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CASSAVA PROGRAM

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CIAT

Centro Internacional de Agricultura Tropical

CASSAVA PROGRAM

INTRODUCTION

Since its initiation the CIAT Cassava Program has maintained a dynamic and productive research and outreach program with numerous achievements, which include unique advances in crop physiology, crop management and natural resources conservation, biological control of several pests, plant resistance to diseases and insects, the development of numerous hybrids based on CIAT germplasm released by national programs in Latin America and Asia and technolgy development in cassava utilization, processing and root quality and conservation.

With the stationing of a physiologist/breeder at IITA, Nigeria, as a CIAT liaison scientist, the CIAT Cassava Program now has research scientists working on all three continents, LA, Africa, and Asia where cassava is an important crop. The CIAT Cassava Program is committed to developing germplasm for selected ecosystems of Africa, particularly the semi arid areas of that continent where the cassava crop has considerable potential. To accomplish this goal we have developed a unique model for collaboration with EMBRAPA in Brazil, in cooperation with IITA. As part of this arrangement the Programa Nacional de Pesquisa de Mandioca (PNPM) (CNPMF/EMBRAPA) will be responsible (in collaboration with CIAT scientists) for developing semi-arid and sub tropical adapted cassava germplasm. The PNPM/CNPMF research program will be stengthened with additional resources to undertake this challenge.

The IITA/CIAT collaborative research project for the biological control of the cassava green mite (CGM) in Africa made considerable progress during 1989. Shipments of phytoseiid mite predators were made to Benin, via Amsterdam, on a monthly basis. Establishment of at least one introduced predator mite species in cassava fields in Benin appears to have been achieved and enhances the possible future success of this project. In addition several new mealybug predators have also been introduced into Africa from CIAT.

The CIAT Cassava Program's role in the development and strengthening of national cassava research programs in Asia progressed considerably during 1989. A one month interdisciplinary course on cassava research for Asian scientists was held at CIAT/Palmira. Twenty seven scientists from 9 Asian countries including India, Thailand, the Philippines, Laos, Vietnam, Indonesia, China, Sri Lanka, and Malaysia participated in this cassava production and utilization course.

Collaboration with national research and extension services in Latin America intensified during the year, especially in Brazil, Paraguay, Panama, Ecuador and Colombia. In Paraguay, Panama and the Atlantic Coast of Colombia, researchers and extensionists combined to formulate recommendations for improved production of cassava. These technical recommendations were based on research results obtained from on-farm research trials. The Paraguayan Extension Service (SEA) produced a comprehensive technical bulletin with recommendations to improve cassava production.

After considerable planning and negociations, a cassava drying project for Ceara, Brazil (The Kellogg Project), was initiated in May 1989. Fifteen drying plants have already been completed with several more under construction. Approximately 200 tonnes of dried cassava already produced have been primarily utilized in rations for the dairy cow industry. The cassava drying industry in Colombia has expanded to an annual production at between 12 and 15 thousand tonnes of dried cassava. In Panama four cassava drying plants are presently in operation.

During 1989 numerous training courses and workshops for Latin America were held. Themes included: Production and utilization technology of cassava starch (held in Brazil); meeting on cassava projects with National Research and Extension Policy-Makers from Northeast Brazil; Integrated pest control for cassava in Latin America; Integrated projects for cassava development in Latin America; and meetings on cassava germplasm.

The success of the integrated production, utilization and marketing projects on the North Coast of Colombia have created a greater demand for cassava. This has lead to a demand for new and improved technology to increase yields as well as the quality of cassava roots. During 1989 ICA held two variety pre-release seminars to present to groups of scientists three new varieties for the North Coast and three for the Eastern plains (Llanos). These varieties are of CIAT origen selected over several years in collective CIAT/ICA trials. The expanding cassava market on the North Coast demands dual purpose varieties, to be utilized in the cassava drying plants for animal feeds but also for the fresh market consumption. This is one of the most demanding markets in the world for cassava root quality. CIAT breeders have, with considerable effort, been able to combine these rigid quality characteristics with higher yield and pest and disease resistance. The selection process involves on-farm trials with considerable farmer participation and has resulted in 3 selected clones for each ecosystem with average yields on the North Coast of 22 t/ha and in the Eastern plains of 24 t/ha.

Additional cassava program highlights during 1989 included:

1. Biochemical characterization by isozyme analysis has now been achieved for nearly 2000 cassava accessions.

2. A marker gen bank for cassava containing known genetic markers in alternate states of hetero and homogocity has been established.

3. Photosynthetic rate is significantly correlated with dry root yield and selection for high leaf photosynthesis is likely to lead to higher yield.

4. Cassava clones tolerant to low-P soils have been identified indicating that yield can be increased through genotype selection.

5. Cassava yields showed a positive response when grown in

association with the forage legumes siratro (149%), Kudzu (126%), Zornia (115%) and Centrosema (107%).

6. Cassava yields better when intercropped with improved maize varieties possibly due to the fact that less light is intercepted by improved maize varieties than traditioanal varieties.

7. It has been found that the tolerance of cassava to flooding is due to a quick formation of a secondary root system on the upper unflooded base of the stem.

8. Resistance to root rot pathogens *Phytophthera drechsheri* and *P.n.* var *nicotianae* have been found in cassava germplasm.

9. The coat protein for cassava common mosaic virus (ccmv) and X virus (csxv) have been characterized.

10. Using race specific electrophoretic patterns, six races of the whitefly (*Bemisia tabaci*) have been identified in Colombia, as well as five species attacking cassava.

11. Two new species of cassava mealybug parasite have been uncovered in Venezuela during exploration for natural enemies.

12. Important strain differences of cassava green mite phytoseiid predators for shipment to Africa have been identified.

13. Several new species of phytoseiid mite predators have been identified and researched for release in African cassava fields.

14. Root HCN content of both cooked and boiled cassava root pieces correlates significantly with bitter taste in cassava.

15. The quantitative enzymatic method was found to be more accurate than the picric acid method for measuring HCN content in cassava roots.

CIAT Cassava Asian Regional Program
1989 Annual Report-draft

Kazuo Kawano

Generating technology by working together with national programs has been the major activity of the CIAT Cassava Asian Regional Program. In pursuit of this goal, a good understanding of the role of cassava in Asian agricultural economies, the national program situation, and implementing mechanism for better cooperation is a prerequisite.

Cassava research need in Asian Agricultural economies

It is a gross over-simplification to assume that the limiting factor in cassava production/utilization in Asia is on the supply rather than the demand side. It is rare to find the situation in which supply is unconditionally the limiting factor; in most cases demand and supply interact with the agricultural policy, processing scheme, marketing situation and the availability of other crops. How the cassava crop productivity comes into this linkage is in itself an interesting research concern.

Even in currently low-income countries such as China, Vietnam, Myanmar (Burma) and Laos, only a minor amount of cassava production is consumed as fresh human food. India is the only Asian country where the greater part of cassava production goes for fresh human consumption; yet, the consumption per capita is decreasing, mainly due to the improved availability of rice. In Indonesia, the Philippines and Vietnam, a significant amount of production is freshly consumed; yet cassava as fresh food is considered mainly as a subsistence food when rice is in short supply. In all these countries, the research officials by and large deny the need of cassava production research for fresh human consumption. This may be justified because 1) most cassava for this purpose is grown in backyard-type plots, where the yield per hectare is seldom a serious concern, 2) the cultural practices cause comparatively small dangers of environmental deterioration, 3) the cultivars may be low-yielding but usually excellent in eating quality, and 4) the processing does not require further refinement. After all, the system is a century-old perfection on its own. It is difficult to improve the components of this system without touching the whole framework and there does not appear to be much need for it either.

Throughout tropical Asia, cassava is processed into flour or starch, which in turn is utilized in the production of numerous food products with varying degrees of sophistication. A large number of small farm communities are involved in the production and processing. Many different production and processing schemes exist, which give endless combinations of not only production with utilization but also of supply with demand. A further analysis of the production and utilization situation is much-needed. The basic understanding is that any improved crop production technology will have to be well integrated with the development of processing and marketing.

Cassava production, both by small farmers and by plantations for large-scale starch production for either national industry or export, is of great importance in many Asian countries. With the development of industry in currently underdeveloped countries, such as Vietnam or Myanmar, the importance of cassava production for starch is expected to increase. Demand and supply sharply interact with the prices of raw and end products as well as with the capacity of processing.

A large amount of cassava, although the exact quantity is not known, goes for animal feed, both fresh and dried, within the country. A more detailed decription of the present status and the analysis of future potential merit serious research attention.

An enormous quantity of cassava in Thailand, and an increasingly significant proportion in Indonesia and China, is exported as animal feed in the form of dried chips or pellets. Countries such as Vietnam and the

Philippines are seeking the same opportunity. The majority of cassava is produced by small farmers, while processing is undertaken by small- to medium-size factories. Demand is predominantly the limiting factor but temporarily and locally supply is often the limiting factor. Millions of people in small farm communities, who otherwise can hardly obtain sources of cash income, are receiving modest but precious benefits from this scheme.

Throughout the different production schemes, the demand for improved cultivars (higher yield and higher starch content, etc.) is considerable and it is particularly strong where the crop is grown for export or for large-scale starch processing. Improved cultural practices will be increasingly needed as the crop moves from subsistence farming to cash cropping. The technology for higher production efficiency, both genetic and cultural, will, in the long run, lead to higher product competitiveness and better alternatives in agricultural policy due to better land use efficiency. Research on soil conservation technology is acutely needed at all levels of production. Demand for new processing technology which will open new markets for cassava products is particularly strong in countries such as Indonesia, Vietnam, the Philippines and China. Socio-economic studies on the role and potential of cassava in small- and large-scale production schemes, in micro- and macro-economic contexts, will give the policy makers, researchers and producers a more sound data base for planning.

