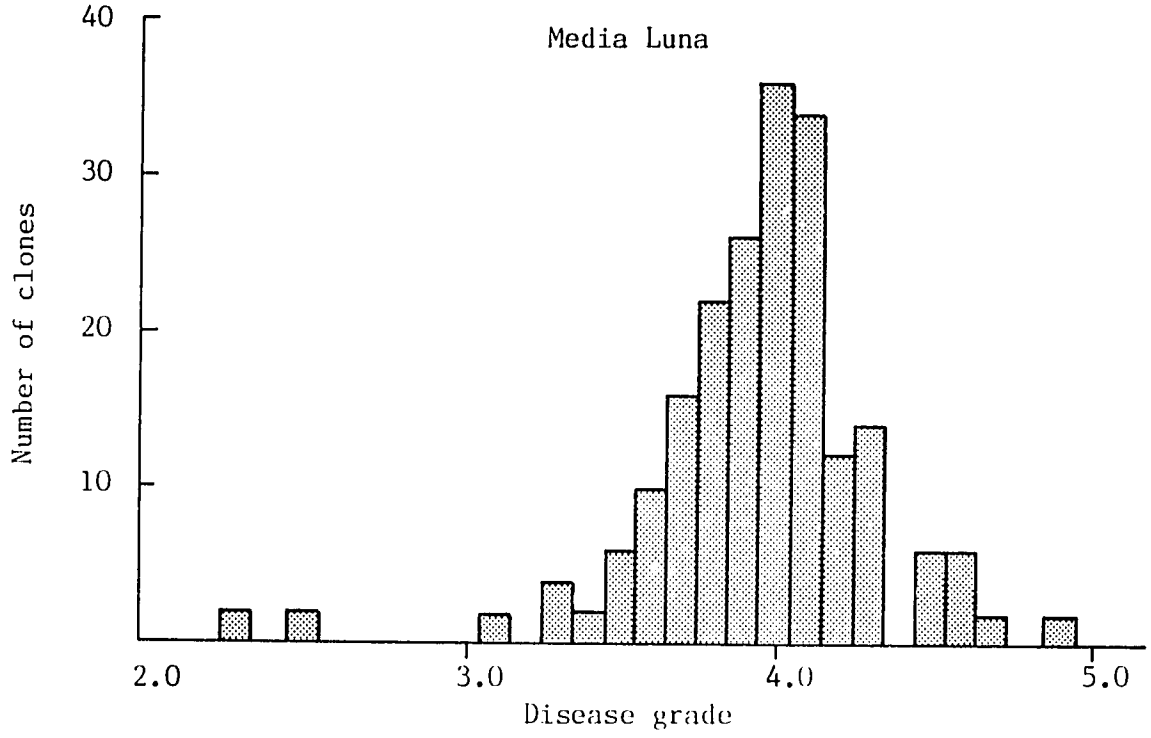


Fig. 1. Distribution of 113 clones according to the percentage of their affected leaf area by Cercospora vicosae and Cercosporidium henningsii in two locations where these two diseases are endemic.



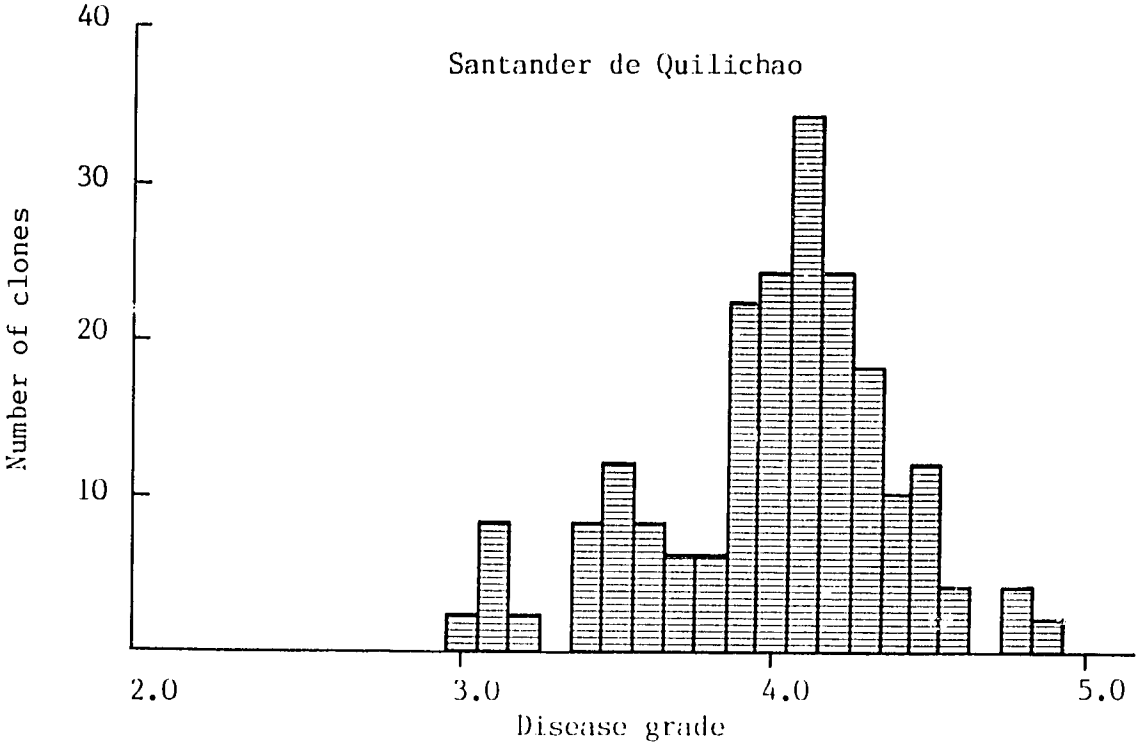


Fig. 2. Number of clones per disease grade in Media Luna (*C. henningsii* endemic) and Santander de Quilichao (*C. vicosae* endemic).

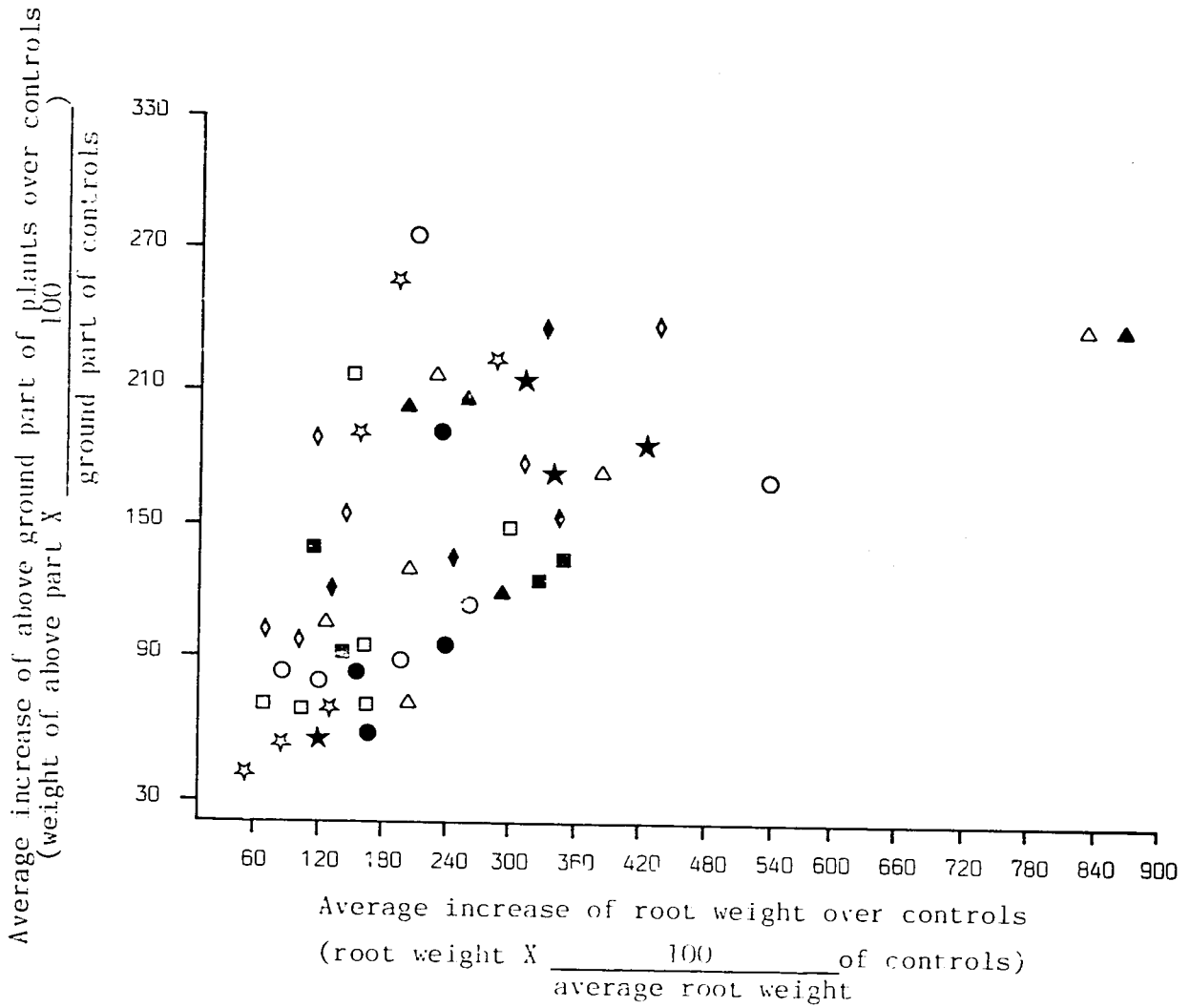


Fig. 3. Reaction of five cassava clones (◊=CM 523-7; □= CMC 40; △ = CMC 92; ☆= M Ven 77; and ○= M Col 2053) to six strains of P. fluorescens (◊ □ △ ☆ ○) and four strains of P. putida (♦ ■ ▲ ★ ●) two months after inoculation.

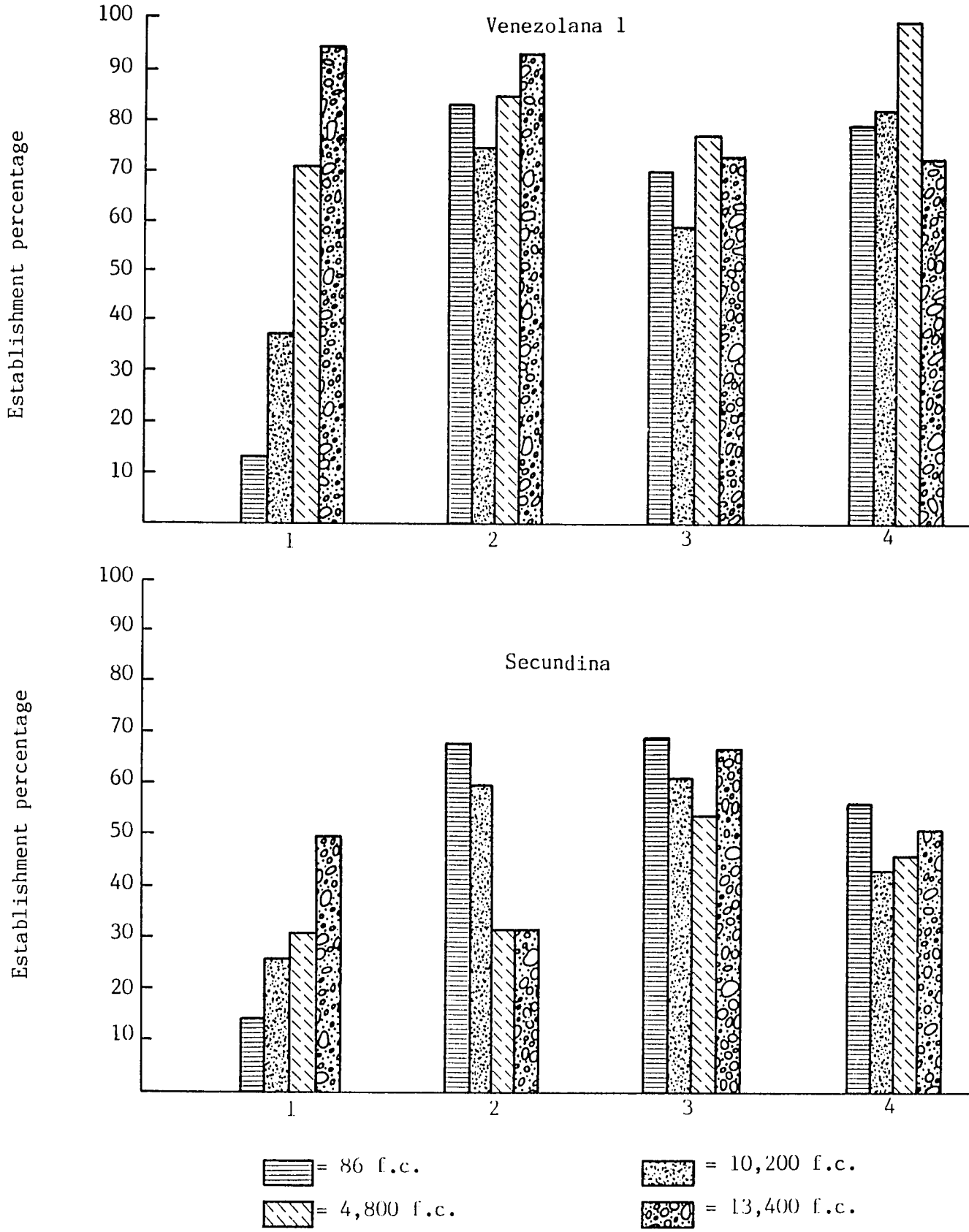


Fig. 4. Percentage of establishment in Media Luna of two clones by using cuttings stored during four months under four different light intensities (foot candles=f.c.) and laid on: 1=soil with water to field capacity; 2=soil with water supplied; 3=the first 5cm of the cut extreme in water; 4=on dry surface.

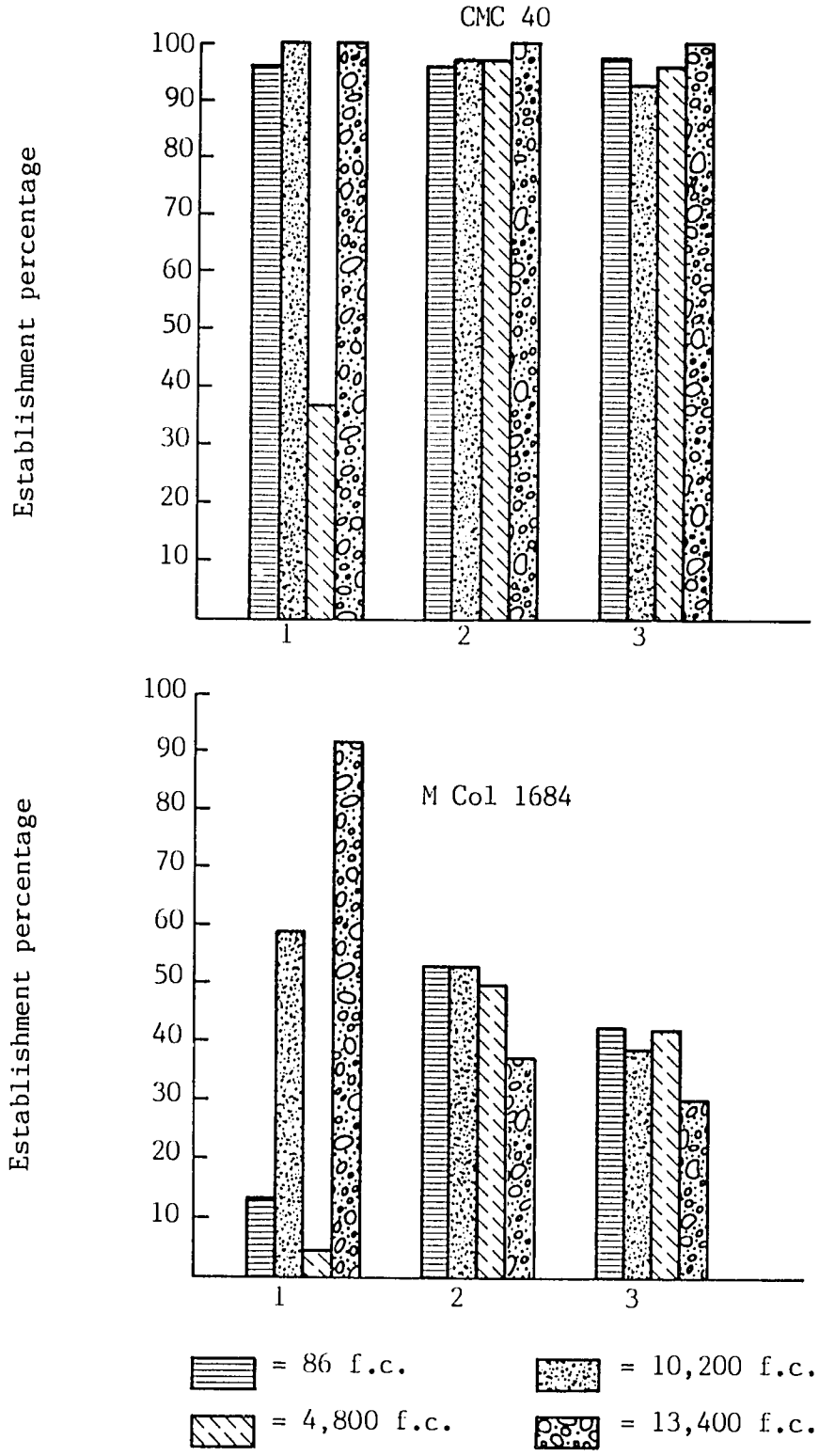


Fig. 5. Percentage of establishment in CIAT of two clones by using cuttings stored during four months under four different light intensities (foot candles=f.c.) and laid on: 1=soil water to field capacity; 2=the first 5cm of the cut extreme in water; 3=on dry surface.

VIROLOGY

During 1986, research activities in cassava virology included: (1) studies on the field dissemination of viruses at CIAT-Palmira and Quilcace; (2) identification of two whitefly vector species; (3) characterization and comparison of five isolates of cassava common mosaic virus; and (4) improvements to the virus indexing protocol currently in use at CIAT.

Field dissemination studies at CIAT-Palmira and Quilcace-Cauca

The clone Secundina (MCol 2063) is susceptible to many Latin American cassava viruses, making it useful as an indicator clone in graft indexing and for monitoring virus spread in the field. Secundina plants rapidly expressed severe mosaic symptoms when grown at Media Luna on the Colombian north coast and at Quilcace, Cauca, where the Caribbean mosaic disease and frogskin disease agents are endemic (CIAT Cassava Program Annual Reports, 1984, 1985). Recently, similar mosaic symptoms have been observed on Secundina plants infected with the frogskin disease at CIAT-Palmira. A trial to assess the affect of planting date on the spread of this mosaic agent, was conducted at CIAT-Palmira during the 1985-1986 season. Plots of Secundina were planted every 3 weeks over a 12 month period. Disease progress was estimated by counting the number of mosaic-infected plants/plot during climatic periods favorable for symptom expression.