Implementing mechanism

The CIATcassava Asian Regional Program in Asia contributes to national cassava research programs in the form of visits, consulations, collection of pertinent varietal and cultural data, on-the-spot training in design and execution of experiments, and last but-not-least, in the setting of research priorities. We offer germplasm materials and conduct varietal and cultural experiments together with national program researchers. We also organize training-courses, workshop, symposia and help in the writing and publication of scientific articles to enable national programs to utilize available technology more efficiently.

CIAT contributes a small amount of financial support (maximum $2000/project) to conduct cooperative research in each country through regional collaborative research contracts. This small monetary support is to enhance the efficiency of existing research programs and is extremely usefull in order to pay for research expenses such as small tools, fertilizers, travel expenses, contract labor etc. Care is taken not to create dependency, where nothing could be continued at the discontinuation of contract funding. A research advisory committee is to be formed to define the priorities for the type of research to be done through these research contracts. Our involvement through these research contracts is expected to be very significant in Indonesia, China, Vietnam, and the Philippines.

Our presence in Thailand and the excellent collaboration and facilities offered by the Field Crops Research Institute offers a regional center of germplasm development and exchange, and makes it possible to be directly involved in more intensive agronomic research to test new ideas or to study more basic principles.

Training

Training has been an extremely important component of our acitivities in forming research capability on the national program side, and on our side, learning about research needs and the situation of national programs. Training has been done in three forms, i.e., 1) Short course, 2) In-service specialized schorlarship, and 3) Degree training. This year we completed the 3rd Cassava Research Short Course for Asian cassava researchs successfully, at CIAT headquarters in Colombia, with participation of 27 cassava researchers from 9 countries.

General objectives of the Course were:

1). To enhance the participants' understanding of cassava as a crop and its socio-economic potential on a world wide basis.

2). To expose the participants to broad information and research opportunities regarding cassava.

3). For the participants to learn basic research know-how in their areas of research specialization.

4). For the participants to learn the operation of a multidisciplinary crop research program in a large research organization.

5). For the participants to gain experience with other cultures and socio-economic situations through international and Colombian trips and interactions with participants from other countries.

6). For all of us to develop a research network in Asia.

Advantage of training Asian national program researchers are:

1). Dealing with research personnel involved in an extremely important part of the national economy (Thailand) or potentially so (Indonesia, China, Vietnam).

2). Most countries have well-established research institutions, in which cassava research occupies a significance proportional to the importance of the crop in the national economy.

3). Most Asian cassava researchers continue to do cassava research within the same research institution for their entire career.

4). Generally serious attitude towards the training course.

The potential effects are:

1). Enhanced skill of research personnel in an already well-established research program with possible direct results (Thailand).

2). Further consolidation of research program and significant improvement in research capability with possible direct results (Indonesia, China, Vietnam).

3). Broader knowledge in cassava research which can be utilized when the research atomosphere is improved (India, Philippines) or new cassava utilization is developed (Malaysia, Sri Lanka).

4). Utilization of training totally dependent on the continuity of outside funding. (Laos)

Cassava Varietal Improvement in Asia
1989 Annual Report-draft

K. Kawano

Situation of progress with national programs

Since the status of national cassava breeding programs in Asia is highly heterogeneous, it may be useful to define five phases of our cooperation in order to understand the present situation and assess the future potential (Table 1).

CIAT has been highly instrumental in Phase I, "Identification of research needs and establishment of research program" and many present cassava research programs in Asia were established inspired by our effort. Vietnam (North), Myanmar (Burma), and Laos are at this phase now and we have established firm contacts with them.

CIAT has strong expertise in Phase II "Research capability building" of national research programs. Our training effort of national program personnel and the contribution of genetic materials have been particularly strong components of our cooperation. We have been most successful in this phase, and Thailand, Malaysia, Indonesia, the Philippines and the South China Academy of Tropical Crops in Hainan, China now have an adequate research capability. We are also working hand in hand with the cassava varietal improvement programs of South Vietnam, Guangxi and Guangdong, provinces of China to upgrade their research capacity. The great majority of breeding material handled by these programs are either CIAT crosses or crosses between CIAT clones and local cultivars.

Considering the significant selection gain we have demonstrated in CIAT-Palmira and Carimagua during the 1970s, we expected that "Identification of superior genotypes" (Phase III) for Asia was not particularly difficult. In every part of Asia, where cassava functions as a cash crop, farmers have selected cultivars well-adapted to local environmental and marketing requirements. Improving beyond these cultivars has not been as easy as originally assumed. Nonetheless, after several years of learning and hard work, we are selecting superior genotypes in many parts of Asia.

We will continue working hand-in-hand with national program breeders to select superior genotypes that will be the real breakthrough to the yielding ability of currently available cultivars. With Rayong hybrids playing an increasingly significant role, we are confident of the effectiveness of our genetic materials. Our cooperative breeding work in Rayong, Thailand, has an additional function of providing breeding materials to other Asian countries. At least in the next several years, Phase III will be the major area of concern to the CIAT cassava breeder in Asia.

The strength of national programs in Phase IV "Varietal release and extension" is highly variable. CIAT cannot help them in this phase as effectively as in the previous phases. However, our work in Phase II and III will certainly help national programs gain strength in this phase.

Phase V, "Socio-economic gain by new cultivars", should be the ultimate goal of our cooperative work. Only a small part of our cooperation as yet has reached this phase. Even if we are successful in phases I, II, III, and IV, things take a very long time to move in cassava. Cassava is traditionally a low-priority crop, planted by small farmers and the crop multiplication rate is 1/10 to 1/100 of that of grain crops. A demand-dominated situation is rare. Thus, the clear case of Phase V achievement has been limited mainly to large-scale cassava production schemes such as in Southern Sumatra. Now that new high-yielding or high-starch cultivars, adapted to semi-arid lowlands, have been released, export-oriented small-farmer production schemes, such as in Thailand, will soon take advantage. Varietal adoption does not occur quickly in small-farmer production for small-scale prosessing schemes; yet, our contribution to this scheme should be the most important objective in the long run. This type of production takes place mostly as a part of intensive agricultural systems. Thus, the quest for efficient land-use is considerable. As long as cassava is a cash crop, higher-yielding cultivars will be sought after. Selection and promotion of scale-neutral high-yielding cultivars fulfilling all the major requirements of small farmers continues to be the area of highest priority.

Rayong materials

We had the opportunity to compare cassava breeding materials from CIAT headquarters with those from Rayong on an equal basis in single-row, preliminary and advanced trials conducted in Rayong, Thailand and in Sumatra, Indonesia during the past three years. At Rayong, Rayong hybrids, mainly crosses between Rayong 1 or Rayong 1 hybrids and locally selected CIAT hybrids or clones, were superior to CIAT hybrids in virtually all the important traits, including germination, fresh yield, root dry matter content and plant type. This is understandable and suggests the importance of local selection of not only cultivars but also of cross parents.

The overwhelming superiority of Rayong hybrids was not quite the case in Sumatra selections, where CIAT hybrids were slightly better than Rayong hybrids in fresh yield while they were slightly lower in root dry matter content. Rayong hybrids were significantly better in plant type.

There is now enough evidence to indicate that the Rayong breeding materials are as good a source of genetic selection for wet lowland tropics as CIAT materials, and may well be superior materials for the semi-arid lowlands.

Convinced by these results, we shipped a total of 14,500 hybrid seeds, produced by our cooperative breeding project at Rayong Field Crop Research Center, to nine national cassava breeding programs in six countries in Asia.

Summary of present technical status

1. Selections from our early hybrids from CIAT headquarters (crosses

made from 1973 to 1979) did not offer superior clones immediately recommendable in Asia.

2. Selections from later hybrids from better-defined cross parents appear to offer superior clones in the wet lowland tropics such as Indonesia, Malaysia and the Philippines.

3. CIAT hybrids have not so far given really superior selections for semi-arid lowland tropics such as Thailand. Hybrids between local clones and locally selected CIAT clones appear to give good selection opportunity under this climatic condition.

4. Rayong hybrids thus made between Thai clones and locally selected CIAT clones by the Thai/CIAT cooperative program appear to be effective, both in the wet and semi-arid lowland tropics.

5. What selection possibility CIAT and Rayong hybrids offer to the sub-tropics, such as China and North Vietnam, is yet to be carefully assessed.

6. Harvest index is the most important selection trait. The key to success is how not to lose the vigorous growing habit of locally adapted cultivars when we try to improve harvest index.

In the past ten years, we have spent most of our energy defending the socio-economic relevance of our research direction. This is correct because without this, any research will be a dead end undertaking, whatever a technical marvel it may produce. yet, it is also true that without sound technological advance, the whole scheme will not reach anywhere even if the research direction is socio-economically justifiable. The small cassava varietal improvement section of the CIAT Cassava Asian Regional Program is going to devote its prime portion of activity to the technical side of the matter; that is to say, demonstrating what breeding can do to this crop cassava.

<u>Examples of successful selection</u>

<u>Thailand</u> The local cultivar Rayong 1 is, for any standard, the world most successful cassava cultivar. It is not only well adapted to the local

cultural conditions but also of high yielding capacity. It has not been easy to select clones which could outyield Rayong 1 in the early years of our cooperative breeding work in Rayong. Nevertheless, gradual progress has been made and new cultivars, Rayong 3 and Rayong 60, were released out of this work. The result of advanced yield trials this year reflects the progress we are making in recent years (Table 2). The best clones gave more than 25% higher dry yield than Rayong 1 in the average over three locations. Many high yielding clones showed higher root dry matter content than Rayong 1. Combination of high yielding ability with higher root dry matter content, good plant type and acceptable germinating ability under erratic rainfall scheme is the current target for recommeadable new cultivars.

Indonesia The cassava varietal improvement program of Brawijaya University, Malang, East Java, has new grown to a full-scale, comprehensive program capable of conducting nearly all steps of varietal evaluation, including multi-locational on-farm trials. In view of the fact that no cassava breeding activity existed as late as in 1984, this is a significant progress. The good leadership and active involvement of local personnel, including the former and present Deans of the Faculty of Agriculture, the training of key research personnel at CIAT, the establishment of their own field research station, constant supply of breeding materials from CIAT, CIAT/Thailand and the other CIAT/Indonesia cooperative program in Southern Sumatra (UJF), the CIAT breeder's constant presence at every important field operation especially, in early years, and financial support by IDRC and CIAT in expanding varietal trials to farmers' fields have been the factors for this successful establishment.

CIAT contribution of breeding materials started with the introduction of 3000 CIAT hybrid seeds from 60 crosces in 1985, followed by the introduction of 60 clones from our UJF selection. From 1987, hybrid seeds from CIAT/Thailand have been also introduced. All these materials have been evaluated in a series of selection trials. The most advanced materials were evaluated in five multi-locational on-farm trials in East

Java this year and the following results were obtained:

1). The best cultivar selected from locally available germplasm, Faroka, showed a highly corvincing yield performance, outyielding prevailing local cultivars in many locations.

2). Adira 4, a newly recommended cultivar for industrial use, selected mainly based on results in UJF, gave yields equal to or better than Faroka in many locations.

3). Locally selected CIAT clones i.e., CM3380-10 UJ/BU, CM3962-2UJ/BU and CM3997-8UJ/BU, gave yields superior to those of Faroka and Adira 4 across locations.

Our three way cooperation among Bogor Research Institute for Food Crops of the Central Research Institute of Food Crops under the Agency for Agricultural Research and Development, P.T. Umas Jaya Farm, and CIAT started with the comprehensive evaluation at UJF in 1982 of hybrid clones locally produced during the 1960s and 1970s and the introduction of 4600 CIAT hybrid seeds from 80 crosses in 1983. The cooperative program has grown into a highly operational varietal selection and multiplication scheme, out of which Adira 4 was selected from the locally produced hybrid population. Adira 4 was multiplied, named and released in 1986. Adira 4 proved to be a highly successful industrial cultivars and is now planted in more than 10,000 ha mainly in large plantations in Southern Sumatra. We are now trying to spread Adira 4 to be planted by small farmers in Sumatra, Java and other outer islands.

From the first CIAT seed introduction, two clones, i.e., CM4049-2 UJ and CM4031-10UJ, have been selected, which have been giving yields far superior to the local control, Kretek and equal to or superior to Adira 4. Besides, CM4049-2UJ has shown good drought tolerance and good adaptation to the drier conditions of East Java. One liability of these clones is their slightly yellow color of root flesh (parenchyma), which may cause some additional difficulty in starch processing. Selection from the population of more recent introductions seems to be producing the combination of high yielding ability with acceptable root color and good plant type (Table 4).

It is noteworthy that many of the latest promising selections come from the crosses with Brasilian clones.

Malaysia. Our cooperation with Malaysia Agricultural Research and Development Institute (MARDI) started with the training at CIAT of key research personnel and the subsequent introduction of breeding materials during the second half of the 1970s. The comparatively modest, in proportion to the relatively low importance of cassava presently in this country, cassava program of MARDI has been highly functional, thanks to competent staff and comparatively adequate support from MARDI. From one of the earlier CIAT seed introductions, CM987-7 was selected and released in 1988. While there is no doubt about the superior yielding capacity of CM982-7 over the successful local industrial cultivar, Black Twigg or C5, CM982-7 is less impressive in vegetative growth and much lower in root starch content than these cultivars.

The fifth hybrid seed introduction in 1982, which mainly came from crossess between well selected hybrid cross parents such as CM849-1 or CM1362-6, has shown great promise in the preliminary and advanced yield trials. In one harvest of a regional trial for selected clones from this introduction conducted on peat soil this year, the best yielder CM3906-31, of good plant type and moderately high root starch content, yielded 14.3 t/ha in root dry matter in six months, outyielding the local check by 100% (Table 5). The results of the same trial planted in other locations at different time were not as striking; yet, they showed a similar promising results. These are encouraging enough to suggest the possibilities of:

1). Selecting new clones with far superior yielding ability than successful local industrial cultivars,

2). Combining high yielding ability with good plant type and high root starch content,

3). High absolute production in terms of calorie/area/time on problematic soils.

Table 1. Five phases of CIAT cooperation with Asian national research institutions in cassava varietal improvement.

		National program	Area
I.	Identification of research need and establishment of research program	N. Vietnam Laos Myanmar (Burma)	
II.	Research capability building a. Training of research personnel b. Germplasm collection, introduction and evaluation c. Creation of new genotypes d. Varietal selection scheme	China S. Vietnam Sri Lanka	
III.	Identification of superior genotypes	Indonesia Malaysia Philippines	
IV.	Varietal release and extension	Thailand (India)*	
V.	Socio-economic gain by new cultivars		Sumatra Mindanao Guangdong Eastern Thailand (Tamil Nadu)*

* Progress in India is presently nearly independent of our direct cooperation.

Table 2. Result of advanced yield trials in Thailand (Conducted at Rayong, Banmai Samrong and Khon Kaen in 1988/89)

Clone	Parents	Dry Root Yield (t/ha)				Root Dry Matter Content (%)			
		Rayong	Banmai	Khon Kaen	X	Rayong	Banmai	Khon Kaen	X
CMR 25-105-112	27-77-10 x Rayong 3	13.9	15.7	9.2	12.9	38.8	41.5	35.2	38.5
CMR 28-05-13	67-77-7 x 21-1	12.6	12.0	10.3	11.6	39.1	40.6	36.1	38.6
CMR 27-27-3	V1 x Rayong 1	12.0	13.8	8.8	11.5	35.9	40.4	32.5	36.3
CMR 28-76-29	M Col 22 x Rayong 1	12.1	14.2	8.1	11.5	33.8	35.5	31.8	33.7
CMR 28-67-76	Kaset x 21-1	12.3	12.8	8.5	11.2	37.7	39.3	34.9	37.3
CMR 25-33-105	Rayong 3 x Rayong 1	12.2	11.6	9.2	11.0	38.5	40.0	33.6	37.4
CM 4054-40	CM 1015-34 x CM 849-1	9.7	15.2	7.3	10.7	35.7	40.4	34.0	36.7
CMR 28-15-4	21-1 x 27-77-10	10.1	12.3	9.5	10.6	39.1	41.0	37.6	39.2
OMR 27-20-149	CMR 24-06-1	12.6	11.8	6.3	10.2	37.9	36.9	31.1	35.3
CG 1354-41	CM 922-2 x M Mal 2	10.8	9.6	9.6	10.0	38.3	37.4	33.7	36.5
Rayong 1		10.0	11.1	9.2	10.1	34.7	37.8	32.6	35.0
Rayong 60	M Col 1684 x Rayong 1	11.4	13.5	7.7	10.9	37.1	38.7	32.0	35.9

Table 3. Result of on-farm trials in East Java, Indonesia (Conducted at five locations in 1988/89)

Clone	Parents	Dry Root Yield (t/ha)					
		Madura	Tarokan	Kandat	Kalipare	Jotikerto	X
CM 3997-8 UJ/BU	CM 681-2 x CM 849-1	9.7	11.4	14.8	13.0		12.2
CM 3962-2UJ/BU	M Col 22 x CM 849-1	11.7	11.8		11.5	13.4	12.1
CM 3380-10UJ/BU	CM 586-1 x CM 523-7	8.1	11.0		12.7	14.8	11.7
Adira 4		7.6	11.5	12.5	11.3	12.1	11.0
Faroka		7.0	9.5	12.6	11.9	11.9	10.6
Local		4.9	10.1	10.4	7.2		8.2

Table 4. Result of advanced yield trial at Umas Jaya Farm, Lampung, Indonesia, 1988/89.

Clone	Parents	Dry yield (t/ha)	Fresh yield (t/ha)	Total plt.wt. (t/ha)	RDMC (%)	HI	Plt type	Root fr. color
CM 4031-10UJ	CM 922-2 x CM 507-37	15.8	40.4	71.7	39.0	.56	4	Y
SM 566-15UJ	M Bra 35	15.4	44.6	70.0	34.5	.64	5	W
SM 564-5UJ	M Bra 5	15.1	40.1	67.1	37.7	.60	5	Y
SM 564-9UJ	M Bra 5	14.9	40.8	67.0	36.6	.61	3	W
SM 554-3UJ	CM 681-2	14.2	40.3	63.5	35.3	.63	3	W
SM 564-15UJ	M Bra 5	14.2	38.6	67.0	36.8	.58	5	W
SM 566-8UJ	M Bra 35	13.8	38.5	56.3	35.9	.68	5	W
CM 4049-2UJ	CM 1013-19 x CM 849-1	13.5	36.1	62.0	37.3	.58	5	Y
Adira 4		13.4	36.3	71.5	37.0	.51	4	W
Kretek (Local control)		10.6	32.2	69.8	33.0	.46	5	W
SM 582-2UJ	CM 2087-101	10.4	34.1	60.5	30.4	.56	3	W

RDMC: Root dry matter content
HI: Harvest index
Plt type: Plant type, 1, poor ... 5, excellent
Root fresh color: Y, yellow; W, white

Table 5. Result of advanced yield trial for early harvest (6 months at Pontien Peat Soil Station, Malaysia, 1988/89.