Disease progress was slow in comparison to the spread in Quilcace (CIAT Cassava Program Annual Report, 1984) and Media Luna (CIAT Cassava Program Annual Report, 1985), where the majority of plants were infected, and expressed symptoms, within the first 90 days. In this trial, disease incidence was usually less than 5% during the first 90 days after germination, and did not reach 100% in any of the plots, even after a one year growing season (Table 1). There was not a marked effect of planting date on disease spread, although incidence in two plots, planted on May 27 and June 18, 1985, remained below 25%. The fluctuation in disease incidence between planting dates, could reflect environmental effects on the population and/or feeding activity of an insect vector. Several species of whiteflies were consistently observed feeding on plants in this trial.

Whiteflies were tested as potential vectors by collecting a random sample of adults from mosaic-diseased plants and caging them on healthy Secundina plants. After several weeks, mosaic-symptoms were observed on two of 30 test plants. Seven of the 30 test plants also reacted with antiserum to cassava X virus (CsXV) in the ELISA test (Table 2). The mosaic agent could not be mechanically-transmitted from plant # 7 to *Chenopodium quinoa*, whereas a virus related to CsXV could be readily transmitted from the ELISA positive plants (# 4, 5, 13, 14, 15, 26 and 30) (Table 2). Plant # 26 was infected with both the mosaic agent and the CsXV isolate.

These results suggest that two viral agents were transmitted by whiteflies at CIAT-Palmira; one produces a mosaic disease on Secundina, is associated with frogskin root symptoms, and is not mechanically

transmissible; the other virus is symptomless on Secundina, is serologically-related to CsXV, a potexvirus, and is mechanically transmissible. This is the first evidence for the apparent whitefly transmission of a potexvirus. The symptomless virus is very similar to CsXV, but does not produce symptoms on Nicotiana benthamiana nor several other CsXV hosts. The isolation and characterization of this CsXV isolate is in progress. Characterization of the mosaic agent has proven more difficult because of lack of mechanical transmission, no apparent serological relationship to other whitefly-transmitted viruses (ie. geminiviruses) and absence of virus-like particles in cassava. Since a mixture of whitefly species were used in these studies, the vector species could not be determined. Transmission experiments with individual species under controlled conditions, are necessary for determining parameters such as the minimum acquisition and inoculation feeding periods required for transmission. These experiments have not been possible due to problems encountered in the establishment and maintenance of whitefly colonies. Growth room space and additional technical support will be allocated to whitefly colony work in 1987.

Quilcace

Similar transmission results were observed in trials at Quilcace where the frogskin disease is endemic. Within three months after placing potted Secundina plants in the field, mosaic symptoms developed on the majority of the plants, and some were infected with the CsXV isolate. In table 3, plants designated 8A, 8B, 14A, 14B, 18A, 18B, 23A, and 23B were virus-free before entering the field at Quilcace, whereas plants designated 1A, 1B, 7A, 7B, 20A, 20B, 21A, and 21B were infected with CsXV before being placed in the field. All plants were symptomless at the start of the experiment. Within the virus-free group, three plants were indexed positive in CsXV ELISA and three plants developed mosaic symptoms after three months in the field. A virus isolated from the ELISA positive plants produced local lesions on C. quinoa but not on N. benthamiana. These reactions are similar to the CsXV-related isolate described in the previous section. Mosaic symptoms developed on all plants that were CsXV-positive before entering the field. The mosaic agent alone produces a mild mosaic with very little leaf distortion and stunting. The CsXV isolate could be transmitted apart from the mosaic agent as observed in plants 14B and 23A. After three months, mild frogskin disease root symptoms were observed on several of the mosaic/CsXV-infected plants, but not on any of the plants infected with the CsXV isolate alone. In summary, there is evidence for the transmission of two viral agents in Quilcace that are similar, if not identical, to the two whitefly-transmitted viruses at CIAT-Palmira.

The role of whiteflies in the transmission of these agents was investigated at Quilcace under field conditions. A random sample of whiteflies was collected in a frogskin-infested field, and individual adults were tested for transmission ability by caging one whitefly per Secundina or MCol 113 plant. After several weeks, the cages were removed and the plants evaluated for mosaic symptoms, and if pupae were present the whitefly species identified. All test plants were also indexed by CsXV-ELISA, transplanted in an isolated field and evaluated for frogskin root symptoms after several months.

The whitefly species could be identified on 158 of the 345 (46%) Secundina plants, and on 164 of the 345 (48%) MCol 113 plants housed with whiteflies. Around 60% of the whiteflies identified were Aleurotrachelus socialis, 22-25% were Trialeurodes variabilis and less than 19% were Bemisia tuberculata (Table 4). One of the Secundina plants caged with B. tuberculata developed mosaic symptoms, and two Secundina and two MCol 113 plants exposed to A. socialis, were positive in CsXV-ELISA. Mild frogskin root symptoms were only observed on the Secundina plant with mosaic symptoms. Until now, frogskin symptoms have not been observed on any of the other plants. Results from this experiment are very valuable in several respects by: (1) providing an accurate census of the whitefly population in Quilcace; (2) associating A. socialis and B. tuberculata with the transmission of different viral agents; and (3) separating these two viruses via whitefly transmission.

To summarize the results from the dissemination and transmission experiments at CIAT-Palmira and Quilcace: (1) there is evidence for whitefly transmission of a mosaic/frogskin agent at CIAT-Palmira and Quilcace; (2) B. tuberculata is the apparent vector of this agent in the Quilcace region; (3) an isolate of CsXV was also transmitted by whiteflies at the same locations; 4) A. socialis was involved in transmission of the CsXV isolate in Quilcace. The identification of these whitefly vectors will be useful in the planning of control practices and screening for disease resistance. The plants infected via controlled whitefly transmissions will serve as an excellent virus source for characterization work.

Characterization of cassava common mosaic virus (CCMV) isolates.

Last year, five isolates of CCMV (3 Colombian, 1 Brazilian, and 1 Paraguayan), were found to differ in symptomatology on a series of host range plants (CIAT Cassava Program Annual Report, 1985). During 1986, the isolates were further compared on the basis of: (1) virus titer in N. benthamiana; (2) serology using immunosorbent electron microscopy (ISEM) and ELISA; and (3) the molecular weights of the capsid protein, nucleic acid and associated dsRNA.

Each isolate was propagated in, and purified from, N. benthamiana. The amount of virus recovered ranged between 370 to 810 milligrams virus/kilogram leaf tissue for four of the isolates. Virus titer was not correlatd with severity of symptoms because the Paraguayan isolate produced the most severe reaction on N. benthamiana but not the highest virus titer. The isolate designated "U", reached a concentration of only 48 mg virus/kg tissue.

The five isolates were determined to be serologically-related based on results from ISEM and ELISA tests. In ISEM, antiserum to the Brazilian isolate trapped approximately the same number of virus particles for each isolate. The experiment was conducted at three different virus concentrations for each isolate with similar results. Results from ELISA confirmed a close serological relationship between isolates. The Paraguayan isolate gave a slightly weaker reaction, but was still readily detected by ELISA.

The relative molecular weight (Mr) of the capsid protein was estimated to be approximately 21,000 for each isolate. The size of the single-stranded RNA genome and associated dsRNAs were similar for all isolates.

In summary, it was not possible to differentiate between these five isolates of CCMV on the basis of serological reaction, nor on capsid protein or nucleic acid size comparisons. Although these isolates, which differ in severity on cassava, can be identified on the basis of host range, it is a laborious procedure and not practical for many field samples. A means for the rapid identification of isolates would be useful in determining which isolate is most important in terms of geographical distribution and spread into new areas. The application of nucleic acid hybridization for comparing the level of base sequence homology between isolates may be useful. A cDNA probe to the Brazilian isolate has been prepared, labeled with non-radioactive biotin and will be used in hybridization experiments.

Production of virus-free planting material

Over the past two years, two important developments in cassava virology have improved the virus indexing protocol. These developments include the availability of antiserum to cassava X virus (CsXV) and the employment of the dsRNA detection method (CIAT Cassava Program Annual Report, 1985). The efficiency of a virus indexing scheme incoporating these latest techniques was evaluated. Daughter plants derived from virus-infected mother plants by meristem-tip culture/thermotherapy or by shoot culture without thermotherapy, were assayed for virus. The sanitary condition of the infected mother plants was established using the same indexing techniques as used for testing the daughter plants (Table 5). The mother plants were infected with a range of common viral diseases including CsXV, CCMV, frogskin and a mosaic agent. Leaf symptoms were only present on the Secundina plant infected with the mosaic agent and on MPar 51 infected with CCMV. Frogskin disease root symptoms were observed on the MCol 113 and MCol 33 plants. CsXV and CCMV were detected in four plants by mechanical inoculation to C. quinoa and in the ELISA test. A high concentration of dsRNA was detected in all mother plants, with the exception of Secundina infected with CsXV. The symptomless CsXV-infected plant was also the only plant indexed negative by grafting to Secundina.

In collaboration with the tissue culture laboratory, a stake from each mother plant underwent thermotherapy followed by the culture of meristem tips (3 mm in length). Plants derived from shoot-tips (5 mm) cut prior to thermotherapy were included as infected controls. Some meristem tips were also cut before thermotherapy. Although this experiment is still in progress several important conclusions can be made from the preliminary results presented in Table 6. The combination of thermotherapy with meristem-tip culture offered the highest probability of obtaining virus-free daughter plants from infected mother plants. However, recovery was not 100% as is evident from the detection of dsRNA in one of the eight MCol 33 plants tested. This result also demonstrates the need for using a range of indexing methods as no virus was detected by ELISA or by mechanical inoculation to C. quinoa. It was sometimes possible to obtain virus-free plantlets by meristem-tip

culture without thermotherapy. This method was not successful when the virus concentration was high, as was the case with CCMV. At least one of the methods included in the standard indexing protocol detected the presence of virus in plantlets cultured from shoot-tips.

It can be concluded that the current combination of thermotherapy with meristem-tip culture is effective for the production of virus-free plants, but is not always 100% efficient. Therefore, virus indexing of the meristem-tip cultured plants is necessary to assure freedom from known viruses. Results obtained in this experiment indicate that plants can be assayed using the ELISA test while still in the tissue culture tube. The plantlet derived from a meristem-tip infected with either CsXV or CCMV would be identified by ELISA and eliminated. First generation plantlets that are ELISA negative could be multiplied via cuttings. Several of these cuttings should be transplanted in soil, maintained in an insect-proof screenhouse and assayed by graft inoculation to Secundina and by dsRNA analysis. By certifying that the first generation of plantlets is free from virus infections, all subsequent generations will be virus free. The virus-free mother plants can be maintained in isolation in the screenhouse as a source of stakes.

Table 1. Virus indexing results for 8 Secundina plants after exposure to whiteflies collected from mosaic-infected Secundina plants at CIAT-Palmira.

Plant number	Mosaic symptoms	CsXV-ELISA	Bioassay[a]
4	-	+	+
5	-	+	+
7	+	-	-
13	-	+	+
14	-	+	+
15	-	+	+
26	+	+	+
30	-	+	+

[a] The presence or absence of local lesions on *Chenopodium quinoa*.

Table 2. Virus indexing results for 16 Secundina plants before and after a three month field exposure at Quilcace, Cauca.

Plants[a]	CsXV-ELISA[b]		Leaf mosaic[c]		Bioassay[d]	
	Before	After	Before	After	Before	After
8A	-	NA	-	-	-	NA
8B	-	-	-	-	-	-
14A	-	+	-	Severe	-	+
14B	-	+	-	-	-	+
18A	-	NA	-	Severe	-	NA
18B	-	+	-	Moderate	-	+
23A	-	+	-	-	-	+
23B	-	-	-	-	-	-
1A	+	+	-	Moderate	+	+
1B	+	+	-	Moderate	+	+
7A	+	+	-	Moderate	+	+
7B	+	+	-	Severe	+	+
20A	+	+	-	Severe	+	+
20B	+	+	-	Moderate	+	+
21A	+	+	-	Moderate	+	+
21B	+	+	-	Moderate	+	+

[a] Eight potted healthy plants and eight CsXV-infected plants were placed in the field near Quilcace for three months.
[b] CsXV= cassava X virus.
[c] Severe=severe mosaic symptoms with leaf distortion; moderate= moderate mosaic symptoms without leaf distortion.
[d] All plants were bioassayed on *Chenopodium quinoa*.

Table 3. An estimation of the proportion of 3 whitefly species in a sample collected from a field infested with frogskin disease in Quilcace, Cauca.

Species	No. of test plants infested		Total (%)	
	M Col 113	Secundina	M Col 113	Secundina
Aleurotrachelus socialis	109	93	66	59
Trialeurodes variabilis	41	35	25	22
Bemisia tuberculata	14	30	9	19
	164	158	100	100

Table 4. Pathogenic condition of mother plants prior to thermotherapy and meristem-tip culture.

Clone[a]	Viral disease[b]	Leaf symptoms	Root symptoms	Bioassay[c]	ELISA			Graft[d] symptoms
					CsXV	CCMV dsRNA		
M Col 2063	CsXV	-	-	+	+	-	+	-
M Col 2063	Mosaic	Severe mosaic	-	-	-	-	+	+
M Col 113	CsXV Mosaic Frogskin	-	Frogskin	+	+	-	+	+
M Col 22	Mosaic	-	-	-	-	-	+	+
M Col 33	CsXV Mosaic Frogskin	-	Frogskin	+	+	-	+	+
M Par 51	CCMV	Mild mosaic	-	+	-	+	+	+

[a] M Col 2063 designates the clone Secundina.

[b] CsXV= cassava X virus; Mosaic= symptoms produced on Secundina. This agent was symptomless in clones M Col 113, M Col 22 and M Col 33 and was detected by graft inoculation to Secundina; CCMV= cassava common mosaic virus.

[c] The bioassay host used was *Chenopodium quinoa*.

[d] Secundina was used in all graft indexing.

Table 5. Pathogenic condition of some daughter plants derived from virus-diseased mother plants by meristem tip culture and/or thermotherapy.

	Mother plants	Treatment		Daughter plants			
Clone[a]	Viral disease[b]	Thermotherapy	Meristem-tip	Leaf symptoms	Bioassay	ELISA	dsRNA
M Col 2063	CsXV	Yes	Yes	0/14	0/5	0/12	0/7
		No	Yes	0/2	0/1	0/2	0/2
		No	No	0/5	4/4	5/5	4/5
M Col 2063	Mosaic	Yes	Yes	0/8	-	-	0/1
		No	Yes	0/1	-	-	-
		No	No	5/8	-	-	-
M Col 33	CsXV	Yes	Yes	0/10	0/5	0/10	1/8
	Mosaic	No	Yes	0/4	1/2	1/4	2/3
	Frogskin	No	No	0/5	3/3	4/5	4/4
M Par 51	CCMV	Yes	Yes	0/2	-	0/2	-
		Yes	No	3/3	-	3/3	-

[a] M Col 2063 designates the clone Secundina.

[b] CsXV=Cassava X virus; Mosaic=symptoms produced on Secundina. This agent was symptomless in M Col 113, M Col 22 and M Col 33 and was detected by graft inoculation to Secundina; CCMV=cassava common mosaic virus.

[c] The bioassay host used was *Chenopodium quinoa*.

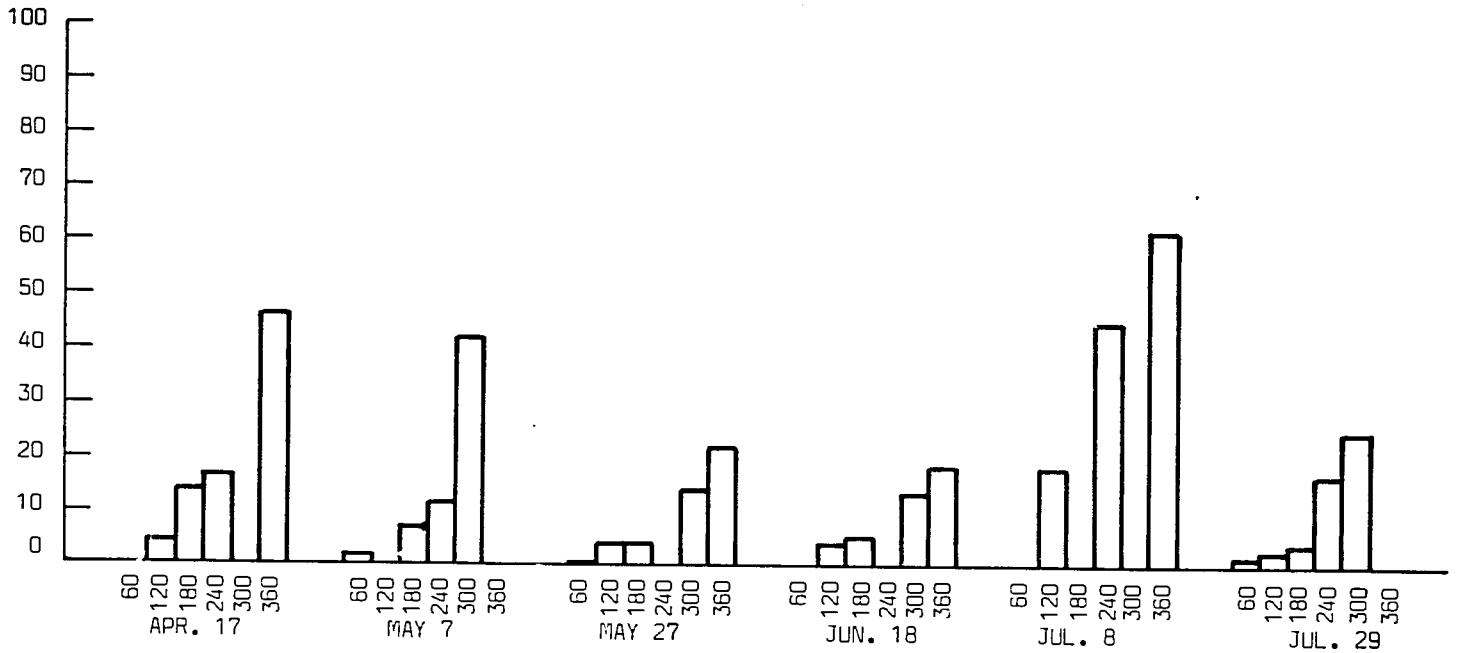


Fig. 1.A. The effect of planting date on the incidence of a mosaic disease on the clone Secundina (M Col 2063) at CIAT-Palmira during 1985-1986[a]

[a]Disease incidence was determined during periods favorable for symptom expression. It was not always possible to calculate incidence at every evaluation 60, 120, 180, 240, 300 and 360 days after germination.