Clone	Parents	Dry root yield (t/ha)	Fresh root yield (t/ha)	Root dry matter content(%)	Harvest index	Total plant wt.(t/ha)	Plant type
CM 3906-31	CM1362-6 x CM 586-1	14.3	41.8	34.2	.67	62.3	5
CM 3380-10	CM 586-1 x CM 523-7	11.8	32.5	36.3	.63	52.2	4
CM 3299-26	CM 849-1 x M Col 22	11.4	30.8	36.9	.60	51.3	5
CM 3906-13	CM 1362-6 x CM 586-1	11.0	31.1	35.4	.56	56.3	4
CM 3898-6	CM 1320-1 x CM 586-1	11.0	31.9	34.5	.53	60.4	3
CM 3855-37	CM 1278-3 x CM 523-7	10.2	28.7	35.7	.58	50.5	3
CM 3371-22	CM 517-1 x CM 728-2	9.5	26.7	35.4	.55	51.5	5
CM 3707-31	CM 1090-59 x M Col 22	9.4	27.2	34.4	.53	53.0	4
CM 3388-15	CM 621-167 x M Col 22	8.9	25.6	34.7	.53	48.7	2
CM 2527-7	CM 1297-9 x M Ven 77	8.1	23.7	34.2	.44	56.4	5
CM 2975-21	CM 1252-12 x CM 523-7	8.1	24.4	33.4	.45	54.3	2
CM 982-7	CM 321-170 x M Col 1684	7.3	23.2	31.6	.63	36.9	3
CM 3303-21	CM 1124-1 x CM 849-1	7.2	21.9	32.8	.54	41.5	3
C 5 (local control)		6.7	20.0	33.5	.35	57.1	5

Annual Report - Cassava Agronomy in Asia, 1989

R. Howeler

Many collaborative agronomy trials initiated in 1988 were harvested in 1989. Detailed reports of these trials will be presented by the researchers of national institutions during the next Regional Workshop planned for October 1990. In the 1988 CIAT Annual Report for the Cassava Program the general conditions of cassava cultivation were described for each country as well as the reason for conducting specific trials in specific countries. Therefore, this report will describe briefly only the most salient results of these trials:

Thailand

In collaboration with researchers from Kasetsart University and the Department of Agriculture of Thailand, several erosion control trials were established in three locations during the past two years. Different treatments of cultural practices were established in plots of 15 m long and 10 m wide on a slope of 5-10%. Below each plot a plastic covered channel was installed to collect the eroded sediments. These sediments were weighed at monthly intervals and samples were taken for determination of moisture content and for chemical analyses. Table 1 shows the results of the first year trial in the Kasetsart University Research Station in Sri Racha. Highest yields were obtained in treatments of contour ridging and of subsoiling. These treatments also produced the lowest levels of erosion. The no-tillage treatment produced very good yields, but surprisingly, also very severe erosion. This was due to the removal of all crop residues and weeds, which left the topsoil completely exposed to the impact of rain drops. Moreover, in the absence of a rough soil surface created by land preparation, the topsoil sealed with the first heavy rains, resulting in excessive amounts of run-off and erosion. Lack of fertilizer application, the common practice among Thai cassava farmers, resulted in severe erosion because of inadequate canopy closure; it also resulted in the lowest yields.

Figure 1 shows the effect of some selected treatments on erosion during the second year. Soil losses by erosion were greatly reduced compared with the previous year. Erosion occured mainly during the first two months of establishment as well as during the heavy rains of Sept-Oct. Lack of fertilizer application again resulted in the highest level of erosion and low yields. Unlike in the previous year, no-tillage markedly reduced run-off and erosion, resulting from a better management in which crop residues and weeds were left as a mulch on the soil surface. Subsoiling and contour ridging were again very effective in controlling erosion, but for some reason, subsoiling caused this year a significant reduction in yield. In a nearby farmer's field a similar trial produced again the highest erosion and lowest yield in plots without fertilization, while high yields and low levels of erosion were observed with contour ridging and with no-tillage.

In the Research Station at Pluak Daeng in Rayong Province (Table 2) low levels of erosion and relatively high yields were obtained with contour ridging, and with closer plant spacing at 0.8x0.8 m. Intercropping was effective in reducing erosion, but it also reduced cassava yields. Peanut was the most promising intercrop. Lack of fertilization again resulted in highest soil losses and a very low yield.

Two trials on method of planting were conducted in Rayong Center, one at the beginning of the wet season and one at the beginning of the dry season of 1987. Figure 2 shows that ridging increased yields slightly in both seasons, but was more effective in the wet season. Stake position during planting, i.e. vertical, inclined or horizontal, had no significant effect on yield in the wet season planting, but during the dry season vertical or inclined positions were significantly better than horizontal planting. Stake length or planting depth had no significant effect on yield. During the second year (1988/89, data not shown), the vertical or inclined planting positions were significantly better than the horizontal position, in both the wet and dry season plantings. During the wet season shallow (5 cm deep) planting of horizontal stakes was better than deep planting (10 or 15 cm deep), but for the dry season planting it was exactly the opposite. During the dry season, planting on the flat was significantly better than on the ridge, since the soil in the ridge tended to dry out faster. Thus, for the rather light textured soils of Rayong the vertical or inclined planting position is definitely superior to the horizontal position, especially in the dry season.

In a green manure trial in Pluak Daeng, ten legume species were grown for 3 months, after which they were cut and incorporated into the soil before planting cassava. Table 3 shows that almost all green manures significantly increased cassava yield over the check without green manure. Incorporation of Sesbania rostrata and Crotalaria juncea was equally effective as the application of fertilizers (100 kg N and 50 kg K_2O/ha). However, cassava yields were extremely low, because, due to green manuring, planting of cassava had to be delayed for 4 months until the end of the wet season, while the crop was harvested at the start of the following wet season. Thus, cassava was grown during only 3 wet months and 6 dry months, which resulted in low yields. If the crop had been planted at the beginning of the wet season, as most farmers do, it would probably have produced about 15 t/ha without fertilizers and 20-25 t/ha with fertilizers. Thus, green manuring may not be a viable option in areas with only one relatively short wet season.

One alternative to this dilemna is to grow the legumes as a cover or intercrop between cassava rows. Cassava was grown in rows spaced 1.80 m with 55 cm between plants in the row. Nine pasture legume species were grown in double rows between the cassava rows, with the objective to control weeds, reduce erosion and improve soil fertility. However, Table 4 shows that all species competed to a greater or lesser extent with cassava, causing a reduction in cassava yield. Stylosanthes hamata and Arachis pintoy were low growing and therefore the least competitive. Centrosema and Macroptilium climbed into the cassava, resulting in severe competition, while Desmodium ovalifolium, Stylosanthes guianensis and Indigo grew tall, causing also severe competition. It is clear that the legumes have to be cut regularly to reduce competition, but this would also increase costs. Cassava yields will have to be increased substantially by this practice to make it an attractive alternative.

Indonesia

In collaboration with the Bogor Institute of Food Crops, two trials were planted in Tamanbogo, Lampung, of southern Sumatra, and two similar trials in Playen, near Yokyakarta, Central Java.

A fertilization trial was planted in Tamanbogo on rather acid, highly infertile Ultisols. Four levels of fertilizers were applied to three cropping systems, as shown in Figure 3. Yields of maize, rice, and cowpea were significantly increased by application of increasing levels of fertilizers, while cassava and peanut were less responsive. Figure 3 shows the response of each system in terms of total income obtained. The cassava + maize + rice followed by peanut and cowpea was economically the most attractive system, which also responded positively to the highest level of fertilization. Comparing the total income with that of the cost of (subsidised) fertilizers, it is clear that fertilization up to the 3rd or 4th level was economically attractive to the farmer.

Figure 4 shows the effect of various crops and intercropping systems on soil erosion, measured in a similar fashion as described above. Erosion was severe, but only during the first three months of establishment, which also corresponded to the months of highest rainfall. Erosion was extremely serious when cassava was grown in monoculture with wide interrow spacing, either in single row at 200x50 cm or in double rows at 273x60x60 cm. These planting arrangements should never be used in monoculture when cassava is grown on slopes. When cassava was grown in a normal square planting system of 1x1 m, it caused less erosion than peanuts; erosion was similar to that caused by rice and more than that caused by maize, all grown in monoculture. All intercropping systems, planted with wide single-row (2.0x0.5 m) cassava, reduced erosion compared with the same arrangement of monoculture cassava; when cassava was planted at 1x1 m square arrangement soil losses in intercropping systems were similar to that of cassava in monoculture, except the intercropping of cassava with peanut followed by mungbean and cowpea, which caused a much higher level of erosion. It is surprising that intercropping or monocropping of peanut in Indonesia caused severe erosion, while in Thailand intercropping with peanut was found to reduce erosion. This may be due to the very high rainfall encountered in the early stages of establishment in Indonesia.

In Playen, Yokyakarta, a cassava spacing/population trial was planted on a heavy Alfisol, developed on limestone. Cassava was intercropped within the row with maize, and between the rows with rice or peanut, both followed by soybean. Cassava root yields were extremely low at the wide interrow space of 4 m (5000 plants/ha) and tended to increase with closer interrow spacings. Highest cassava yields were obtained with a population of 10,000 plants/ha (Figure 5). At that population the cassava yield was higher in the square (1x1 m) planting arrangement than in the rectangular arrangement (2.0x0.5 m). Since maize was planted within cassava rows, its yield also increased with increasing cassava population. Rice, peanut and soybean yields, however, decreased slightly at narrower cassava row spacing (data not shown). The highest net income was obtained with cassava planted in the square (1x1 m) arrangement.

A level-of-fertilization trial in various cropping systems was conducted in a nearby farmer's field with treatments similar to those in Tamanbogo described above. Cassava, maize and rice responded markedly to fertilization, while the second intercrop of soybean did not respond. Total net income was highest at the second (75N-67.5P_2O_5-90K_2O/ha) or third (210N-150P_2O_5-195K_2O/ha) level of fertilization.

In collaboration with Brawijaya University in Malang, E-Java two trials were conducted, one on erosion control and one on method of fertilization, both using a cassava-maize-intercropping system. Table 5 shows that soil losses due to erosion were extremely high, especially when cassava was planted on the flat. Contour ridging reduced erosion to about 70%, while planting elephant or setaria grass on every sixth ridge further decreased erosion. It is clear that run-off and erosion losses are quite high, even on a gentle slope of about 10%, mainly because of the high intensity of the rainstorms in this area. Cassava root yields were not significantly effected by treatments.

The method of fertilization trial produced excellent yields of maize (up to 4.8 t/ha) but relatively low yields of cassava (12-16 t/ha). The time and method of fertilization treatment effects were only significant in terms of maize yields, which were highest when all fertilizer was applied at planting and on the surface of the soil. The results were not very consistent and will have to be corroborated.

China

In collaboration with the South China Academy of Tropical Crops an erosion control trial was planted in Xhi Fang village of central Hainan Island. Cassava was planted on about 8% slope on a relatively fertile clay loam, classified as Ultisol. Plots were 8x10 m and soil loss due to erosion was determined as described above. Figure 6 shows that erosion was extremely severe during the first 3-4 months of establishment, even on a gentle slope. This is probably due to the very high intensity rainfall, combined with low spring-time temperature, which resulted in slow sprouting and canopy closure. The horizontal planting system used in China may also contribute to this. Similar to what was observed in Thailand, erosion was most severe when cassava was grown on the flat or on up-and-down ridges. Contour ridging, on the other hand, reduced erosion to about one third. Live barriers of Brachiaria decumbense reduced erosion to about two-thirds. Unlike almost all other erosion-control experiments, in this trial fertilizer application increased erosion compared with the non-fertilized treatment. Table 6 indicates that fertilizer application had no significant effect on yield, while the soil loosening during the split application may actually have contributed to erosion.

Table 7 shows the effect of intercropping cassava with pasture species such as *Brachiaria decumbens*, *Stylosanthes guianenses* (CIAT 184) or *Arachis pintoi*. Both in monoculture and when intercropped, cassava yields were considerably higher when planted in a normal square planting system than in the double row system. Because of the erect, non-branching habit of most Asian cassava varieties, the square planting system at relatively high populations tends to give higher yields than the rectangular or double row arrangements. However, intercropping with these pasture species reduced slightly cassava yields in the square planting but not in the double row system.

In collaboration with the Guangxi Subtropical Crops Research Institute in Nanning, Guangxi, two trials were planted on a relatively fertile clay loam Ultisol. A long-term NPK trial showed no significant response to N and P and only a slight response to K in one of the two varieties. A trial on method of stake storage during the cold winter months also showed no significant differences among treatments.

During 1989 most of these trials were repeated, while additional trials were established in Malaysia, Philippines, Sri Lanka and Vietnam.

Table 1: Effect of soil and crop management on cassava yield and soil losses due to erosion in Sri Racha, Thailand. 1987/88

Soil and crop management	Cassava yield	Dry soil loss
A. Soil preparation practices	t/ha	
1. no tillage	30.7	93.8
2. strip preparation, alternating prepared and unprepared strips	26.7	42.1
3. one plowing with 4-disc plow	22.3	37.5
4. two plowings followed by two discings	25.8	30.5
5. two plowings and discing followed by up-and-down ridging	25.6	35.4
6. two plowings and discing followed by contour ridging	35.5	11.1
7. subsoiling only	34.3	22.2
B. Intercropping and live barriers		
1. no intercropping or live barriers	25.8	30.5
2. intercropping double-row cassava with maize	22.5	44.9
3. intercropping double-row cassava with peanut	22.8	17.2
4. live barrier of *Brachiaria humidicula* grass	22.6	52.7
5. live barrier of elephant grass	23.3	36.5
C. Crop management practices		
1. with fertilization, low population, hand weeding	25.8	30.5
2. without fertilization	18.8	54.9
3. higher plant population	25.4	24.4
4. chemical weed control	30.9	25.7

Table 2: Effect of land preparation methods and crop management on cassava yield and soil loss due to erosion in Pluak Daeng, Thailand, 1988/89.

Treatments	Fresh root yield t/ha	Dry soil loss t/ha
I. Land Preparation		
3-disc plow	26.6	55.1
3-disc plow + 7 disc harrow	29.9	34.9
twice 7-disc harrow - no ridge	21.2	47.9
twice 7-disc harrow + contour ridge	27.1	25.7
twice 7-disc harrow + up-down ridge	32.9	60.4
cassava harvester	19.3	46.5
II. Intercropping		
no intercrop	21.2	47.9
peanut intercrop	20.9	28.6
mungbean intercrop	12.5	23.8
soybean intercrop	18.0	24.7
cowpea intercrop	16.5	34.6
III. Fertilization		
with fertilizers	21.2	47.9
without fertilizers	18.1	69.8
IV. Cassava Spacing		
1.0 x 1.0	21.2	47.9
0.80 x 0.80	27.7	26.1

Table 3:
Effect of incorporation of green manure on cassava yield in Pluak Daeng Thailand, 1988/89

	Cassava root yield t/ha
No green manure, no fertilizer	3.21
Sesbania rostrata, no fertilizer	9.29
Crotalaria juncea, no fertilizer	9.04
Crotalaria mucronata, no fertilizer	6.71
Crotalaria spectabilis, no fertilizer	5.81
Sesbania speciosa, no fertilizer	5.61
Canavalia ensiformis, no fertilizer	5.37
Indigo, no fertilizer	5.37
Mucuna fospeada, no fertilizer	5.21
Sesbania aculeata, no fertilizer	5.19
Cajanus cajan, no fertilizer	2.06
No green manure, with fertilizers*	8.75

* 100 N, oP, 50 kg K_2O/ha

Table 4:
Effect of intercropping cassava* with leguminous covercrops or cassava yield in Pluak Daeng, Thailand, 1988/89.

	Cassava yield t/ha
No covercrop	11.68
Covercrop of Stylosanthes hamata	10.27
Covercrop of Arachis pintoy	8.46
Covercrop of Centrosema acutifolium	7.66
Covercrop of Centrosema pubescence	7.51
Covercrop of Mimosa envisa	7.49
Covercrop of Desmodium ovalifolium	7.26
Covercrop of Macroptillium atropurpureum	6.61
Covercrop of Stylosanthes guianensis	3.21
Covercrop of Indigo	3.05

* cassava received 25 kg N-25P_2O-25K_2O/ha

Table 5: Effect of various cultural practices on erosion as well as on yield of cassava grown on 10% slope in Jatikerto experiment station in Malang, Indonesia in 1987/88.

Treatment	soil loss (t/ha)	root yield (t/ha)
contour ridges	98.0	20.6
contour ridges ; elephant grass	69.1	25.2
contour ridges ; setaria grass	79.2	21.4
contour ridges ; peanut	93.5	20.4
contour ridges ; Gliricidia sepium	91.1	20.5
contour ridges ; Leucaena leucocephala	85.5	24.2
flat ; peanut	126.8	22.8
flat ; setaria grass	114.6	23.6
fallow plot	224.5	

Table 6:
Effect of several cultural practices on cassava root yield and soil losses due to erosion in Xhi Fang, Hainan, China.

	Root yield t/ha	Dry soil loss t/ha
1. no ridging, no fertilizers	26.4	164
2. no ridging, with fertilizers	30.4	208
3. contour ridging, with fertilizers	31.4	67
4. up-down ridging, with fertilizers	25.9	210
5. no ridging, with fertilizers, _Brachiaria_ barriers	22.6	139

Table 7: Effect of intercropping cassava with pasture grasses and legumes on cassava[1/] root yield in Xhi Fang, Hainan, China.

	Root yield t/ha
1. 4 rows cassava alternated with 2 rows _Brachiaria decumbens_	19.7
2. 4 rows cassava alternated with 2 rows _Stylosanthes guianensis_	19.3
3. 4 rows cassava alternated with 1 rows _Brach_, and 1 row _Styl._	18.1
4. 4 rows cassava alternated with 2 rows _Arachis pintoi_	17.5
5. cassava monoculture in square planting	21.1
6. double row cassava alternated with 2 rows of _Brachiaria_	15.0
7. double row cassava alternated with 2 rows of _Stylosanthes_	17.0
8. double row cassava alternated with 1 rows of _Brach._ and 1 row _Styl._	14.5
9. double row cassava alternated with 2 rows _Arachis pintoi_	15.3
10.cassava monoculture in double row planting	14.2

1/ cassava population maintained at 10,000 plants/ha.