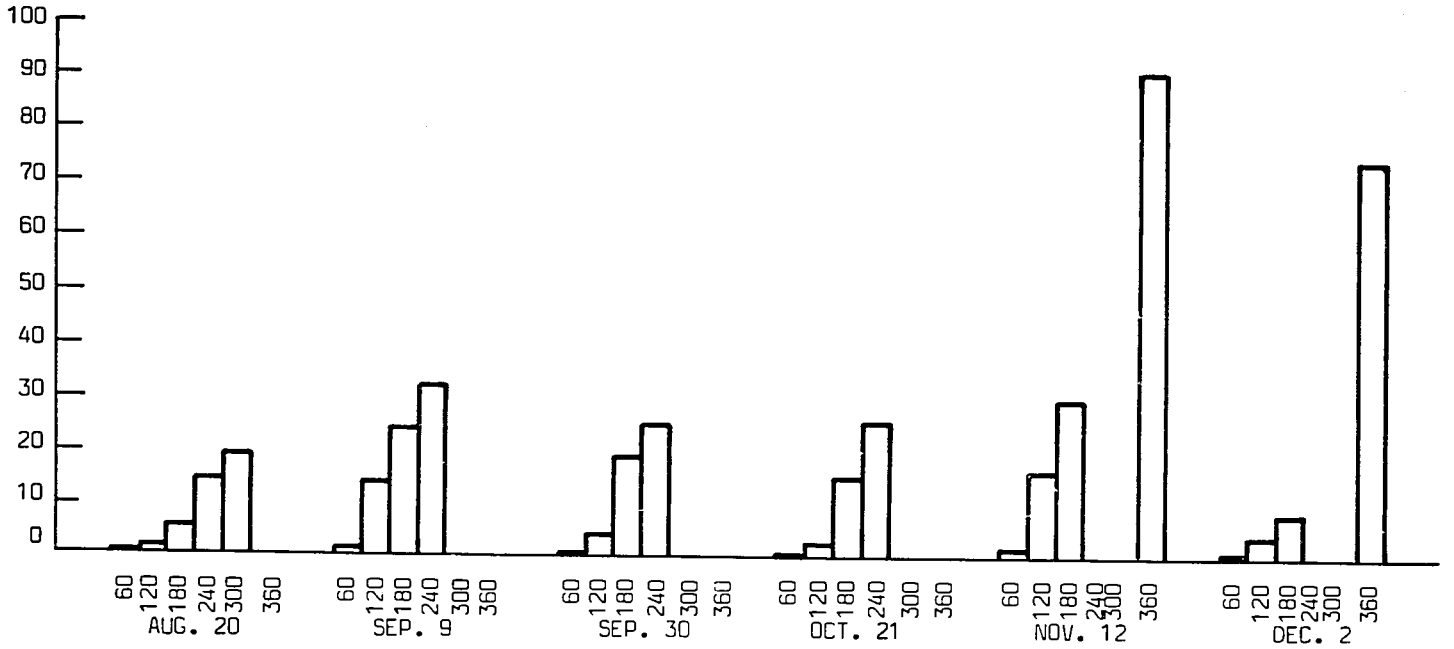


Fig. 1B. The effect of planting date on the incidence of a mosaic disease on the clone Secundina (M Col 2063) at CIAT-Palmira during 1985-1986[a] .

[a] Disease incidence was determined during periods favorable for symptom expression. It was not always possible to calculate incidence at every evaluation 60, 120, 180, 240, 300 and 360 days after germination.

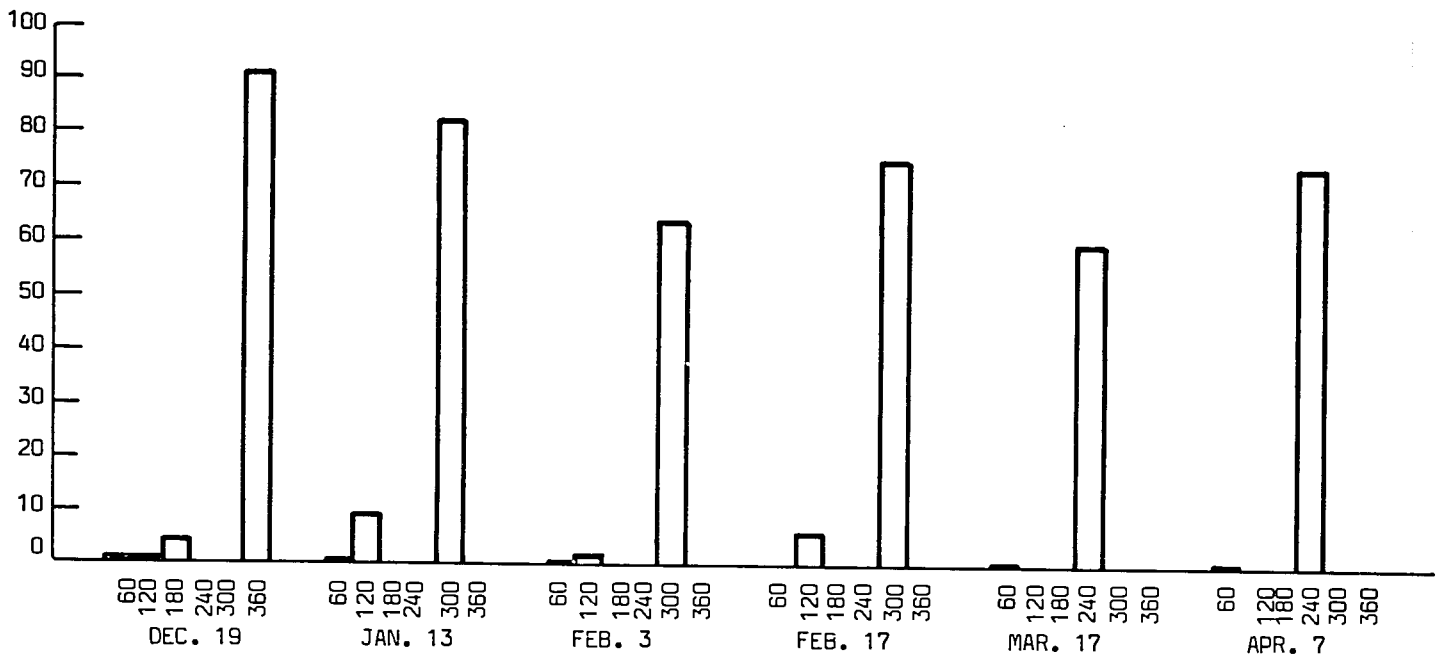


Fig. 1C. The effect of planting date on the incidence of a mosaic disease on the clone Secundina (M Col 2063) at CIAT-Palmira during 1985-1986[a]

[a]Disease incidence was determined during periods favorable for symptom expression. It was not always possible to calculate incidence at every evaluation 60, 120, 180, 240, 300 and 360 days after germination.

GERMPLASM AND BREEDING

Objectives

The objective of the germplasm and breeding section is to provide farmers with varieties which produce stable, high yields of cassava of acceptable quality. To meet this objective CIAT works closely with colleagues in national programs, providing them with germplasm from which they select varieties adapted to local conditions. The germplasm given to national programs may come directly from the CIAT germplasm collection (the world's largest collection of cassava varieties), or from improved populations developed through our Colombia-based breeding program.

Breeding Strategy

As a species, cassava is widely adapted in the tropics and subtropics, but individual cassava genotypes tend to be rather narrowly adapted to local environmental conditions. In order to produce improved populations of genotypes adapted to specific types of environmental conditions, selections are made at several ecologically distinct sites in Colombia. The edaphic and climatic conditions at these sites represent five of the six major edapho-climatic zones (ECZs) in which cassava is grown world wide. The edaphic and climatic conditions, as well as the major diseases and pests present in the six ECZs, are summarized in Table 1. More thorough discussions of the ECZ concept for cassava breeding are presented in previous Cassava Program Annual Reports (particularly 1983). The specific conditions at the selection sites in Colombia are presented in Table 2 (altitude, temperature, total rainfall and soil analyses) and Figures 1 and 2 (rainfall distribution from 1985 to 1986).

When a request is received from a national program for germplasm, we respond in one or more of the following ways:

1. By sending germplasm accessions (*in vitro*) which come from regions which are ecologically similar to the target area.

2. By sending improved materials (seed and/or "elite" clones) from our selection site which is ecologically similar to the target area.

3. By sending seed of crosses made between the best local varieties of the target area and clones with desired traits from our improved populations.

Germplasm shipments are followed up with collaboration in their evaluation where possible. This improves our ability to select materials for future germplasm shipments.

The Cassava Germplasm Collection

Introduction

The purpose of the germplasm collection is to assemble, for use in breeding and for preservation, the full range of genetic variation which exists in cassava. At the most recent count, the collection included

4,250 accessions from 21 countries (Table 3). The majority of the accessions are from Central and South America, the center of origin of cassava, but materials from Africa and Asia are also included.

Figure 3 presents a history of the acquisition of materials in the germplasm collection.

Accessions received during 1986

During the last year over 400 accessions were added to the germplasm collection. These include two major collections from Colombia, one from Peru, accessions from the national collections of several Asian countries, and two clones from Nigeria.

The Colombian collections were both made in the east of the country (one in Guainia and the other in Vaupes) where indigenous people cultivate cassava traditionally and use several processing techniques to prepare foods from it. In contrast to much of the cassava germplasm collected earlier, these accessions were collected with information on their uses and agronomic characteristics. The collection from Peru (Province of Pasco) was also well documented, and composed exclusively of varieties having a low linamarin (HCN) content.

The accessions received this year from Malaysia, Indonesia, Thailand, Philippines, Nigeria and China are helping to make the germplasm collection more truly a world collection.

Conservation

The cassava germplasm collection is maintained in three forms: as a field genebank which is renewed yearly, as an *in vitro* meristem culture collection (by the Biotechnology Research Unit), and as seed in cold storage.

Field maintenance of the collection is a time-consuming and expensive task. Based on appearance alone, a fair number of accessions in the germplasm bank seem to be duplicates. We are collaborating with the Biotechnology Research Unit to identify these duplicates and to consolidate our field genebank by using botanical descriptors and newly developed electrophoresis techniques.

The *in vitro* copy of the germplasm collection safeguards the field genebank by maintaining clones in a disease free environment. It is also necessary for international shipment of cassava clones, due to phytosanitary restrictions.

This year, the International Board for Plant Genetic Resources (IBPGR) has started funding a project at CIAT to examine the stability of cassava clones *in vitro*. Its goal is to establish guidelines for the operation and conservation of active *in vitro* germplasm collections.

The preservation of cassava germplasm as seed does not preserve cassava varieties (or specific gene combinations) but only their genes. This technique is now being used as a backup to the clonal conservation techniques already mentioned. Open pollinated seed from germplasm accessions in the field genebank is being collected and stored and will

be used to examine the possibility of using self pollinated seed for conservation purposes.

The CIAT collection of wild cassava relatives in the genus Manihot, consists of very limited quantities of seed of 31 species plus living plants of a very few species. We hope to establish a field collection of wild Manihot species in a permanent location so that we can undertake basic studies on their genetics and biology, and evaluate their potential contributions to cassava breeding.

Evaluation and utilization

Germplasm accessions are evaluated for resistance to pests and diseases, and for adaptation to soil and climatic conditions, at all of the selection sites in Colombia. Outstanding germplasm accessions pass from evaluation in single row trials to preliminary and advanced yield trials. Selected germplasm accessions are added to the list of elite clones, and broaden the genetic base of breeding populations when included in hybridizations. The first semester planting at the Florencia, Caqueta (ECZ 3) selection site included 441 Brazilian and Colombian germplasm accessions. At Carimagua, Meta (ECZ 2) and Media Luna, Magdalena (ECZ 1) 318 accessions from Argentina, Brazil, Colombia, Costa Rica and Peru are being evaluated.

Until this year all of the germplasm has been evaluated only in the first semester (early rainy season) planting, which is the main planting season for cassava worldwide. Accessions selected in the first semester have, nonetheless, been used in hybridizations which have produced seed for second semester plantings. Since the environmental conditions are very different for first and second semester plantings, evaluation has begun of germplasm accessions in the second semester. Around 200 accessions from Brazil and Colombia are being evaluated at the ECZ 1 and 2 selection sites.

Population Improvement

Several ecologically distinct selection sites in Colombia are used to select populations adapted to varying edaphic and climatic conditions, and having resistance to most of the major pests and diseases. CIAT then works with colleagues in national programs to select superior genotypes from these improved populations for specific target areas. A thorough discussion of the selection methodology for population improvement may be found in the 1983 Cassava Program Annual Report. A schematic summary of the stages of selection is presented in Figure 4.

The selection criteria used varies with selection site, different diseases and pests being important in each ecosystem (Table 1 shows the major yield constraints at each selection site).

A large-scale program of hybrid seed production, both for the population improvement program in Colombia and to provide seed populations to national programs has been undertaken. Hybrid seeds are produced by both hand pollination in controlled pollination blocks (where the identities of both parents are known), and by bee pollination in polycross blocks (where the identities of only the female parents are

known). Hand pollination allows the production of specifically desired crosses, but has the disadvantage that it is labor intensive and produces only limited quantities of seed in comparison with open pollination. Polycross blocks are used to produce the bulk of the seed.

The majority of crosses are made between clones adapted to the same ECZ, but crosses between ECZs are made to combine certain traits. For example, clones from ECZ 1 having thrips and mite resistance are being crossed with clones from ECZ 2 having resistance to cassava bacterial blight (CBB) and superelongation disease (SED). Seed from these crosses will be sent to Mexico and Panama where thrips- or mite-resistance, along with CBB and SED resistance, are required.

Elite Clone Selection and Evaluation

Clones which are selected from second year yield trials advance for further testing to regional trials which are conducted at a number of sites in a region. These clones are included in hybridizations and are placed on a list of "elite" clones. Elite clones are placed into *in vitro* meristem culture by the Biotechnology Research Unit, and are assured to be free of virus diseases by the virologist. These clones are available for international shipment to colleagues in national programs. Table 4 lists certain characteristics of a selected group of elite clones.

There are currently about 170 elite clones. They do not all receive equal emphasis in hybridizations and international shipments. Following their selection, evaluation continues for a range of characteristics. General adaptation within an edapho- climatic zone is measured through performance in regional trials, and later through performance at sites outside of Colombia. Some results of regional trials conducted in the various ECZs within Colombia in 1986, are presented in Tables 5, 6, 7 and 8.

The pathology section is evaluating the elite clones for resistance to *Diplodia manihotis*, *Fusarium oxysporum* and *Fusarium solani*, *Cercosporidium henningsii*, *Cercospora vicosae*, and *Phaeoramularia manihotis*. The entomology section is evaluating some of the elite clones for resistance to mites and to mealybugs.

Although ratings on diseases and pests encountered in breeding trials are taken regularly, it is difficult to assure that uniform infection or infestation occurs under natural conditions in the fields.

Characterization of the elite clones, under both field and controlled conditions, greatly aids decisions concerning their use in international germplasm shipments or in hybridization.

Several other projects for evaluation of the elite clones are planned or are in progress. These include screening for tolerance of planting material to storage under hot, dry conditions, evaluation of

growth and yield under very low rainfall conditions, and evaluation of performance during both semesters in ECZs 1 and 2.

Disease and Pest Resistance

One of the advantages of locating a plant breeding program near the center of origin of a crop, is that most of the important diseases and pests which evolved with the crop will be present. Moderate levels of resistance to these diseases and pests should also be present in the traditional varieties from the area, providing a good genetic base for selection. Both of these advantages hold true for cassava in Latin America.

High levels of important diseases and pests are manintained, where possible, in the selection fields, in order to permit efficient selection for resistance. During the early selection stages (the F_1C_1 and single row trial), there are usually enough highly susceptible genotypes in the trials to maintain high inoculum levels of the disease/pest throughout the field. By the more advanced stages of selection (preliminary and advanced yield trials), there is often a high proportion of resistant genotypes in the trial. Thus, inoculum levels in the trial may be low and individuals which appear to be resistant may actually be susceptible genotypes which have escaped inoculation. To eliminate this sort of problem "spreader" rows of susceptible genotypes are interspersed in certain advanced trials. Spreader rows susceptible to thrips and mites were planted in the trials at CIAT this year, and spreader rows susceptible to cassava bacterial blight and superelongation disease were planted at Carimagua.

Resistance to certain important diseases, such as Diplodia and Fusarium root rots, is difficult to screen for under field conditions, collaboration with the pathology section is needed in the screening of these diseases at an early selection stage under controlled conditions.

Considerable progress in this area has been made by placing strong emphasis on the selection of genotypes resistant to major diseases and pests. Many high yielding, resistant genotypes, which provide a broad genetic base from which to select materials possessing other characteristics of importance, now exist at CIAT.

Root Quality

Cassava has many different uses (fresh-boiled, farinha, casave, chikwange, fufu and dried chips for animal feed are but a few), each of which may require different quality characteristics in the fresh roots. High dry matter content is one quality trait that seems to be important for most end uses. Thus, emphasis is being placed on high dry matter content in all of the populations.

Selection for quality factors important for specific cassava products, has not received much emphasis in the breeding program to date. The strategy has been to maintain broad-based populations, from which programs can select for their own specific quality traits. Nevertheless, as more is learned about these traits, it may be possible to effectively select for them in the Colombia-based breeding program.

One quality factor which clearly differs for different end uses is root cyanide content. Cassava for fresh consumption requires a low cyanide content, while cassava for feeding to animals, following chipping and drying, may have a much higher HCN content since most of it will be lost during processing. Cassava varieties which are used for processing into products such as farinha and gari, are almost always bitter (or high in cyanide). There is some evidence that bitter varieties are required to produce a product which has the necessary taste and texture (the finished products are low in HCN). It is extremely important to understand the basis of the relationship between HCN and product quality, since HCN consumed in the diet causes serious health problems in some parts of the world. Research is needed to show whether it is possible to select for high quality finished products, while selecting for low HCN. The cassava utilization section will be giving priority to studying the relationship between HCN and product quality in the coming year.

Because of the disparate HCN levels required for various end uses, separate populations based on HCN levels will be established for ECZ 1 (which includes the north coast of Colombia, northeast Brazil and parts of Africa). A strong emphasis will be placed on low HCN levels in one of these populations (for fresh consumption), and not considered in making selections in the other. Special emphasis on HCN in the ECZ 1 gene pool is needed, since the long dry season of this zone tends to exacerbate HCN levels.

Trends in Selection Emphasis

Aside from diseases and pests, important selection criteria do not vary greatly from site to site. At present, the most important selection traits other than disease and pest resistance are yield, dry matter content, HCN content, root form, and plant architecture. High yield has always been an important selection criterion in the cassava breeding program, but the other characteristics which are associated with root quality and the agronomic characteristics of the crop have received greater emphasis in recent years.