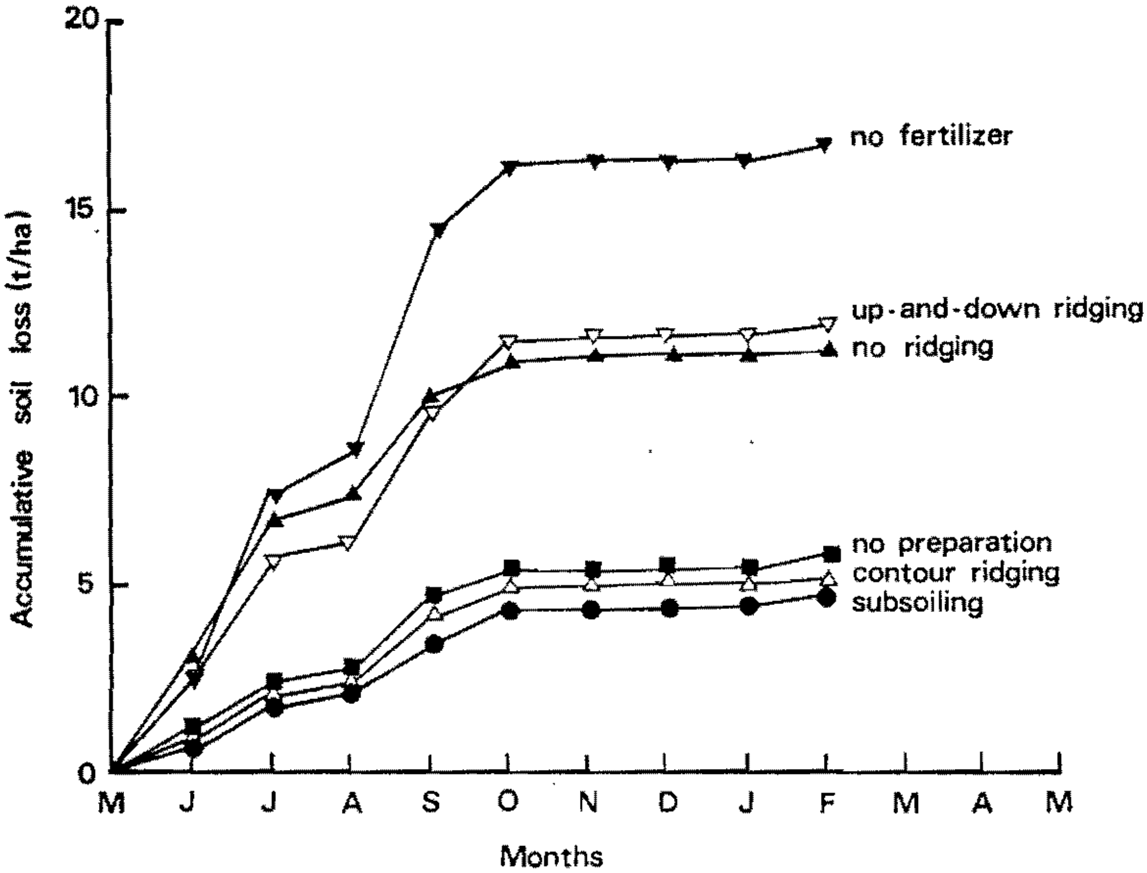

Figure 1: Effect of various agronomic practices on accumulative dry soil loss due to erosion in cassava grown on 8% slope in Sri Racha Research Station, Thailand. 1988/89

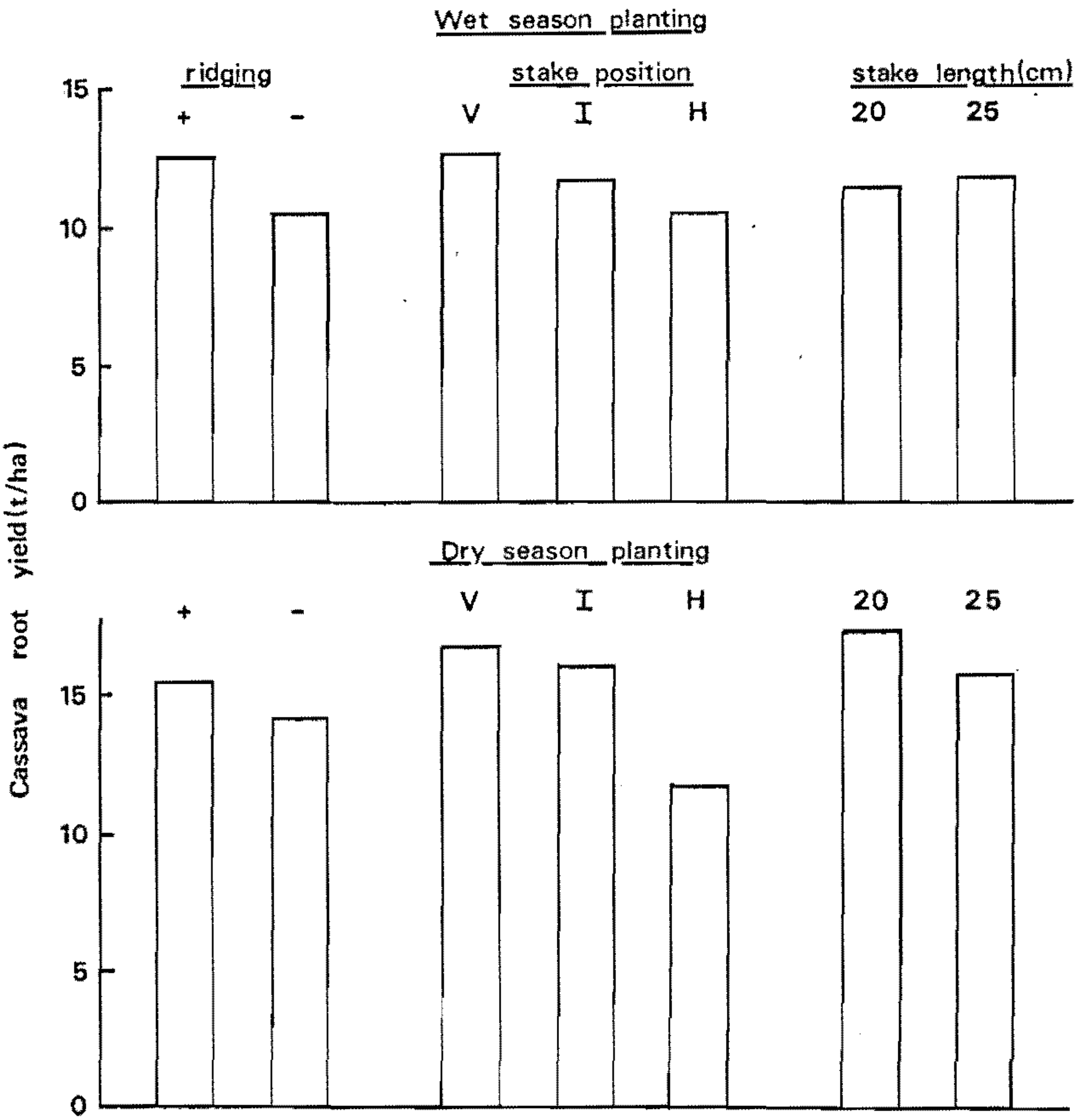

Figure 2: Effect of ridging, stake planting position and stake length on cassava root yield during wet and dry season plantings in Rayong Research Center, Thailand. 1987/88. V = vertical, I = inclined and H = horizontal.

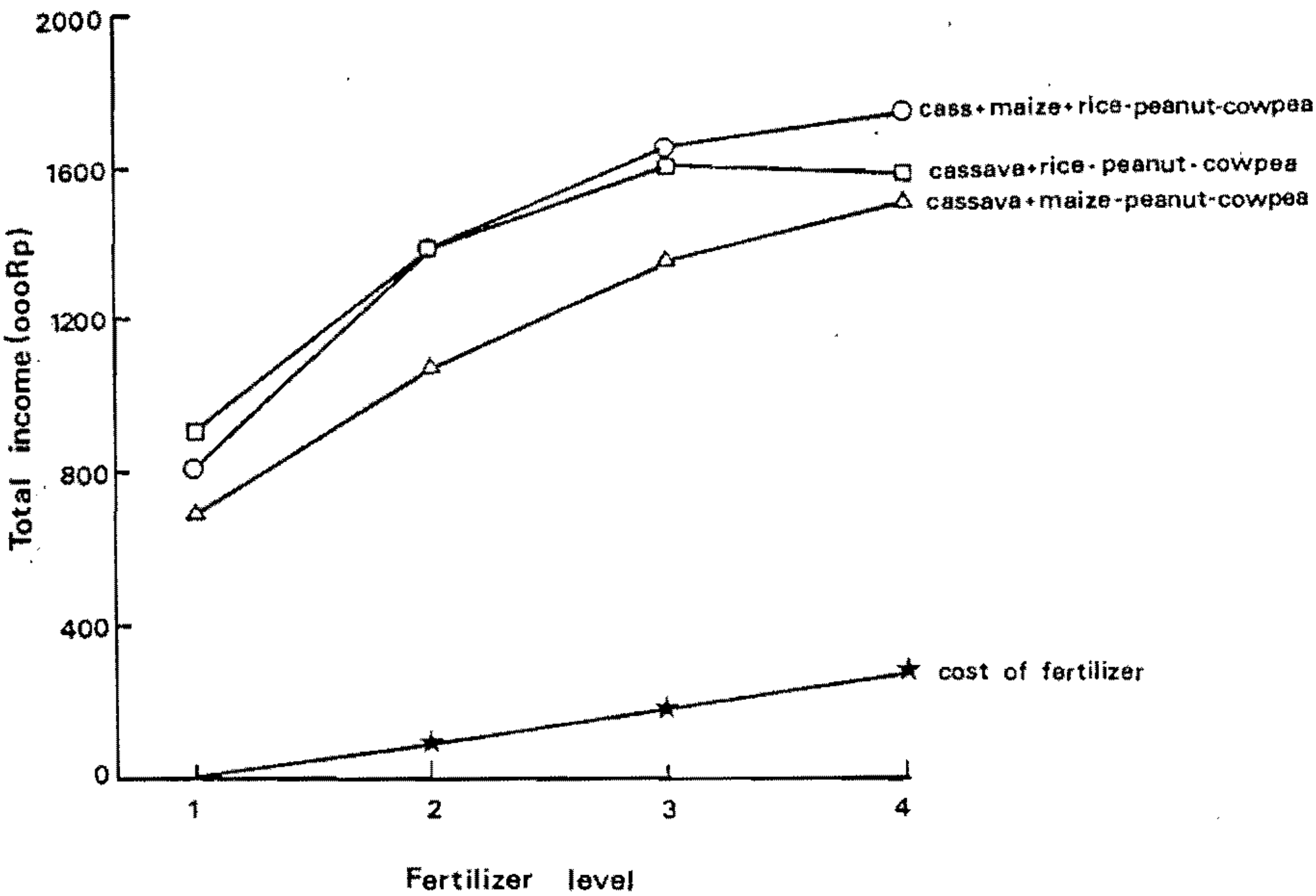

Figure 3. Effect of four levels of fertilization on total gross income in three cropping systems in Tamanbogo, Lampung, Indonesia in 1987/88.