One way of getting a general idea of the importance which has been placed on various traits during selection, is to compare the means of selected individuals with the trial mean. This was done for the fresh root yield, root dry matter content, and root HCN content of the yield trials at Carimagua and Media Luna for the period from 1982 to the present (see Figure 5). The plotted data were obtained by subtracting the trial means from the means of the selected individuals. Thus, positive values indicate that the mean of the selected individuals was greater than the mean of the trial. The magnitude of the difference, indicates the amount of emphasis (or selection pressure) that was placed on that particular trait during the selection process. It can be seen that there has been a generally increasing emphasis on root dry matter content over the past four years, and that this year stronger emphasis was placed on selection for lower HCN content.

Somewhat less emphasis was placed on yield than in the past, since significant gains in yield have been made. The actual trial means for

the trials at Media Luna and Carimagua from 1982 to 1985, are presented in Table 9.

Breeding Methodology Development: Evaluation cf Germplasm by Farmers in Colombia

Most of the centers in the CGIAR system were established following the spectacular successes of the wheat and rice breeding programs at CIMMYT and IRRI, respectively. Many of the crops which were included in the new centers' responsibilities, cassava among them, were small farmer crops which are often grown under difficult conditions and widely varying cropping systems. The breeding of these crops has not followed the successes of wheat and rice.

Programs at international centers with responsibilities for small farmer crops, are presented with the problem of having mandates for vast regions in which multitudes of cropping systems exist. Within countries, and even within regions of countries, high levels of variation in the conditions under which the crop is grown are found. Thus, the problem of targeting breeding efforts to specific agronomic practices or production conditions exists even at a very local level.

The case of cassava is perhaps more difficult than that of most other crops. Cassava is a long-season crop which normally has no obvious critical harvest time. It has a variety of uses, and is grown on soils which range from fertile to very infertile.

Selecting varieties adapted to specific local conditions, while maintaining responsibility to an entire region, nation, or continent, is thus, a critical problem in cassava breeding. The traditional breeding approach has been to focus on the regional level by conducting uniform regional trials. Selected materials advance to the regional trials where they are often evaluated with satisfaction by researchers. When these materials are given to farmers for evaluation under their conditions, however, they too often prove unacceptable for one reason or another.

In an effort to more thoroughly evaluate cassava genotypes under the conditions in which they will be grown, a program of evaluations by farmers has been created. In conjunction with Colombian national program colleagues around 45 genotypes have been distributed, to over 100 farmers in several regions of Colombia. This program has two main objectives. The first is to provide farmers with new varieties, and the second is to gain information on the shortcomings of materials which prove unacceptable to farmers. This information will be used by the Colombian Cassava Research Program and by the CIAT Cassava Breeding Section in making selections.

Evaluations by farmers differ somewhat from traditional on-farm trials, in that no demands have been placed on the farmers in terms of experimental design. Farmers have simply been given small quantities of planting materials (25-50 stakes) of only three varieties, and have been asked to evaluate these materials in any way that they wish. Each gentotype has been given to a minimum of four farmers in an area. In addition to evaluating these materials for adaptation to local

conditions, the farmers should be able to evaluate a number of characteristics which are difficult to evaluate in standard breeding trials, including time and duration of harvest, as well as eating quality.

An interview procedure is being developed during visits with farmers and it is hoped that in the coming year, local collaborators, such as extension agents, will distribute the seed and conduct interviews more or less independently.

A system, run in collaboration with the Colombian National Program, is envisaged, which will efficiently distribute materials to farmers for testing and which will then collect information on the performance of those varieties. This information will be used to help the breeding program in making selections. It will also be used to monitor the acceptance of the new materials and to help plan the distribution of acceptable materials to other farmers. Acceptable materials will be potential candidates for varietal release.

If by involving farmers in the breeding process, it is possible to improve the rate of production of new varieties to be adopted by farmers, this selection "technique" may be encouraged in other countries.

Selected Country Reports

Brazil

The Centro Nacional de Pesquisa de Mandioca e Fruticultura (CNPMF), has the responsibility of coordinating cassava research at the national level. Considering the immensity and diversity of the country, and the limited research resources available, the task is formidable. Nevertheless, several state programs have been independently carrying out cassava breeding research for their own regions.

The breeding strategy adopted by the national center until 1984, was to do initial selection at the Cruz das Almas headquarters, then send out clones which passed this preliminary selection to regional centers. Emphasis was given to the Campo Cerrado (Minas Gerais) and the northeast (Ceara and Bahia), with some work in the humid tropics and the subtropics. With this system, most of the variability in segregating populations was eliminated in the initial selection, thus reducing the probability of obtaining superior clones for other ecosystems.

As the problems of centralized research became apparent to the cassava team at CNPMF, a new model of organization was proposed (April 1984). The model proposes organizing cassava research on a regional basis, with a coordinating center designated for each region. Five such centers, encompassing the major broadly described ecosystems of the country, were tentativley defined. The national center at Cruz das Almas would distribute, or coordinate distribution, of germplasm to the regional coordinating centers. In turn, the coordinating center would collaborate with other institutions in the region in germplasm collection, varietal evaluation as well as in research in other disciplines. The model is eminently logical, but politically difficult to organize; thus, establishing this system is still in the planning

stage. Nevertheless, the breeding program is already moving toward further decentralization.

Production constraints vary from one region to another. In the south and south central regions, bacterial blight (CBB) is a major yield limiting factor. Although superelongation disease (SED) is potentially important, it has so far been limited to the Amazon region by internal quarantine. In the Campo Cerrado, mites and lacebug are important during the dry season.

Since Brazil appears to have the world's widest diversity of native Manihot germplasm, CIAT's contributions are likely to be in fairly narrowly defined breeding objectives, such as providing sources of resistance to particular pests and diseases. Crosses with resistance to CBB, SED, green cassava mite and Vatiga lacebug have especially been requested.

Because Brazil has a well-established breeding program and trained breeders, CIAT has always emphasized germplasm exchange via sexual seed. Apart from a 3-year period when one of the breeders was away for post-graduate studies, the flow of germplasm to Brazil has been continual since the first years of establishment of the national program in 1976.

From early introductions, promising clones have been selected in various sites. In Cruz das Almas, MMex 59 and CM 424-9 (MMex 1 x MCol 686) have been selected in advanced trials for four years and show promise as potential new varieties. In the humid tropics (Belem), two CIAT introductions are close to release (M. Porto, personal communication).

In late 1983, seeds were planted in Cruz das Almas to provide vegetative propagative material for other sites. With only a minimal selection (against obvious morphological defects), a single stake from each plant was sent to Ceara, Minas Gerais and Para in late 1984 and early 1985. Selection is continuing independently in each region. This full decentralization of selection will give a very high probability of selecting superior clones with local adaptation.

Panama

Cassava is a relatively minor crop in Panama at present, found mainly in scattered plantings by small farmers. As part of a pilot project in integrated production, processing and marketing, lack of good varieties was identified as a potential production constraint. Local germplasm was assembled, and in 1982 CIAT began in vitro introductions.

In spite of only a modest overall research effort in cassava, a very efficient system of germplsm flow has been established in Panama. This efficiency is probably related in part to the fact that the person receiving the in vitro clones also processes and evaluates that germplasm.

All germplasm is introduced to Rio Hato, where it is multiplied for distribution to other sites. The principal target area is in the llanos

of Ocu. Production constraints in the Ocu region are similar to those in the Colombian llanos - CBB and SED in the rainy season and mites in the dry season; and acid, infertile soils.

The first CIAT introductions were advanced to regional trials in 1985, and harvested in 1986. The local clone, Brasilena (MPan 51; see section on Mexico), continues to be one of the most tolerant to the wide range of pests and diseases throughout the country. The selection of introductions has been refined over time and more recent introductions should have considerably better chance of success than earlier ones.

From the first introductions, a clone whose identification was lost, has consistently been superior through the regional trial stage, and shows promise for release in the near future. The clone has been locally named "Dayana", though its equivalent name in CIAT is still unknown. The Panamanian program has agreed to send this clone to CIAT for isozyme analysis, to try to match it to an existing elite clone in CIAT.

First sexual seeds were introduced in 1984, and selections from individuals were planted in an observational trial in both Rio Hato and Ocu. Since this system appears to be functioning well, CIAT will begin placing emphasis on seed introduction, as is the general policy for nearly all countries.

Colombia

Colombia's major cassava production region is on the north coast, although the crop is widely grown throughout the country excepting the Andean zone above about 2000 masl. The diverse geography and climate of the country mean that a wide range of varieties needs to be developed for adaptation in the various regions. This edaphoclimatic diversity is advantageous in allowing the CIAT Cassava Breeding Program to identify areas for selection which are relatively homologous to many of the world's major cassava-growing regions. Thus, the breeding trials in Colombia are both regional and global in nature.

Though the national research program, ICA, does not have a cassava breeding program *per se*, all CIAT materials are available for ICA evaluation at any stage of selection. ICA personnel are invited to harvests of the major varietal trials, and many materials have been independently evaluated by ICA after being selected from CIAT trials.

ICA has released three cassava varieties in the past three years, and all are widely commercially grown. CIAT regional trials were used as supporting data for recommedation of the releases, and have been partially responsible for dissemination of these clones. Manihoica P-12 (MCol 1505; CMC 76) is now widely grown throughout the north coast region as a result of farmer-to-farmer distribution.

Although cassava drying plants are absorbing an increasing proportion of cassava production, fresh consumption of cassava in the region remains high. It is now recognized that for the forseeable future, varieties of good eating quality will be preferred by farmers, since this market demands a higher price. The excess production can

then go for processing. Many of the high yielding clones produced by the CIAT breeding program, do not meet the high quality standards in this region, though they are good for processing. More emphasis will be given in the future to eating quality, although this will necessarily involve compromises in the rate of advance which can be made in other factors such as yield potential.

The demand for higher production that the drying plants have fomented, has resulted in a renewed interest on the part of ICA to promote new cassava varieties. While in the past, ICA has received relatively advanced lines from CIAT for further testing, in 1986 the experiment station at Carmen de Bolivar requested segregating populations of specific rosses. This early generation selection for traits of specific local interest should be an effective form of CIAT/ICA collaboration in cassava breeding.

As described in earlier sections, many CIAT hybrids are performing well in other regions of the country, and with the present high priority given to cassava by ICA, several of these should be candidates for release over the next few years.

Mexico

Because cassava is virtually non-existent as commercial crop in Mexico, this country faces a wide range of problems of integrated production, processing and marketing development. In fact, the varietal development aspects have been carried on rather efficiently, and two varieties released from early (1976) clonal introductions from CIAT. The variety Sabanera (MPan 51) constitutes most of the cassava area planted in Tabasco State, where the cassava research is concentrated. Although Sabanera is satisfactory in yield and appears to have good year to year stability, there is a need to develop a broader genetic diversity to reduce potential vulnerability. Other objectives are to increase yield potential and improve root form (Sabanera tends to have long, difficult-to-harvest roots).

Sabanera has only intermediate CBB and SED resistance, and therefore must be planted at the end of the rainy season when disease pressure is lower. When the cassava industry of Mexico begins to demand large quantities of cassava, production will have to be spread more evenly over the year. One way of doing this is to stagger plantings from beginning to end of the rainy season; however, at present there are no clones which will yield well with an early planting. In 1985, the Mexican program began selecting in both early and late season plantings.

The program produces hybrids from polycross blocks which include several CIAT clones, and also has established a routine system of introduction of CIAT seed every planting season. Some 50 clones have been introduced *in vitro*, although there have been delays in moving this material to field evaluations.

The Mexican program has often stated its intention to expand cassava research outside of Tabasco to other regions where cassava has potential to be grown and markets exist. So far this expansion has been

limited to a few regional trials. When such expansion occurs, there will be demand for germplasm adapted to very different ecosystems.

As in several other national cassava programs, after a strong beginning in breeding, the breeder left for post-graduate studies, and the program came to a standstill for a while. Only in the past few years has germplasm introduction and evaluation begun to flow smoothly once again. Several clones now in advanced stages of evaluation have disease resistance levels similar to Sabanera, but higher yield potential (Table 10). Some of these appear to be potential candidates for release within a few years.

Cuba

The National Cassava Program (INIVIT), based in Santo Domingo, Villa Clara, has carried out a well-organized and logically sequenced set of research activities in breeding. These have included evaluation of local germplasm, introduction of advanced clones from CIAT, definition of a selection strategy based on extensive G-E interaction studies, development of a certified seed production program, and a multiclonal planting strategy which reduces genetic vulnerability of the crop, as well as providing cassava to the marketplace over an extended period of the year.

The introduction of CMC 40 from CIAT, and its subsequent release have been breakthroughs in obtaining a high yielding clone with early harvestability and good eating quality. CMC 40 is one of three clones recommended in the multiclonal policy of INIVIT. CEMSA 74-725 and Senorita are recommended for medium and late harvests, respectively.

The presently recommended clones are susceptible or intermediate in CBB and SED resistance, and can only be planted near the end of the rainy season. To further extend the period when fresh roots are available on the market, it will be necessary to select varieties with high CBB and SED resistance for earlier planting. INIVIT has placed most of its effort in the last few years, on developing and promoting the "Colombian system" of recommended agronomic practices developed at CIAT, and the multiclonal system. Now that these are in place, they are turning their efforts to developing new higher yielding and disease resistance varieties. Late in 1986, the INIVIT breeder introduced some 60 elite clones, and segregating populations from 41 crosses, selected for potential adapatation in the various regions of the country. Though it will be several years before new varieties could come through the system from these introductions, the knowledge and the infrastructure are all in place to make good use of these new genetic materials. It is expected that this exchange of germplasm will become routine.

Table 1. Edaphoclimatic zones for cassava production and their main characteristics.

Edaphoclimatic Zone no.	General description	Regions in Colombia for germplasm evaluation and technology testing	Major yield constraints
1	Lowland tropics with long dry season, low to moderate annual rainfall, high year-round temperature.	Magdalena, Atlantico, Bolivar, Sucre, Cordoba	Drought, mites, thrips, mealybugs, termites, CBB, root rots, viruses.
2	Acid soil savannas with moderate to long dry season, low relative humidity during dry season.	Meta	Low soil fertility, drought CBB, superelongation, anthracnose, leaf spots, mites, mealybugs, lace bugs.
3	Lowland tropics with no pronounced dry season, high rainfall, constant high relative humidity.	Caqueta	Low soil fertility, leaf spots, root rots.
4	Medium-altitude (800-1500 msl) tropics with moderate dry season and temperature.	Valle, Cauca	Thrips, mites, mealybugs, CBB, anthracnose, root rots, and viruses.
5	Cool, tropical highland (1600-2200 msl) area with mean temperatures of approx. 17-20°C.	Cauca	Low temperatures, *Phoma* leaf-spot, anthracnose, mites.
6	Subtropical areas, with cool winters and fluctuating daylengths.	None	Low winter temperature, CBB, superelongation, anthracnose.

Table 2. Edaphoclimatic characteristics of selection sites in Colombia.

Location	Edapho-climatic zone	Altitude (msl)	Mear temperature (°C)	Rainfall during cycle (mm)	Soil characteristics				
					pH	Organic matter %	P (ppm) Bray II	K (me/100g)	Texture
Media Luna, Magdalena	1	10	27.2	A: 847 B: 828	6.8	0.6	6.5	0.09	Sandy Loam
Carmen de Bolivar, Bolivar	1	152	26.8	A: 887 B: 950	7.3	2.7	17.0	1.15	Clay
Carimagua, Meta	2	200	26.2	A:2287 B:2963	4.5	3.5	4.0	0.14	Clay Loam
Florencia, Caqueta	3	450	25.0	A:2900	4.3	3.8	7.2	0.30	Clay
CIAT-Palmira, Valle	4	1000	23.8	A: 672 B: 809	6.7	3.6	49.0	0.60	Clay
Popayan, Cauca	13	1760	18.0	A:3209	5.0	25.6	5.0	0.28	Loam

Table 3. Origin of accessions in CIAT's cassava germplasm collection

Country of origin	No. of accessions
Colombia	1774
Brazil	778
Peru	376
Venezuela	242
Paraguay	193
ICA-CIAT hybrids	188
Costa Rica	148
Ecuador	117
Guatemala	91
Cuba	74
Malaysia	66
Mexico	64
Indonesia	47
Panama	41
Argentina	15
Puerto Rico	15
Thailand	8
Dominican Republic	5
Bolivia	3
Philippines	2
Nigeria	2
China	1
Total	4250

Table 4. Characteristics[a] of a selected group of elite clones adapted to different edaphoclimatic conditions.

Clone	Origin, cross parents; common name	General adaptation in edaphoclimatic zone						Yield and quality characters[a]				Level of resistance to:[b]				
		I Lowland tropics, long dry season	II Acid soil savanna	III Lowland humid tropics	IV Middle altitude tropics	V Highland tropics	VI Subtropics	Yield	Dry matter	HCN	Eating quality	Thrips	*Mononychellus mite*	Bacterial Blight	Superelongation disease	*Phoma* leaf spot
CG 5-79	M Col 22 x M Col 414				++			+	+	-	++	++	++	-	—	
CG 7-64	M Col 113 x M Col 22				++			++	+	0	+	+	+	-	—	
CG 7-66	M Col 113 x M Col 22				++			++	+	-	++	++	+	-	—	
CG 32-22	M Bra 20 x M Pan 97		++		+			+	+	0		0	+	+	+	
CG 35-3	M Bra 20 x M Ven 77		++		++			++	-	++	--	-	+	+		
CG 165-2	M Col 1495 x M Pan 90		++		++			++	-	0	-	+		+	+	
CG 354-2	M Col 309 x M Col 1468					++		+	0	-		+	-	—	+	
CG 358-3	M Col 335 x M Col 2060					++		+	++	—		0	-	—	+	+
CG 401-3	M Col 1522 x M Col 340					++		+	+	0		+	-	—	+	+
CG 401-6	M Col 1522 x M Col 340					++		+	+	-		+	-	—	+	+
CG 403-18	M Col 1522 x M Col 1468					++		+	0	0		+	0	—	+	+
CG 406-5	M Col 1522 x M Ecu 169					++		+	+	-		+	-	—	+	+
CG 406-6	M Col 1522 x M Ecu 169					++		+	0	0		0	-	—	+	0
CG 487-2	M Col 2061 x M Col 2060					++		+	+	0		+	-	—	+	+
CM 91-3	M Col 688 x M Col 1438				++			+	+	-	++	0				
CM 489-1	M Col 882 x M Ven 270				++			++	-	-	-	0	0	-	—	
CM 507-37	M Col 1438 x M Col 1684		+	++	+			++	-	+	-	-	-	+	0	
CM 523-7	CM 655A x M Col 1515	+	++		++			+	++	—	++	+	-	++	+	
CM 849-1	SM 76-66 x M Ven 218				++			++	-	+	-	0	0	0	0	
CM 955-2	CM 309-37 x M Ven 218	++			++			++	+	-	+	+	+	-	-	
CM 962-4	CM 309-93 x M Pan 70	++			++			++	0	+	-	0	+	0	0	
CM 976-15	CM 321-160 x M Col 1684	++			+			+	+	0	-	+	0	-	0	
CM 996-6	CM 323-99 x M Col 638		+	++				++	-	-		0	-	0		
CM 1223-11	CM 323-125 x M Col 1684	++	+		+			+	0	++	--	0	0	+	+	
CM 1305-3	M Col 446-22 x M Col 1684	+			++			++	0	++	--	0	0	—	—	
CM 1491-5	M Ven 270 x M Mex 11				++			++	+	0		0	+	-	0	
CM 1533-19	CM 309-163 x M Col 1684	++		+	+			++	0	+		+	0	-	0	
CM 1999-5	CM 516-15 x CM 517-1				++			++	+	0		0	+	-	-	
CM 2088-1	CM 727-14 x CM 517-1		++					++	0	0		0	0	+	++	
CM 2166-6	CM 430-37 x M Ven 218		++					++	-	0		+	+	+	++	

(cont.)