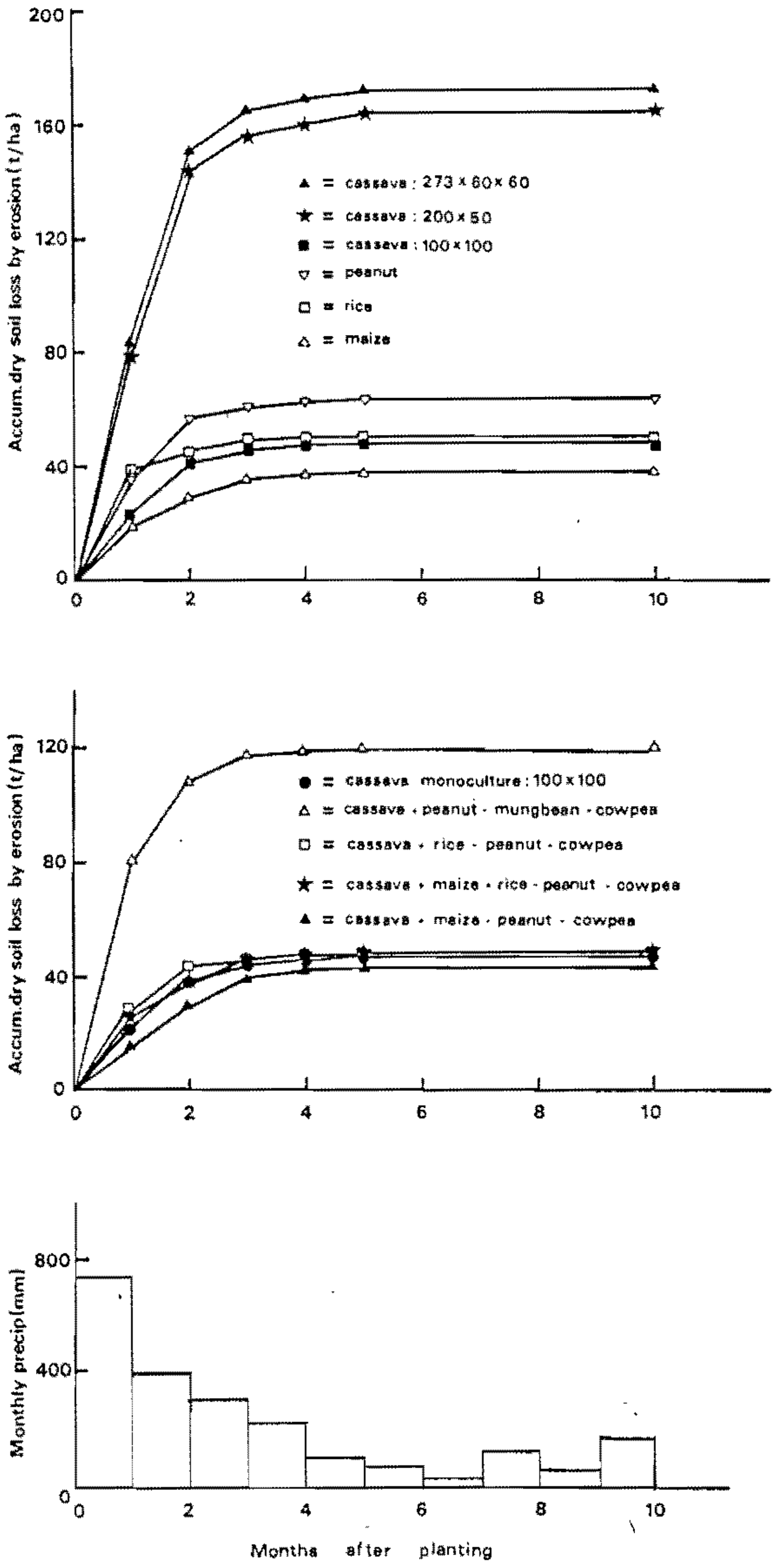

Figure 4: Effect of various mono and intercropping systems on dry soil losses due to erosion during a 10 month growth cycle in Tamanbogo, Lampung, Indonesia in 1987/88.

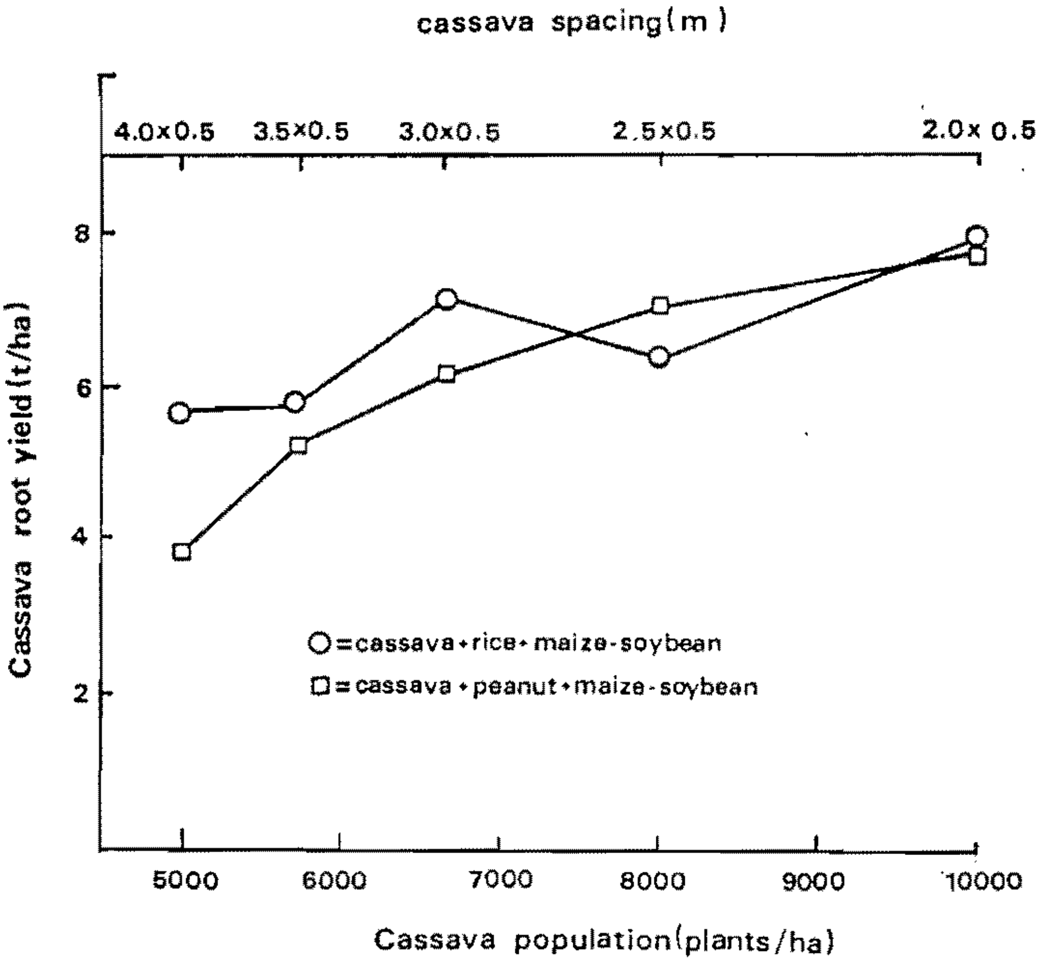

Figure 5: Effect of plant population and spacing on cassava root yield in two cropping systems in Playen, Yokyakarta, Indonesia in 1987/88.