Table 4. (Cont.)

Clone	Origin, cross parents; common name	General adaptation in edapho-climatic zone						Yield and quality characters[a]				Level of resistance to:[a]				
		I Lowland tropics, long dry season	II Acid soil savanna	III Lowland humid tropics	IV Middle altitude tropics	V Highland tropics	VI Subtropics	Yield	Dry matter	HCN	Eating quality	Thrips	Mononychellus mite	Bacterial Blight	Superelongation disease	Phoma leaf spot
CM 2177-2	CM 430-37 x CM 840-138		++		++			++	+	--	+			+	+	
CM 2766-5	CM 723-3 x CM 523-7		++	+				++	+	0				+	++	
CM 3883-1	CM 952-2 x M Ven 77			+	++			++	+	-		+				
CM 3281-4	M Bra 12 x M Col 22	+-						+	+	0						
CM 3299-4	CM 849-1 x M Col 22	++						+	0	-						
CM 3306-4	M Col 22 x CM 523-7	+-						+	++	-						
CM 3306-9	M Col 22 x CM 523-7	++						+	++	-						
SG 104-57	Open pollination from mixed pop.		++	++				++	0	0		0		++	+	
SG 104-74	" " " " "		++	++				++	0	++		0	0	++	+	
SG 104-164	" " " " "		++	++				++	-	0		0	0	++	++	
SG 104-264	Open pollination from mixed pop.		++	++	++			++	0	++		+	+	++	++	
SG 104-283	" " " " "		+	++				++	0	++		-	-	+	++	
SG 104-284	" " " " "		+		++			++	-	0		+		++	++	
SG 106-59	" " " " "		++		++			++	0	0		+		++	++	
SG 107-35	" " " " "		++	++	++			++	0	0		0		++	+	
SG 302-1	M Col 1684	++						+	-	0		0				
SG 455-1	M Col 1684	++						+	++	++		0				
M Bra 71	SIPEAL 02 (NE Brazil)	++						+	0	++		-				
M Bra 125	Aipim Aipinzinho I (NE Brazil)	++						+	0	++		-		-	--	
M Col 22	Uvita (Cordoba, Col.)	++						+	+	0		+	0	-	-	
M Col 72	Ramirana (Sucre, Colombia)	++						0	++	0	-	+	+	--	0	
M Col 1468	CMC 40; Mantiqueira (S. Brazil)				++	++		+	-	-	+	--	-	0	0	
M Col 1505	CMC 76 (Ven.); Manihoica P-12	++						+	+	-	+	0	+	--	0	
M Col 1522	CMC 96; Algodona (Cauca, Col.)						++	++	+	-	+	++	+	-	--	+
M Col 2032	Cachicama (Casanare, Col.)	++	+	+	+			+	+	0	+	0		0	0	
M Col 2054	La Paloma (Casanare, Col.)	++	+					+	+	0	+	0		0	+	
M Col 2057	La Blanca (Casanare, Col.)	++						+	+	0	+	+		-	+	
M Col 2060	Regional Amarilla (Cauca, Col.)	++				++		+	+	-	+	++				+
M Col 2215	Venezolana (Magdalena, Col.)	++			+			+	++	-	++	0	+	-	--	
M Mal 2	Black Twig (Malaysia)	++		++	+			++	0	0	-	0		0	--	
M Pan 51	Brasileña (Panama)		+					+	+	-	+	+	+	+	+	
M Tai 1	Rayong I (Thailand)	++		+	+			+	+	+	-	+	+	-	-	
M Ven 77	(Venezuela)		++					+	-	+	0	-	0	+	++	
HMC 1	Manihoica P-13; ICA hybrid				++			+	+	-	++	+	0	+	-	

[a] --, -, 0, +, ++ indicate very low, low, intermediate, high and very high in the respective categories. Blanks indicate no data available.

[b] Evaluation of performance in zones where adapted.

Table 5. Fresh root yields (t/ha) and dry matter contents (%) (in parenthesis) of clones harvested from regional trials in ECZ 1 in 1986.

Clone	Media Luna Semester A	Media Luna Semester B	San Vicente de Chucuri	Momil	Carranzo	El Olivo	El Salado	Relative[a] performance
M Bra 71	25(29)							1/1
M Bra 73	30(29)							1/1
M Bra 125	29(31)							1/1
M Bra 158	33(30)							1/1
M Col 72	21(35)			25(37)	12(36)	13(35)	18(39)	0/5
M Col 1505	24(31)	9(29)	26(36)	30(36)	23(33)	19(35)	18(35)	2/7
M Col 2032	22(31)							0/1
M Mal 2	34(30)							1/1
M Ven 25	30(31)	8(25)	28(37)	32(37)	22(37)	23(37)	14(35)	4/7
M Ven 185	24(30)							0/1
HMC 2			28(32)					1/1
CG 1-37			23(36)					0/1
CG 5-13			19(41)					0/1
CM 489-1			30(33)					1/1
CM 507-37			33(33)					1/1
CM 523-7			21(39)					0/1
CM 681-2	24(30)	13(30)	26(37)	20(36)	18(34)	21(34)	14(30)	2/7
CM 696-1		20(25)						1/1
CM 847-11			29(33)					1/1
CM 849-1			28(38)					1/1
CM 922-2		3(26)	22(38)					0/2
CM 955-2			29(34)					1/1
CM 962-4	27(28)		27(35)	40(34)	24(30)	34(33)	30(32)	6/6
CM 975-5			26(37)					0/1
CM 976-15		9(26)	31(38)					1/2
CM 982-20			36(32)					1/1
CM 1015-16		19(29)						1/1
CM 1016-34		3(26)						0/1
CM 1022-4			13(38)					0/1
CM 1223-11	23(25)			36(33)	18(33)	35(32)	35(34)	4/5
CM 1288-17		14(29)						1/1
CM 1305-3		6(26)	43(34)					1/2
CM 1335-4			24(36)					0/1
CM 1532-19	28(30)		42(31)	34(34)	19(32)	21(34)	24(32)	5/6
CM 1785-6		18(30)						1/1
CM 1797-4		15(26)						1/1
CM 1797-8		9(30)						0/1
M Col 22	19(27)	4(27)		29(36)	9(30)	25(33)	23(34)	2/6
M Col 1684	31(28)	18(27)		27(33)	7(31)	30(30)	19(32)	3/6
M Col 2063[b]	16(31)	3(29)						0/2
M Col 2215[b]	19(34)	3(32)						0/2
Mojonera[b]			19(34)					0/1
Coralita[b]			18(35)					0/1
Efrain[b]							18(36)	0/1
Sofa[b]							17(41)	0/1
Trial mean	25(30)	10(28)	27(36)	30(35)	17(33)	24(34)	21(34)	
LSD (5%)	10.2(2.7)	4.8(4.9)	12.2(2.8)	10.7(1.8)	14.5(3.)	9.3(2.2)	7.3(3.6)	

[a] Number of sites at which the yield of a clone equalled or exceeded the site mean, divided by number of sites at which that clone was planted.

[b] Local check varieties

Table 6. Fresh root yields (t/ha) and dry matter contents (%)(in parenthesis) of clones harvested from regional trials in ECZ 2 (Meta) during 1986.

Clone	Carimagua		Puerto Lopez	Puerto Gaitan	Apiay	San Martin	Relative performance[a]
	Semester A	Semester B	Semester A	Semester A	Semester A	Semester A	
CM 507-37	18(29)	26(32)	23(33)	23(31)	33	43	6/6
CM 523-7	17(34)	19(38)	20(39)	23(38)	24	44	5/6
CM 723-3		24(37)			18	31	1/3
CM 996-6	19(26)		18(26)	18(28)	20	33	4/5
CM 1335-4	16(33)		14(38)	19(37)	25	24	2/5
CM 2086-16	14(28)		16(33)	19(34)	18	37	2/5
CM 2087-101		29(35)					1/1
CM 2088-1	19(29)	18(36)	18(32)	19(30)	17	27	3/6
CM 2166-6		26(35)					1/1
CM 2174-7		28(37)					1/1
CM 2177-2		34(37)					1/1
CM 2600-2	17(31)						1/1
CM 2668-6	21(29)						1/1
CM 2766-3	20(33)						1/1
CM 2766-5	24(29)						1/1
CM 2772-3	10(27)						0/1
CM 2952-3		24(33)					
CM 2962-4		19(32)					0/1
CM 3110-8		36(35)					1/1
CM 3168-15		30(36)					1/1
SM 301-3		25(36)	13(40)	18(34)	21	46	4/5
CG 32-22			18(36)	19(36)	22		3/3
CG 165-7			21(32)	23(32)			2/2
SG 104-74			18(33)	21(34)	24		3/3
SG 104-164	16(32)		23(36)	21(33)	30	38	4/5
SG 104-284	24(29)		18(34)	18(32)	17	30	3/5
SG 107-35	19(32)		18(36)	16(31)	20	29	2/5
SG 265-2		20(33)					0/1
HMC 1					28		0/1
HMC 2			12(33)	18(28)	14		1/3
M Col 1438[b]	8(31)	6(34)	8(35)	10(33)	11	25	0/6
M Col 1468	13(25)	12(29)	8(32)	12(29)	14	30	0/6
M Col 1684	11(27)	17(31)	15(32)	16(26)	19	32	0/6
M Col 2066						33	1/1
M Ven 77	19(27)	15(31)	13(31)	12(33)	23	29	2/6
Chiroza [b]						30	0/1
Trial mean	17(30)	23(34)	16(34)	18(32)	21	33	
LSD (5%)	8.2(2.6)	6.5(2.7)	4.4(4.2)	3.1(3.2)	6.3	9.2	

[a] Number of sites at which the yield of a clone equalled or exceeded the site mean divided by the number of sites at which the clone was planted.

[b] Local check varieties

Table 7. Fresh root yields (t/ha) and dry matter contents (%) (in parenthesis of clones harvested from regional trials in ECZ 4 in 1986, Semester A.

Clone	CIAT, Valle	Quilichao, Cauca	Quilcace, Cauca	Relative performance[a]
M Cub 74	35 (33)	27		0/2
CG 3-3	35 (29)	34		1/2
CG 4-27			10 (31)	0/1
CG 5-79	33 (34)			0/1
CG 7-64	55 (37)	36	18 (36)	3/3
CG 7-66	41 (35)	34		2/2
CG 35-3	19 (28)			0/1
CG 165-2	33 (33)	30		0/1
CG 165-7	36 (32)			1/1
SG 104-264	31 (32)			0/1
SG 107-35	36 (32)			1/1
CM 305-41			24 (33)	1/1
CM 489-1	52 (30)		21 (33)	2/2
CM 516-7		33		1/1
CM 955-2	40 (35)	36	15 (38)	3/3
CM 962-4		39	4 (35)	1/2
CM 975-1			17 (39)	1/1
CM 1305-3	52 (32)	41	18 (34)	3/3
CM 1335-4	42 (34)	29	4 (38)	2/3
CM 1491-5		42		1/1
CM 1533-19		35		1/1
CM 1999-5	45 (35)	35	16 (40)	3/3
CM 2512-12	37 (28)	30		1/2
CM 2610-1	23 (31)	39		0/2
CM 2632-2	47 (31)			1/1
CM 2777-8	35 (32)			0/1
CM 2883-1	43 (34)			1/1
M Col 113[b]	23 (32)	28	5 (32)	0/3
M Col 1468	25 (32)	26		0/2
M Col 1684	18 (31)	25	3 (35)	0/3
Peciolo rojo[b]	3 (35)			0/1
Trial mean	36 (32)	33	13 (35)	
LSD (5%)	12.2(3.8)	6.6	6.6 (37)	

[a] Number of sites at which the yield of a clone equalled or exceeded the site mean, divided by the number of sites at which the clone was planted.

[b] Local check varieties.

Table 8. Fresh root yields (t/ha) and dry matter contents (%) (in parenthesis) of clones harvested from regional trials in ECZ 5 in 1986.

Clone	Popayan	Mondomo	Relative performance
HMC 2		13	0/1
M Col 2019	7(29)	10	0/2
M Col 2058		13	0/1
M Col 2059	18(33)	13	1/2
M Col 2060	16(32)	16	2/2
M Col 2061	8(31)		0/1
M Col 2257		15	1/1
M Col 2259		11	0/1
M Col 2260		16	1/1
CG 358-3	18(35)	11	1/2
CG 401-3	16(35)		1/1
CG 401-6	11(33)	12	0/2
CG 402-11		14	1/1
CG 403-18	20(32)	15	2/2
CG 406-5	14(34)		1/1
CG 406-6	15(33)		1/1
CG 481-3		9	0/1
CG 487-2	14(34)	14	2/2
CG 501-2		16	1/1
CM 1089-1	11(35)		0/1
CM 1090-52	16(34)		1/1
M Col 22			
M Col 1468	2(29)		0/1
M Col 1522	22(33)	11	1/2
Algodona		18	1/1
Valluna negra		16	1/1
Trial mean	14(32.9)	14	
LSD (5%)	5.6(1.8)	6.4	

[a] Number of sites at which the yield of a clone equalled or exceeded the site mean, divided by the number of sites at which the clone was planted.

[b] Local check varieties.

Table 9. Mean fresh yield, dry matter and HCN content of roots from first semester yield trials conducted at Carimagua (ECZ 2) and Media Luna (ECZ 1) from 1982 to the present.

Parameter	Site	Yield trial	Growing season			
			1982-83	1983-84	1984-85	1985-86
Yield (t/ha)	Carimagua	Preliminary	15.0	8.8	13.9	6.3
		Advanced	13.1	14.7	16.4	20.7
	Media Luna	Preliminary	10.5	16.0	17.4	21.3
		Advanced	13.8	13.1	11.6	21.9
Dry matter (%)	Carimagua	Preliminary	28.7	30.3	28.8	25.6
		Advanced	28.0	31.4	30.5	32.1
	Media Luna	Preliminary	27.7	30.0	28.4	30.1
		Advanced	31.8	30.6	26.1	30.6
HCN (1-9)[a]	Carimagua	Preliminary	6.1	5.9	5.0	7.1
		Advanced	5.6	5.6	5.5	6.9
	Media Luna	Preliminary	7.1	7.1	7.5	7.5
		Advanced	7.3	7.2	7.9	7.7

[a] 1 = very low (< 20 ppm CN^-); 9 = very high (> 150 ppm CN^-)

Table 10. Selected results of yield trials in Tabasco, Mexico, 1986.

Clone	La Palma (3 parcels harvested, 16 plants per parcel)						La Victoria 2 (3 parcels harvested, 16 plants per parcel)					
	Fresh root yield (t/ha)	Dry Matter %	Super-elongation rating*	CBB rating*	Evaluation of foliage*	Evaluation of roots*	Fresh root yield (t/ha)	Dry matter (%)	Super-elongation rating*	Thrips rating*	Evaluation of foliage*	Evaluation of roots*
Sabanera	10.2	-	1.8	1.5	3	3	14.9	32.2	2	2.5	3.2	3.2
CGM 1311-1	17.5	-	2	2.3	3.3	2	24.8	29.4	1.7	2.7	3.7	3
CGM 1311-3	20.5	-	1.3	1	3	2	12.0	28.9	3	3	4	3
CGM 1506-5	18.8	-	1.7	1.7	3	1.7	28.5	35.2	2	3	2.7	2.3
CMM 2868-1	19.0	-	1.7	1.3	3	2	7.9	24.1	2	2	4	3
CMM 4143-1	14.6	-	1.7	2.3	2.7	2	18.0	33.3	2.7	2.7	3	3
CGM 1309-1	11.3	-	1.7	1.7	3.3	2.3	12.1	32.0	3.3	2.7	3.7	2.7
CGM 1312-3	15.4	-	1.3	1.7	3	2.3	23.8	31.2	1.7	2.7	3.7	3
CGM 1312-5	10.9	-	1.3	1	3	2.7	15.9	31.6	2	2	3.7	2.7
CGM 1322-4	10.3	-	1.3	1.3	3	3	15.9	29.5	2	2	3	2.7
CMM 3957-8	14.3	-	1	1	1.7	2.3	8.8	32.4	1.7	2.3	2.3	3
Unidentified	17.6	-	2	1.8	2.3	2	27.6	32.1	1.7	2.3	3.3	2.3
Trial mean n = 35	12.8						Trial mean n = 38	15.6				

* Ratings are from 1 to 5; 1 is most resistant or best and 5 is least resistant or worst.

SOURCE: J. Acosta E., INIFAP

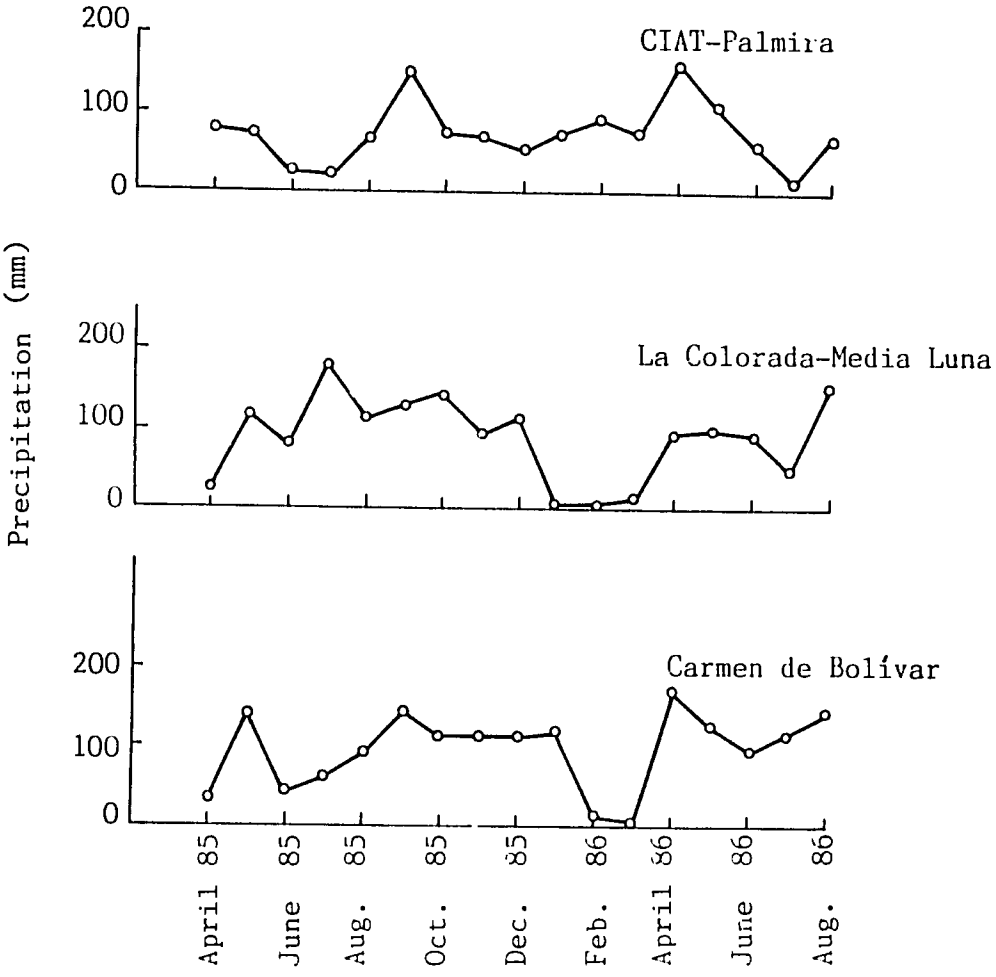


Figure 1. Monthly total precipitation at the CIAT-Palmira, Media Luna and Carmen de Bolivar selection sites during the 1985-86 growing season.

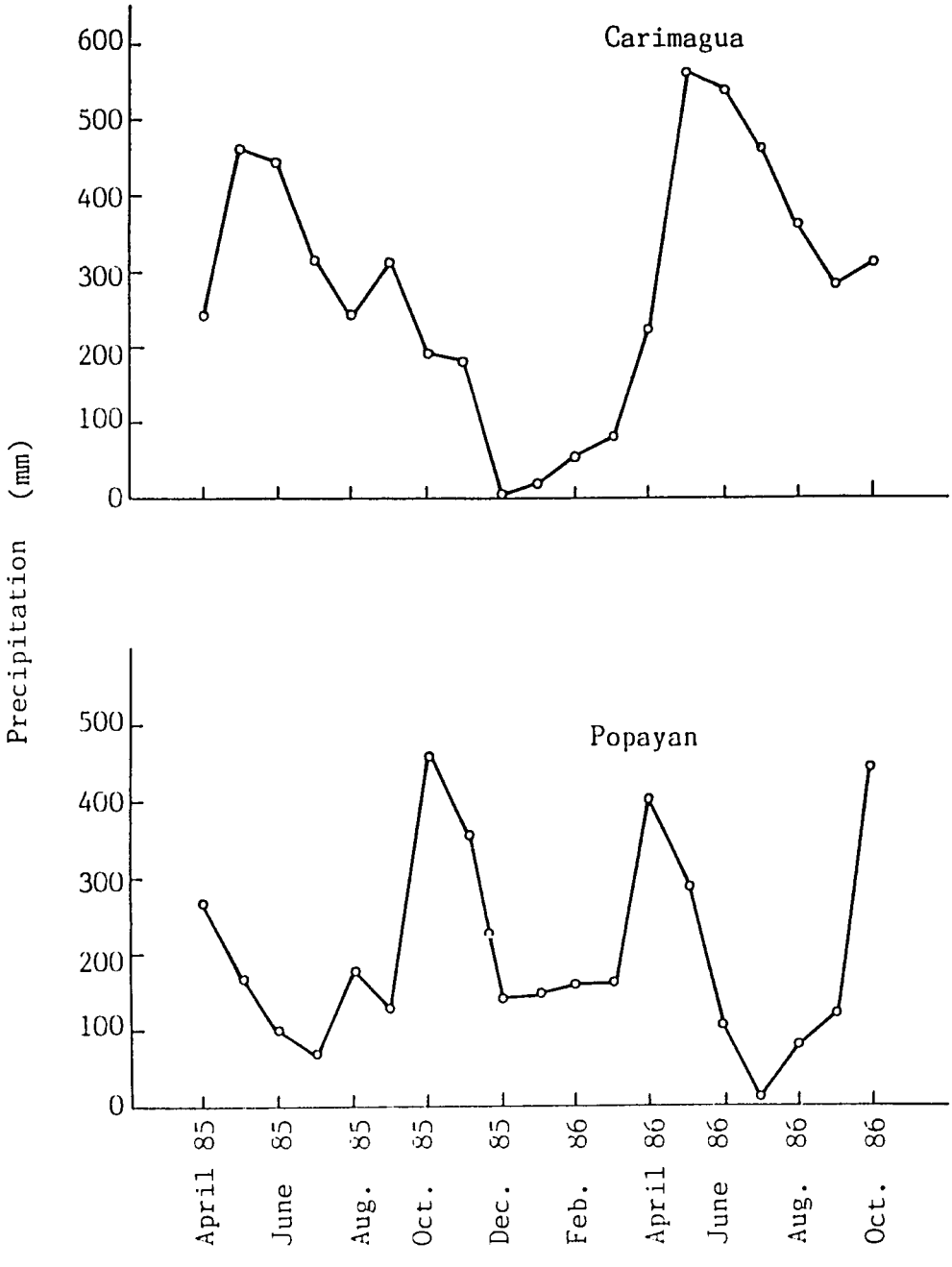


Figure 2. Monthly total precipitation at the Carimagua and Popayan selection sites during the 1985-86 growing season.

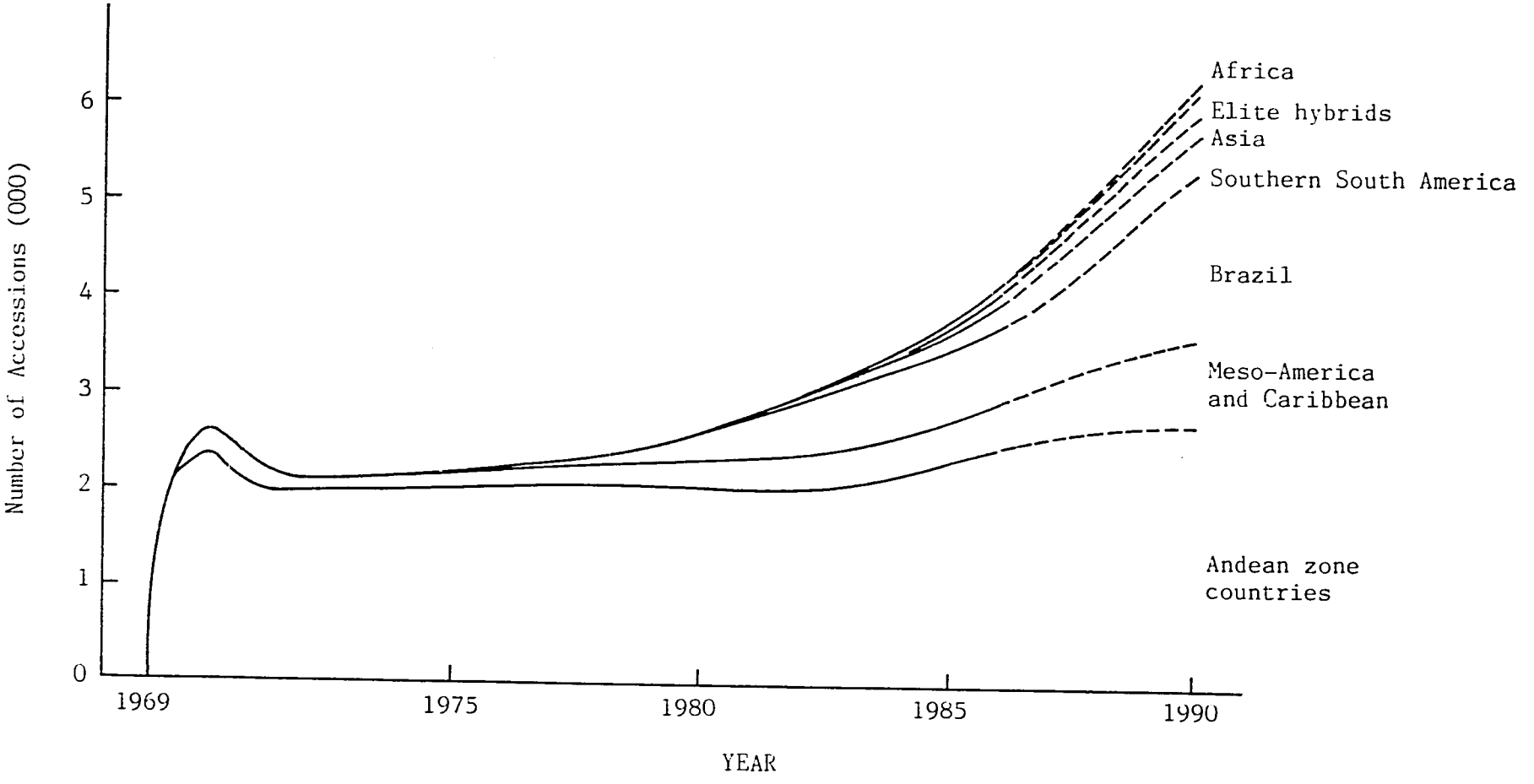
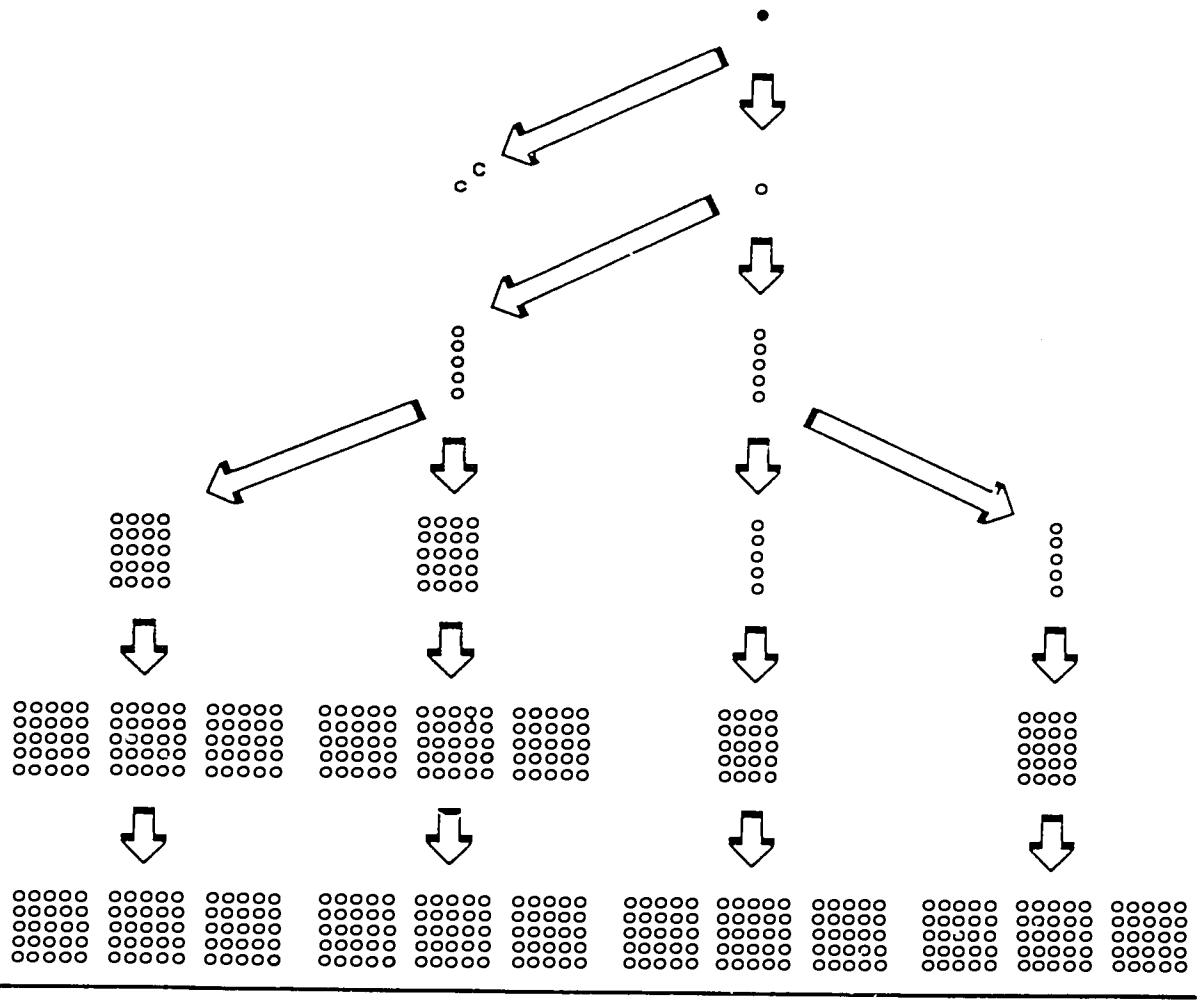


Figure 3 . Actual and projected regional composition of CIAT'S cassava germplasm collection.

Figure 4. Stages of selection in CIAT Cassava Breeding Program

Selection stage	Description	Design: Secondary selection site[a]	Design: Principal selection site	Design: CIAT Palmira	Design: Other evaluation sites[b]
F_1	From hybrid seed				
F_1C_1	First clonal generation				
CO	Observational trial				
EPR	Preliminary yield trial				
ER	Yield trial Year 1				
ER	Yield trial Year 2				



[a] Same ECZ as principal selection site

[b] Different ECZ than principal selection site

[c] Selection in principal selection site, but stakes for CO from CIAT-Palmira.

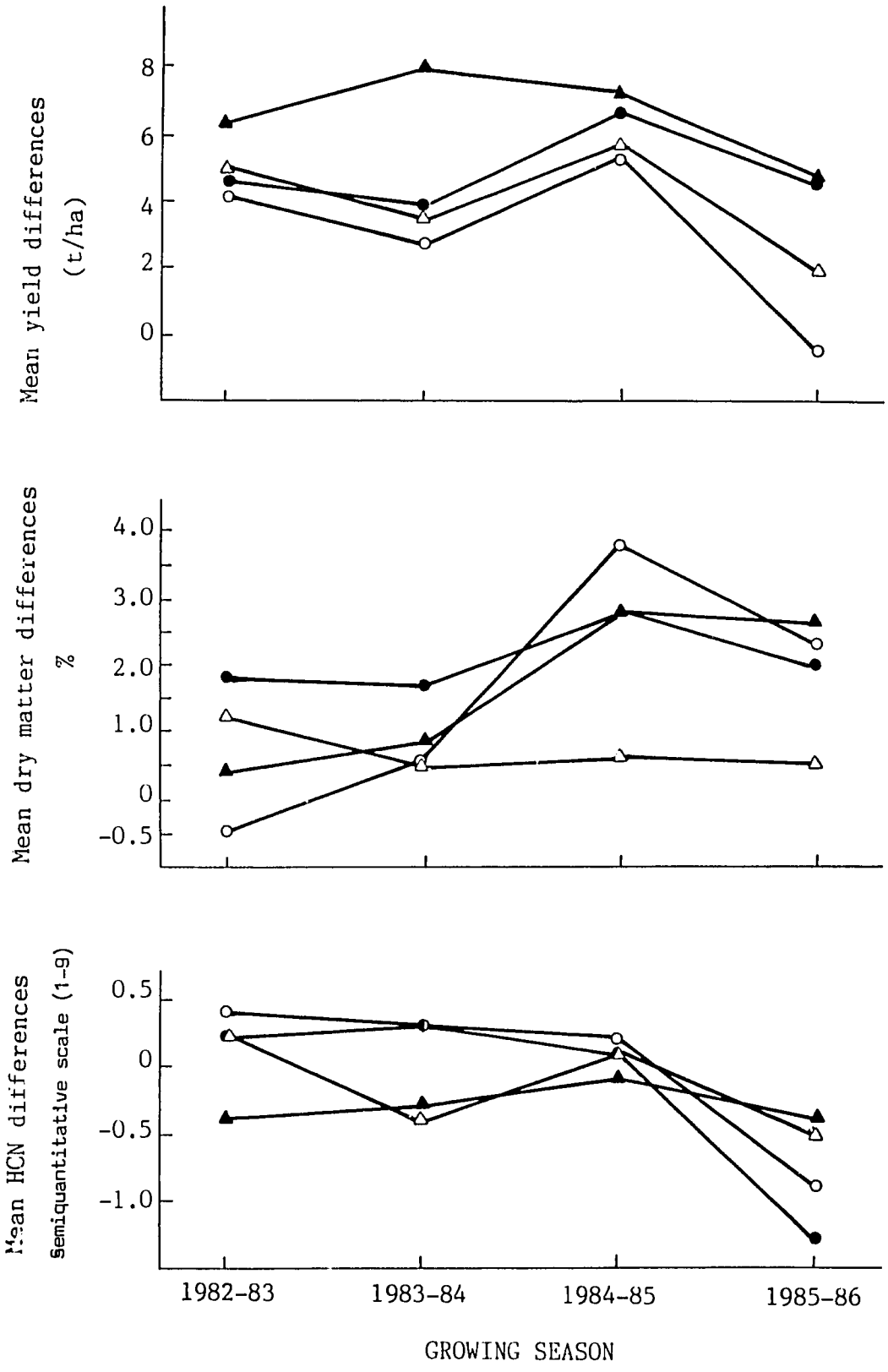


Figure 5. Trends in selection emphasis for root yield, dry matter and cyanide content in the first semester trials at Carimagua (ECZ 2) and Media Luna (ECZ 1) from 1982 to the present.
Each plotted value was obtained by subtracting the trial mean from the mean of the selected individuals. ● - Preliminary yield trial, Media Luna; ○ - Advanced yield trial, Media Luna; ▲ Preliminary yield trial, Carimagua; △ Advanced yield trial, Carimagua.

CASSAVA UTILIZATION

Introduction

Research into the conservation and handling of cassava has always had a high priority within the Cassava Program. In the 1970s, before the formation of the Utilization Section, work was carried out in certain specific areas which served to build up basic knowledge on the post harvest characteristics, processing and utilization of the crop. Table 1 summarizes the activities and results of the work undertaken during this period.

The economic studies initiated by the Cassava Program in the late 70s and early 80s, indicated - and this has subsequently been confirmed by the in-depth studies recently completed - that the two end uses which have the greatest potential for absorbing increased cassava production in Latin America, are fresh cassava for human consumption and dry cassava, either for use as an animal feed or for human consumption. Since the creation of the Utilization Section in 1980, the work has therefore concentrated on:

1. Developing a low cost fresh cassava storage technology.
2. Developing small to medium scale processes to produce dry cassava for animal feed.
3. Evaluating the use of dry cassava in rations for pigs and poultry.
4. Developing small to medium scale processing plant to produce dry cassava for human consumption.
5. Evaluating the use of dry cassava in human food products.
6. Research into the factors that affect the quality of fresh and processed cassava products.

An important part of the activities in these areas has been to demonstrate both the technical and economic viability of the technologies developed, and the acceptance of the products by the potential end users. It has therefore been necessary to incorporate into the work of the Section, the means by which the storage and processing technologies may be evaluated under real conditions and the products test marketed to assess consumer reaction. This has been achieved through the setting up of pilot projects in Colombia, in cooperation with the Integrated Rural Development Program. This year's report will include a brief description of the nature of the work being carried out in the areas mentioned above and details of the activities undertaken and the results obtained during 1986.

Fresh cassava storage

Fresh cassava can be stored for periods of two or more weeks by combining chemical treatment of the roots and packing them in polyethylene bags. The high humidity and temperature conditions that develop within the sealed bag enable root curing and wound healing to occur, and prevent post-harvest physiological deterioration. The chemical treatment, using a thiabendazole based fungicide (Mertect 450 FW, Ciba-Geigy at 0.4%) prior to packing, inhibits subsequent microbial deterioration of the roots (CIAT Cassava Program Annual Report, 1982). This simple and relatively low cost method of fresh cassava root storage

TABLE 1. Pre 1980 research activities on the post harvest conservation and handling of cassava

	Area	Date	Description of work carried out	Participating Institutions
1.	Fresh cassava for human consumption	1973/75	Physiological and pathological characterization of cassava deterioration and development of on farm clamp storage method.	TPI[a]/CIAT Cassava Program
		1979/84	Biochemical characterization of cassava deterioration and development of polyethylene bag storage method.	TPI/Wye College/CIAT Cassava Program
2.	Cassava Drying for animal feed	1970/72	Optimization of the parameters that affect the natural drying of cassava.	Michigan State University/ Universidad del Valle/CIAT Cassava Program
		1976/77	Development of small scale drying technology for farmers.	TPI/CIAT Cassava Program
3.	Cassava as a swine feed	1970/79	Life cycle swine feeding with fresh and ensiled cassava.	CIAT Swine Program
4.	Cassava as a substrate for single cell protein production	1976/79	Pilot plant production and biological evaluation of single cell protein.	Guelph University/IDRC[b]/ CIAT Swine and Cassava Programs

[a]TPI Tropical Products Institute, now ODNRI (Overseas Development Natural Resources Institute).
[b]IDRC International Development Research Centre.

has been successfully tested in four edaphoclimatic zones (CIAT Cassava Program Annual Reports, 1983, 1984).

Bucaramanga pilot project

In 1985 a pilot project was initiated in the Department of Santander del Sur, Colombia, to (a) demonstrate the viability of the new cassava storage technology under commercial conditions, (b) evaluate and monitor consumer acceptance of stored cassava, and (c) describe quantitatively the impact of the technology on total demand for fresh cassava, on farm level and consumer prices and on the structure of the fresh cassava market.

The first phase of this project included production, marketing and consumption surveys. These were followed by on-farm trials of the storage technology and consumer panel testing of the stored cassava (CIAT Cassava Program Annual Report, 1985). The results of the evaluation of fresh roots and roots stored for two weeks in bags by a panel of 100 consumers, indicated that there were no significant differences between the two with respect to taste and texture. 93% of the housewives interviewed, said that they would buy cassava sold in bags if it was available in the shops at the same price as normal, fresh cassava. There was, in general, no adverse reaction to the fact that the roots had been chemically treated.

Following the positive results obtained in the consumer panel tests, semi-commercial marketing trials were inititated in February 1986. In the municipality of San Vicente, approximately 140 km from the city of Bucaramanga, a group of 13 farmers that had shown interest when demonstrated the storage technology began by treating and packing 500 kg of fresh roots which were distributed to 3 small shopkeepers in two lower - middle class neighborhoods of Bucaramanga. Since February, the quantity of bagged cassava marketed has progressively increased, stabilizing at a level of between 2 and 3 tonnes of roots every week (Figure 1). Bagged cassava is now sold in Bucaramanga by retailers in the principal market and several shopkeepers in 5 neighborhoods. Recently new markets have openned up in two towns, San Vicente and Malaga, which are located 2 hours and 7 hours respectively, from where the cassava is being treated and packed.

The increase in volume of cassava marketed, has led to the introduction of certain changes in the storage method as described in earlier reports. The cassava is harvested in the morning, between 6 and 8 am, and transported by donkey to one of several centralized points where the roots are selected and trimmed. Trimming was initially done with a machete, however inexperienced trimmers tended to damage the roots and so pruners (garden secateurs) are now used. The selected and trimmed roots are packed into 4 kg polyethylene bags and sprayed, using a knapsack sprayer, with the fungicide solution. High pressure knapsack sprayers which produce a finer atomisation of the solution have proved to be much more efficient than the simple type, increasing the quantity of roots treated per litre of Mertect from 6 to 10 tonnes. The excess solution that collects in the bottom of the bags is drained out, either by tipping the bag upside down or by making a small incision into the botton of the bag. This latter method is simpler and saves labour. The

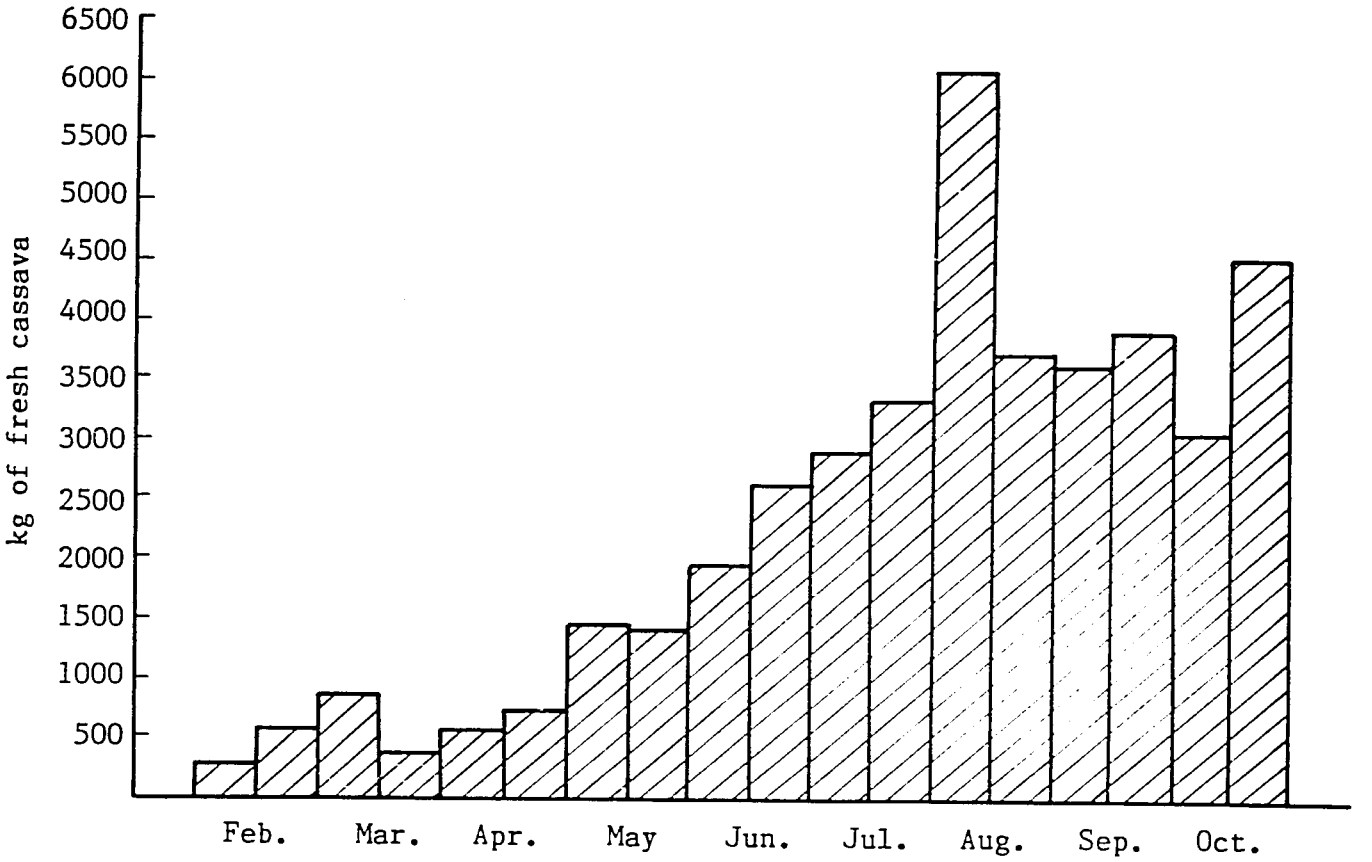


FIGURE 1. Supply of fresh cassava stored in polyethylene bags to shopkeepers in the city of Bucaramanga during the semi-commercial marketing phase, February-October, 1986.

bags are then sealed using a hand stapler and a label is attached which indicates to the consumer that the cassava roots will keep for upto 14 days in good condition from the date of packing. The date of packing is stamped onto the label. Printed polyethylene bags and heat sealing are now replacing the labels and stapler, with a consequent improvement in the presentation of the product and a reduction in costs. The farmers' group arranges the transport of the bagged cassava to a wholesaler in Bucaramanga who delivers to the stall and shopkeepers in the city.

Table 2 shows the cost structure and margins that have been available to the farmers' group during the period July - October 1986. The group buys cassava roots either from members or non members. The average price paid over the four month period was Col.$ 15,070 per ton, which is 25% more than the Col.$12,000 that the farmers normally receive from the intermediaries. The cost of treatment and packing amounts to Col.$ 6,200, and an additional Col.$ 3,330 is required for transporting the bagged roots to Bucaramanga. Total costs to the farmers' group are, therefore, Col.$ 24,600 per ton of roots. The group sells the bagged roots at Col.$ 27,000 to the wholesaler who distributes the cassava in Bucaramanga. The net profit on the operation is Col.$ 2,400 per ton.

TABLE 2. Cost structure and margin for fresh cassava storage in bags July-October, 1986

	Partial Col.$/t	Total Col.$/t
A. Total costs		24,600
Fresh roots	15,070	
Mertect	650	
Polyethylene bags	3,300	
Labour	2,250	
Transport	3,330	
B. Selling price		27,000
C. Margin		2,400

The principal problems that have been encountered in this phase of the project relate to, (i) the inherent quality of the roots, and (ii) the quantity of roots that have to be discarded due to some form of mechanical damage that make them unsuitable for storage. In order to maintain the confidence of both retailer and consumer, it is essential that the roots stored in the bags are of high quality. Since inherent root quality can vary with both edaphic and climatic changes, it is necessary that the roots to be stored are taste tested beforehand. The farmers on the whole have understood this and, except for on one occasion when a batch of bagged cassava was rejected because of "glassiness", this no longer poses a problem. On the other hand, the inclusion of mechanically damaged roots in the bags reduces storage time to 4 or 5 days and can cause considerable losses. It is becoming imperative that there exist some alternative market for rejects, which can represent up to 50% of the total weight of roots harvested, so that the farmers do not feel obliged to try and get away with packing unsuitable roots. In Santander del Sur a large potential demand for dry cassava exists, as a source of carbohydrates in animal feed rations, and so the setting up of a small drying plant is being contemplated.

The results to date, of the semi-commercial marketing of bagged cassava, suggest that the storage technology is economically viable, although the effect of high levels of reject roots needs to be studied further. Furthermore, consumer reaction has been positive. Before expanding the use of the technology it will be necessary to consolidate the present markets by ensuring a continuous supply of high quality product. As volumes increase, further modifications in the treatment and packing procedure will undoubtedly have to be introduced.

Lima pilot project

Based on the promising results of the experimental fresh cassava storage trials undertaken in Peru during 1985 (CIAT Cassava Program Annual Report, 1985), a one year special project, partially financed by AID, has been initiated with the Proyecto Especial Pichis Palcazu, PEPP, of the Instituto Nacional de Desarrollo. The aim of the project is to achieve the semi-commercial adoption of the fresh cassava storage technology, bringing cassava to the Lima market from the Satipo region of the Selva Central.

Preliminary results of a survey carried out among consumers indicate that cassava consumption in Lima is limited by the high price, bad quality and inconvenient nature of the product. Per capita consumption is estimated to be between 6 and 12 kg, compared with 120 kg for potatoes. As income rises so cassava consumption declines, higher income groupings consume 20% less cassava than the lower income strata. The greater availability of cassava would, therefore, tend to benefit most the poorer segments of the population. It is estimated that if bagged cassava were available, with the consequent improvement in quality and reduction in price, present consumption levels would double.

Consumer testing of stored cassava revealed that after a 7 day storage time losses were acceptable, but that at 14 days, losses were too high. These losses are attributed principally to (a) damage during

transport over the Andes, which leads to physiological deterioration setting in, and (b) excessive humidity (free water in the bags) which accelerates microbial deterioration.

At the farm level, it has been found that because of the large size of the roots, and damage during harvest, 20-30% of the cassava is not suitable for storage. This proportion is higher than one would wish for. However, the non-selected cassava can be maintained in good condition for 5 to 6 days by packing into bags without Mertect treatment. This is sufficient time for the roots to reach Lima where they may by sold for immediate consumption.

Excessive humidity during storage is caused by harvesting too soon after heavy rains. This problem has been overcome by introducing 1 to 3 small cuts in the bottom of the bags which allow excess water to drain out. Root curing for 1 to 2 days prior to transport over the mountains, prevents physiological deterioration. However, damage to the roots during transport caused by the poor condition of the roads, will have to be resolved by developing an improved form of packing.

Although root storage times are shorter than those obtainable in the Bucaramanga situation, it is felt that 7-10 days will be sufficient to greatly improve the consumers' conception of the product. Semi-commercial trials, in which a steady supply of bagged cassava will be maintained for a period of two to three months, are underway to reliably assess the costs involved and the impact of the introduction of the storage technology.

Cassava drying for animal feed

The Thai cassava chipping and drying technology has been studied and adapted by CIAT for use under Latin American conditions (CIAT Cassava Program Annual Reports 1972, 1976, 1981). This technology was introduced to a group of cassava farmers located on the Atlantic Coast of Colombia in 1981 through a cooperative pilot project between the Integrated Rural Development Program and CIAT which had the financial support of the Canadian International Development Agency. By 1986, a total of 34 farmers' cooperatives had been established processing cassava in plants with capacities ranging from 115 to 460 tons of dry product per year. Similar projects are now underway in Mexico, Panama, Ecuador and Brasil.

The Utilization Section provides technical assistance to these projects in aspects related to the construction and operation of the drying plants, with special emphasis on the factors that control the quality of the end product. Back-up research at CIAT has focused on modifications to the chipping machine (CIAT Cassava Program Annual Report, 1985) with a view to increasing its throughput, improving its operability and optimizing the drying characteristics of the chips produced. The use of forced air bin driers, coupled to a flat plate solar collector, has also been studied at the experimental and pilot plant scale. However this drying system was not found to be an economic proposition (CIAT Cassava Program Annual Report 1984, 1985).

Natural drying of cassava for animal feed no longer represents an important area of research as it is felt that a technically and economically viable process has been developed and validated on a commercial scale. Future work in this area will concentrate on the introduction and testing at a pilot scale of an artificial drying system, using a bin drier to enable drying during the rainy season or in areas where natural drying cannot be carried out because of high air relative humidity (CIAT Cassava Program Annual Report, 1985). The development of small scale milling and mixing plants that use dry cassava as the principal source of carbohydrate in animal feed rations is also contemplated. This activity is seen as an important second generation technology for areas where a cassava drying industry has been established and where there also exists the opportunity of promoting local livestock production.

Dry cassava in animal feed rations

Extensive experimental information on the use of cassava for swine feeding were obtained at CIAT during the 1970s as part of the activities of the Swine Production Unit. This work was continued by the Cassava Utilization Section in the period 1980-1983, with emphasis being put on evaluating the incorporation of cassava meal in both pig and poultry diets by using least cost formulation. Due to budget restrictions this area of research was phased out during 1983. Based on the work and experience gained, a technical manual will shortly be published on the use of cassava and cassava products in animal feeding.

Recently, the Utilization Section has collaborated with bachelor degree thesis students of the Faculty of Agriculture of the National University in supplying cassava and preparing rations for pig and poultry experiments run by the Instituto Colombiano Agropecuario, ICA. The objective of this thesis work is to fill in gaps in the knowledge on the use of cassava in animal rations. Two experiments are in progress to evaluate cassava based diets in pigs and poultry, fed either in the form of meal or as a pelletized ration. Future experiments are likely to focus on the formulation of diets using non-traditional sources of protein, as a back-up to the work on milling and mixing of animal feed rations for local use in cassava growing regions.

Cassava flour production for human consumption

Work in this area forms part of a joint project that is currently being carried out in collaboration with the Instituto de Investigaciones Tecnologicas, IIT, and the Universidad del Valle, Univalle. The objective of the project is to determine the technical and economic conditions required to establish a rural cassava flour industry in Colombia (CIAT Cassava Program Annual Report, 1984). Specifically, the Utilization Section and Univalle have been working together to develop an appropriate small to medium scale cassava processing technology which will produce a high quality flour suitable for human consumption.

Last year (CIAT Cassava Program Annual Report, 1985) it was reported that dry cassava chips could be successfully obtained using mills similar to those used for wheat. During the milling process, fibre and the lignified cassava bark is separated from the flour by sifting. The preliminary results suggested that, if the chips were to

be milled in this type of mill, it would not be necessary to peel the cassava prior to chipping and drying. During 1986, further roller milling trials have been carried out and the design of a pilot plant for the production of cassava chips completed.

Roller milling of dry cassava chips

Preliminary roller milling trials were carried out in a laboratory mill (Buller Laboratory Flour Mill Type MLU-202), at IIT. These trials were followed by larger scale evaluations in two industrial mills, one located in Bogota which has a capacity of 10-15 tonnes per 8 hours (mill A), and the other located in Buga with a capacity of 70 tonnes per 24 hours (mill B). Approximately 3000 kg of dry cassava chips were processed in both mills. Before milling it was necessary to reduce the size of the chips to allow continuous feeding to the first bank of roller mills. This was achieved using a modified bean thresher.

The results of these milling trials are shown in Table 3. Flour yields ranged from 83% in the laboratory mill to 98% in the industrial mill A. It can be observed that the by-products contain higher levels of fibre, protein and ash compared with the cassava flour fraction. No technical problems were encountered during the trials carried out in mills A and B, and it is therefore concluded that roller milling is a technically feasible alternative for producing a high quality cassava flour from dry cassava chips.

Pilot plant design and development

On the basis of the above results, the design and development of the pilot plant for producing dry cassava has continued. The process operations are shown in Figure 2. The original plant conception included the peeling of the roots before chipping and the milling and screening of the chips after drying. These operations are no longer felt to be necessary in the Colombian situation. The pilot plant has been designed to produce 1 ton of dry cassava chips per day. The following is a description of the plant and its operation.

Reception. The cassava roots on arrival at the plant (3 tons/day) are weighed on arrival at the plant and an initial inspection is undertaken to ensure that physiological and/or microbial deterioration are absent.

Selection and sorting. Roots are spread over an inspection table in batches of 120 kg. Deteriorated roots are picked out by hand and woody stems are removed. Excessively large roots are cut in two.

Washing. The washing machine consists of a 0.82 m diameter x 0.65m deep cylindrical steel drum, mounted horizontally and rotating at 40 rpm. A water spray is provided through the mounting axle. Roots are fed into the machine, in batches of 120 kg, through a hatch in the drum's surface, and are unloaded axially using a tilting hopper, which enters the machine and extracts the roots as they fall from the uppermost part of the rotating drum. Batch washing time is 2 minutes, and it is estimated that water consumption is in the order of 0.5 m^3/min per ton of fresh roots. The washing process eliminates soil and approximately 85-90% of the cassava bark.

TABLE 3. Results of dry cassava chip milling trials in wheat mills.

Type of mill	Flour				Shorts				Bran							
					Semola/Moyuelo[a]				Har.de tercera/Salvadillo[a]				Salvado fino/Salvado grueso[a]			
	Yield	Fibre	Protein	Ash	Yield	Fibre	Protein	Ash	Yield	Fibre	Protein	Ash	Yield	Fibre	Protein	Ash
	%	— % d.b. —			%	— % d.b. —			%	— % d.b. —			%	— % d.b. —		
Laboratory mill	82.7	2.4	4.9	1.8	15.2	6.8	4.2	1.8	2.0	18.2	6.3	3.5	-	-	-	-
Industrial mill A	97.8	2.5	3.9	1.8	0.6	4.1	5.3	2.2	1.2	16.4	8.3	3.5	0.4	35.3	8.1	4.6
Industrial mill B	95.4	1.9	5.6	2.3	2.6	18.3	8.0	1.0	1.0	15.0	11.7	10.6	0.9	32.9	9.9	4.5

[a] Terms used by mills A and B respectively to describe the different by-products. The specifications of the by products grouped together are not necessarily the same but their appearance is similar.

Source: Universidad del Valle, Cali.

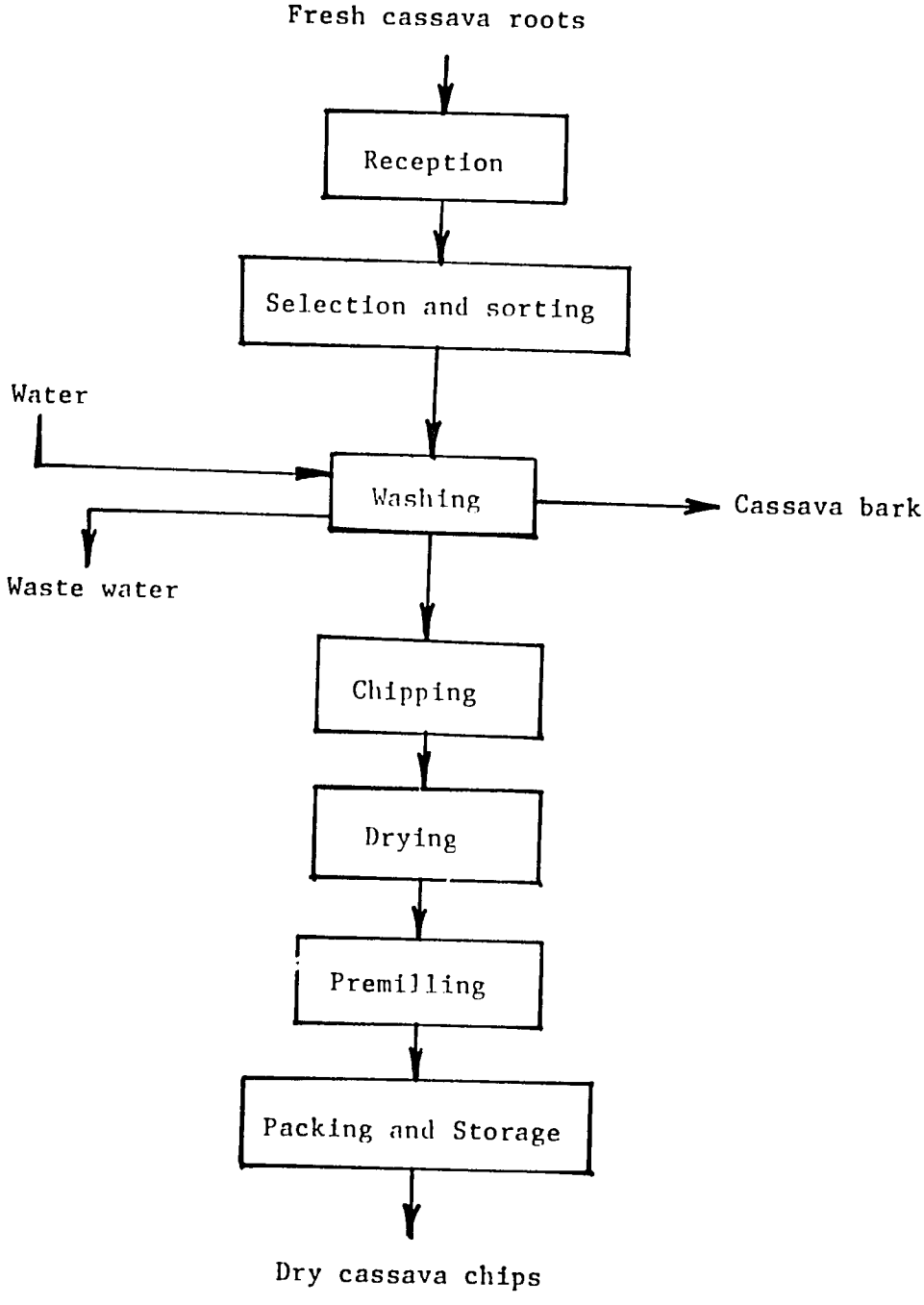


Figure 2. Flow diagram for the production of dry cassava chips destined for human consumption

Chipping. The chipping machine is a modified Malaysian type model consisting of an angle iron frame which supports a vertical 0.9 m cutting disc and feed hopper. The cutting disc is fitted with replaceable blades that produce chips in the form of rectangular bars of approximate dimensions 8x10x70 mm. The washed roots are fed by gravity directly from the washing machine into the chipping machine. As the roots are cut, a specially designed trolley, that couples onto the front of the chipping machine, collects the cassava chips. The trolley is also used for transporting the chips to the drying area.

Drying. The plant has provision both for mixed natural and artificial drying during the dry season (20 weeks) and for artificial drying during the wet season (20 weeks). Natural drying is carried out in inclined mesh bottomed trays supported on racks. The fresh cassava chips are predried during one day by spreading them evenly over the trays at a loading density of 16 kg/m^2. 118 drying trays with dimensions 0.75 m x 1.80 m are required. Artificial drying is achieved in a 19 m^2 bin drier coupled to 5 hp centrifugal fan. The drying air is heated to 60°C by means of a vertical indirect coal-fired burner, connected to the fan inlet. Drying times, airflow rates and coal consumption for the two drying systems are presented in Table 4. During the dry season the plant capacity is doubled to 2 tons/day, giving a total yearly production of 360 tons.

TABLE 4. Drying times, airflow rates and coal consumption for the 1 ton/day cassava drying plant.

Drying system	Drying time		Airflow[a]	Coal consumption
	Predrying	Artificial		
	h	h	m^3/min.t	kg/t.product
Mixed natural/artificial	9	8	66	150
Artificial	-	10	110	450

[a] Airflow rate: m^3/min. per tonne of predried or fresh chips respectively.

Premilling. After drying, the cassava chips are transported, either by trolley or in sacks, to the storage area where they are premilled. Size reduction of the dry chips was first achieved using a modified bean thresher, however, this machine produced a large quantity of fine material and dust. More satisfactory results have been achieved using a simple roller mechanism that produces small chips of approximate

dimensions 5x5x5 mm. A prototype version of this machine is being constructed.

Packing and storage. The premilled chips are stored in polypropylene sacks before despatch to the wheat mill.

Table 5 shows the operating parameters of the pilot plant and Table 6 the investment and operating costs. The operating cost calculations have assumed a fresh cassava price of Col $9,000/ton, which is the price that the farmers' cooperatives on the Atlantic Coast of Colombia are paying for roots that will be processed into dry cassava for animal feed. The present wheat grain support price in Colombia is Col $52,800, which suggests that at a cost of Col.$37,410 the production of dry cassava as a partial substitute for wheat could be economically viable. More reliable capital and operating cost data will be obtained in the future by the setting up of a pilot project on the Atlantic Coast.

Cassava flour in human food products.

The laboratory trials carried out last year by IIT (CIAT Cassava Program Annual Report, 1985), showed that 15% of wheat flour in bread could be replaced by cassava flour, although there appeared to be varietal and age factors that affect the baking characteristics of the composite flour. Of the four cassava flours evaluated, that produced from the variety M Col 22 gave the best results at 12 months plant age. During 1986 these results have been validated by undertaking trials in commercial bakeries in Bogota and evaluating bread using a consumer taste panel.

Exploratory trials in a commercial bakery.

To confirm the experimental results achieved in the laboratory and before initiating the consumer panel tests, a commercial bakery undertook to replace successive quantities of wheat flour by cassava flour in the elaboration of the whole range of bakery products (bread, cakes, cookies, etc.). The cassava flour used was obtained from the variety M Col 22, harvested from 8 through 12 months and chipped and artificially dried in a bin drier. The dry chips were milled in an industrial wheat mill (mill A) located in Bogota.

During the trials, each week the wheat flour substitution rate was progressively increased from 0 to 17%. Samples of "pan blandito" and "pan frances" (literally "soft" bread and french bread) were taken, and their specific volume evaluated. The results, presented in Table 7, reveal the great variation in this parameter from batch to batch, even when using 100% wheat flour. As the rate of substitution increased so the specific volume tended to decrease, although the results were not significantly different up to a 10% substitution for "soft" bread, and a 17% substitution for french bread. No negative consumer reaction was noted up to the 15% substitution level. The trial was terminated at the 17% substitution level at the request of the bakery owner because of the noticeable drop in quality of the bread. It was concluded that a 15% substitution could be safely used in the consumer panel tests.

TABLE 5. Operating parameters of 1 ton/day dry cassava chip plant

Conversion, t fresh roots (65% m.c.)/t dry chips (12% m.c.)	2.75
Labour requirement, man-hours/t dry chips	26
Water consumption, m^3/t dry chips	3
Electricity consumption, kwh/t dry chips	40
Coal consumption, t/t dry chips	0.28
Yearly production, t/year	
Mixed natural and artificial drying, 20 weeks	240
Artificial drying, 20 weeks	120
Total	360

TABLE 6. Investment and operating costs of 1 ton/day dry cassava chip plant.

	Cost Col.$
A. Investment cost, Col.$	4,168,000
B. Operating cost, Col.$/t dry chips	
1. Direct costs	
Raw material at Col.$ 9,000/t	24,750
Labor	2,470
Water, electricity and fuel	1,810
Sacks	2,200
2. Indirect costs	
Administration	2,250
Maintenance and depreciation	1,400
Interest	2,530
TOTAL	37,410

Consumer panel testing of composite flour bread.

The consumer taste panel was set up in Bogota to

(a) determine whether consumers can detect differences between pure wheat and composite wheat/cassava flour bread;

(b) identify those characteristics which cause differences between the breads, if they exist; and

(c) assess the acceptability of a composite wheat/cassava flour bread.

The taste panel was made up of 100 consumers taken from 5 neighborhoods in Bogota. Table 8 shows the basic characteristics of the 5 neighborhoods included in the panel, together with the information regarding bread consumption habits in each neighborhood. "Soft" bread is the most popular bread type, although in the high socio-economic grouping, other types of bread (wholemeal and speciality breads) represent a high proportion of the total expenditure on this food.

TABLE 7. Influence of the cassava flour substitution level on the specific volume of "soft" bread and french bread produced in a commercial bakery.

Substitution level %	"Soft" bread 20 peso loaf	"Soft" bread 10 peso loaf	French bread 20 peso loaf	French bread 10 peso loaf
0	4.21 [a]	4.27 [a]	3.84 [a]	3.80 [a]
5.0	3.90 [abc]	4.09 [abc]	3.76 [a]	3.62 [a]
10.0	4.10 [ac]	4.00 [abc]	3.47 [a]	3.65 [a]
12.5	3.48 [b]	3.75 [abc]	3.27 [b]	3.44 [a]
15.0	3.66 [bc]	3.64 [b]	3.47 [a]	3.52 [a]
17.0	3.31 [c]	3.47 [b]	3.41 [a]	3.59 [a]

DMS: 0.44

Values with the same letters are not significantly different at the 0.1 level. Each value is the mean of six determinations.

Source: Instituto de Investigaciones Tecnologicas, Bogota

Consumers were asked to evaluate bread on two occasions. On the first occasion a sample of bread, sufficient to cover the needs of the whole family during one day, was delivered between 6.00 and 8.00 a.m. The sample, which contained both "soft" bread and french bread, had been prepared by a baker from the same or a similar neighborhood, using 100% wheat flour. The following day, the housewives of the families were questioned about their opinion of the bread. One week later the procedure was repeated, but on this occasion the sample, prepared by the same bakers in each neighborhood, was formulated using 85% wheat flour and 15% cassava flour. On neither occasion were the consumers told of the bread formulations. Only at the end of the survey were they informed that cassava flour had been incorporated into the second sample. Table 9 shows the results of the consumer evaluations of the two bread samples.

TABLE 8. Socio-economic stratum and expenditure on bread in five Bogota neighborhoods included in the consumer test panel.

Neighborhood	Socio-economic stratum	Expenditure on bread[a] Col.$/capita. year			
		Total	Soft bread	French bread	Other types
Niza	High	11,240	4,150	2,920	4,170
Tierra Linda	Middle	6,500	3,020	1,970	1,510
Paris Gaitan	Lower middle	6,270	3,390	1,650	1,230
Tibabuyes	Low	4,660	3,070	1,140	450
Tuna baja	Lower low	4,660	3,470	900	290

[a] Data from a survey of bread consumption habits. Economics Section, Cassava Program.

Consumers did perceive differences between the breads prepared from pure wheat flour and composite flour. These differences were significant for aroma, freshness and appearance, with the composite flour breads being marginally inferior to the pure wheat flour breads. Asked to give their overall opinion on the breads, consumers again scored the breads made from composite flour lower, even so, their opinions fell between "liking moderately" to "liking very much", which hardly indicates a rejection of the product. Questioned as to which of the two samples the consumer preferred, a total of 68% in the case of "soft" bread, and 58% in the case of french bread, replied that they preferred the composite flour bread or that their preference for the two samples was the same. On being informed that the second sample had contained cassava flour, 81% of consumers indicated that in principal they would accept composite flour instead of wheat flour bread. They cited a number of reasons or conditions: improved flavour 15%, improved

quality 9%, lower price 7%, provided that there are no changes in quality 46%, and no inconvenience 4%. 8% of consumers objected to the use of cassava flour because: wheat flour bread is better 1%, it is bad for one's health 2%, habit 3%, and possible changes in flavour 2%. 11% of consumers did not reply. This information suggests that in general consumers will accept bread prepared from 85% wheat flour and 15% cassava flour, provided that there are no marked changes in quality.

TABLE 9. Consumer quality evaluation of 100% wheat flour bread and 85% wheat/15% cassava flour bread.

Quality parameters [a]	"Soft" bread		French bread	
	100% wheat	85% wheat-15% cassava	100% wheat	85% wheat-15% cassava
Flavour	2.17	1.95 *	2.03	1.92
Colour	2.56	2.69	2.55	2.53
Aroma	2.09	1.90 **	2.05	1.89 *
Texture	1.99	1.86	1.89	1.69
Freshness	2.35	1.99 **	2.27	1.96 **
Volume	2.05	2.02	2.08	1.98 *
Appearance	2.21	2.00 **	2.12	1.94 **
Crust hardness	2.02	1.96	1.87	1.86
Overall opinion [b]	7.00	6.58 *	6.82	6.44 *

* Mean evaluations significantly different at the 5% level.

** Mean evaluations significantly different at the 1% level.

[a] Evaluation scale 0 bad, 1 fair, 2 good, 3 very good.

[b] Hedonic evaluation: 0 dislike extremely, 1 dislike very much, 2 dislike moderately, 3 dislike slightly, 4 neither like nor dislike, 5 like slightly, 6 like moderately, 7 like very much, 8 like extremely.

Development of new food products

The use of cassava flour as a partial subsitute for wheat flour in bread is only one of the many possible end uses of this product. The production of a high quality flour which is price competitive with wheat

or other grain flours opens up a number of alternatives. There are numerous processed or semi-processed food products that incorporate a starch based component (noodles, pastas, soups, snack foods, etc.), and it is proposed in the future to investigate some of these alternative uses. As far as possible the Section will enter into collaboration with food research institutes that have already worked in this area, such as the Centro de Investigaciones en Tecnologia de Alimentos, San Jose, Costa Rica, the Instituto de Nutricion de Centro America y Panama, Guatemala, the Instituto de Investigaciones Tecnologicas, Bogota, Colombia, and the Centro Tecnologico de Alimentos, Rio de Janeiro.

Quality of fresh and processed cassava

Quality is a factor of prime importance in the development of cassava products whether they be for fresh human consumption, as in the case of stored roots, or raw materials for the food or feed industries. Objective measurement of quality is easily carried out by means of physical or chemical analysis, and in the case of subjective parameters such as taste and texture, by means of expert taste panels. In the past quality evaluations have been implicitly included in the work that has been carried out on product development.

The results of quality evaluations consistantly reveal that physical, chemical and biochemical differences exist in fresh cassava roots that markedly affect the quality of the end product. These differences occur, not only between cultivars, but also within cultivars at different plant ages and under varying edapho-climatic or stress conditions. The factors that cause these quality changes are at present poorly understood. Obviously, a better understanding of these factors, and the way in which they affect certain quality characteristics or parameters, is of critical importance for the selection of improved cultivars suitable for specific end uses.

In future much higher priority will be given to studying the causes and effects of changing fresh root quality. A joint project with the Tropical Development Research Institute, TDRI[a], London is underway, to define quality parameters of fresh and stored roots, and dry cassava for human and animal consumption. Ultimately, it is hoped that methods suitable for rapidly screening cultivars for specific quality characteristics and end uses will be developed.

[a] Now Overseas Development Natural Resources Institute (ODNRI).