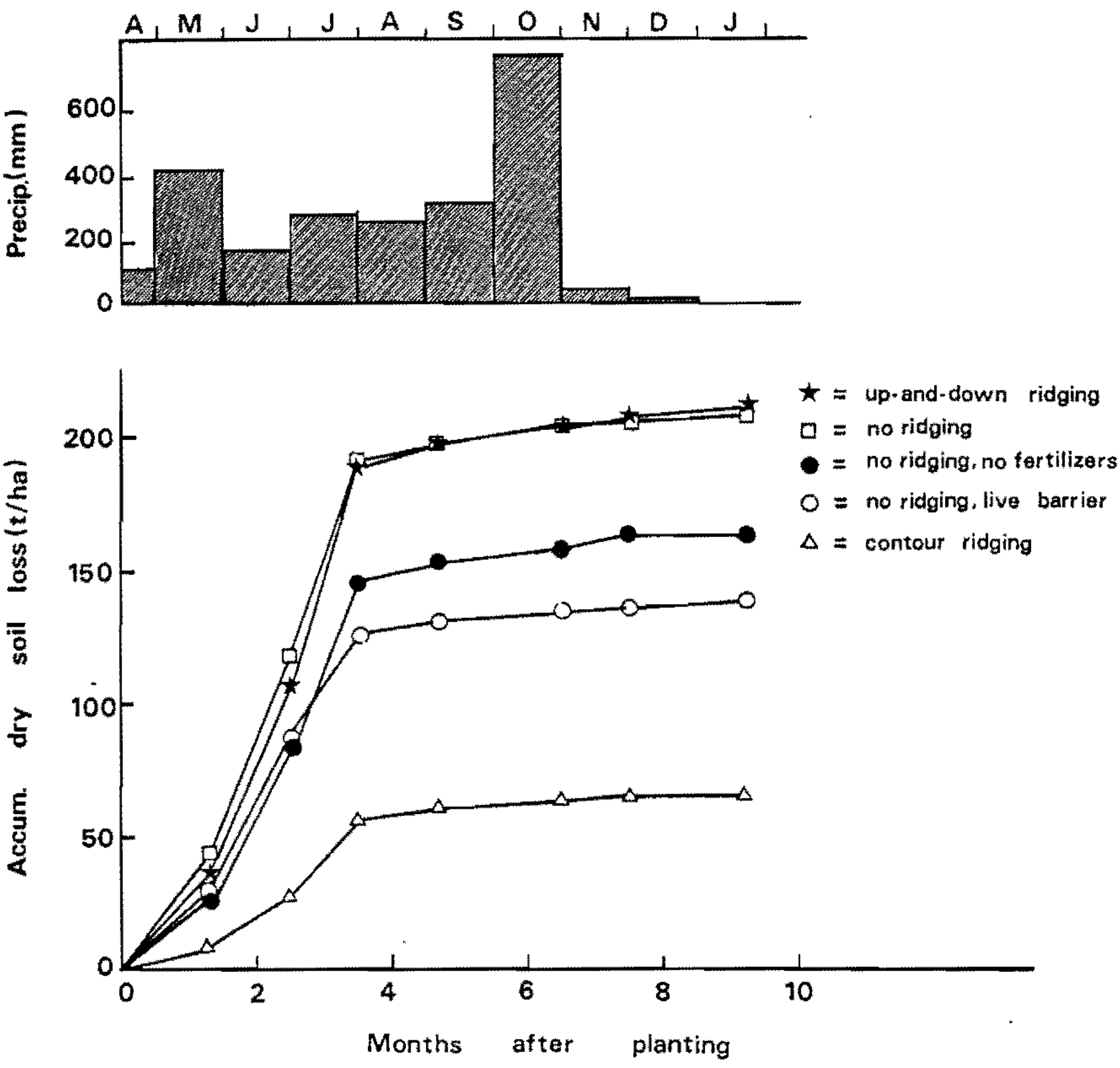

Figure 6: Effect of various agronomic practices on accumulative dry soil loss in cassava grown on 8% slope in Xhi Fang, Hainan, China. 1988/89

Relationship between root yield and photosynthesis.

Preliminary screening for biomass, root yield and single leaf photosynthesis was conducted with large number of cassava clones (127 clones) grown in the field in the Patia Valley, Cauca, Colombia, in 1986-1987 (CIAT Annual Reports 1987, 1989). The crop received only 700 mm of rain, 60% of which fell during the first three months of establishment (October to December) and the rest in April-June with dry periods in mid and final stages of growth. Leaf gas exchange (CO_2 uptake and H_2O loss) was monitored several times at 4 to 6 months after planting and the crop was harvested at 11 months after planting. When light interception was not limiting, i.e. at high level of leaf area index, there were significant correlations among leaf photosynthesis, total biomass and root yield. The same trends were observed for correlations among mesophyll conductance, total biomass and root yield. There were no significant correlations between these traits and stomatal conductance (CIAT Annual Reports 1987 and 1988). This information suggests that when light interception is not limiting selection for high leaf photosynthesis is likely to lead to higher yield.

A second year trial in 1988-1989 growing season was conducted with 16 cassava clones selected from the original group on the basis of their yield. The trial was conducted in La Fonda, Patia Valley, Dept. of Cauca on a private farm with four replications for each cultivar. Half of the experimental area was fertilized at planting (13 April, 1988) with 50, 100, 100 kg ha^{-1} N, P and K, respectively. The second half was left unfertilized. From planting to the final harvest (308 days), the cassava crop received about 950 mm of rain with 560 mm in October and November, 1988. Measurements of single leaf gas exchange (CO_2 uptake and H_2O loss) were made only once with a LCA-2 portable infrared gas analyzer on 29 August to 7 September 1988. Across all blocks and fertilizer treatments, 35 fully expanded upper canopy leaves were measured per cultivar. All measurements were made from 0800 to 1300 h with a solar irradiance of 1500 to 2000 μ mol m^{-2} s^{-1}.

Table 1 presents data of dry root yield and leaf gas exchange of the 16 cultivars selected on the basis of their yield performance from the preliminary screening trial. Due to the lack of significant differences between the fertilized and unfertilized plots with respect to yield and leaf gas exchange, the data were pooled. The mean dry root yield ranged among cultivars from 15 to 27.4 t ha^{-1}, whereas the mean leaf photosynthesis ranged from 14.7 to 18.4 μ mol CO_2 m^{-2} s^{-1}. The mesophyll conductance ranged from 65 to 81 mmol m^{-2} s^{-1}, whereas the leaf conductance ranged from 720 to 990 mmol m^{-2} s^{-1}. The average internal CO_2 ranged from 247 to 257 μ LL^{-1} among cultivars. There were significant differences among cultivars with respect to yield and leaf gas exchange characteristics (Table 1).

Despite differences in climate between the two seasons, the photosynthetic rates measured in the first growing season (1986-1987) were significantly correlated with the dry root yield of the second season (1988-1989) ($r = 0.65$, $P < 0.01$) (Fig. 1). Furthermore, average leaf photosynthesis as measured only once in 1988-1989 season was significantly correlated with the rates measured over a longer period of time in 1986-1987 season (Fig. 2). The dry root yield and the average leaf photosynthesis of the 1988-1989 crop were significantly correlated ($r = 0.53$, $P < 0.05$) (Fig. 3). The same pattern of correlation was observed between dry root yield and the mesophyll conductance ($r = 0.57$, $P < 0.05$) (Fig. 4). The leaf conductance was not significantly correlated with dry root yield. This indicates that differences in leaf photosynthesis among cultivars were due, mainly, to differences in non-stomatal factors. This conclusion is further supported by the significant and negative correlation ($r = -0.57$, $P < 0.05$) between dry root yield and intercellular CO_2 (Fig. 5). Moreover, single leaf instantaneous water use efficiency (CO_2 uptake/H_2O loss) was also significantly correlated with dry root yield ($r = 0.52$, $P < 0.05$).

In view of the recent biochemical evidence that large variation in the activity of the key C_4 enzyme PEP-carboxylase exists among cassava clones (CIAT Annual Report, 1987 and Table 2), differences in leaf photosynthesis could be partially explained by differences in PEP carboxylase activity. It is also possible that differences in leaf photosynthesis that resulted in differences in yield were due to variation in leaf anatomy. From these data it can be concluded that under field conditions where stress occurs, a positive and significant correlation exists between the photosynthetic rate of individual leaves as measured in the field and root yield of cassava. The relation is associated with variation in the biochemical or anatomical features of the leaves and not the stomatal conductance, indicating that there may be genotypic variation in anatomy and biochemistry that can be exploited by breeders to obtain higher yields. It should be noted that this approach will only be successful if selection for high photosynthetic capacity is combined with other yield determinants such as optimum light interception (i.e. optimum leaf area index) and strong sink capacity (i.e. storage-root characteristics). Selection for long leaf life and hence higher leaf area index and greater leaf area duration should lead to a better light interception and to a greater canopy photosynthesis throughout the growth cycle. On the other hand, selection of cultivars with strong storage-root sink may enhance the expression of leaf photosyntheis. Storage root number and size might be used as a selection criteria for sink strength. However, the validity of this approach should be tested since these storage root characteristics are highly influenced by environment and crop management.

Cassava response to phosphorus (by Didier Pellet, Ph.D. candidate).

Generally in the tropics and particularly in Latin America, most of the cassava growing areas are characterized by a strong acid and phosphorus (P)-deficient soil. The low P levels can limit cassava yield at least in the first cycles when it is grown continuously for several years. The cassava germplasm at CIAT is currently being characterized for tolerance to low-P soils at Santander de Quilichao. Since 1980, more than 1500 clones were evaluated and several of them were found to be tolerant to low-P soils (CIAT Annual Reports 1982 to 1987). A collaborative research project was initiated in 1988 between CIAT and the Swiss Federal Institute of Technology, and funded by the Swiss Development Cooperation (SDC) to study varietal response to P and to elucidate the possible mechanisms underlying this response.

A field trial was conducted on a private farm near CIAT station at Santander de Quilichao. The experimental site was under tropical pasture grass for several years and soil-P level was about 2.5 ppm (with coefficient of variation 34%), a level much lower than the critical level required for optimum cassava growth. The experiment was laid out in a split-plot design with three replications and the following fertilizer treatments were assigned to the main plots:

(1) unfertilized

(2) 100-0-100 kg ha^{-1} NPK

(3) 100-50-100 kg ha^{-1} NPK

(4) 100-100-100 kg ha^{-1} NPK

The cassava cultivars CM 489-1, CM 523-7, M Col 1684 and CM40 were planted as subplots at a population density of 10,000 plants ha^{-1}. Sequential harvests were made every 2 months to determine the pattern of growth over time. Single leaf gas exchanges (CO_2 uptake and H_2O loss) were measured on the 5th-7th upper canopy leaves 2, 3, 4 and 6 months after planting using a portable infrared gas analyzer. Measurements were always made 0800 to 1300 h with a solar irradiance over 1000 μ mol m^{-2} s^{-1}.

Root yield and total biomass

Figure 6 illustrates fresh root yield with time after planting. The clone CM489-1 had the highest yield at any given P level and showed a significant response to P at the latest 3 harvests. Significant response to P was also noted with the early bulking clone CM 40 and the late bulking clone CM 523-7. The clone M Col 1684 did not show significant response to P. Across the four clones, application of NPK significantly increased yield as compared with unfertilized plots indicating the low fertility of the experimental site.

Figure 7 presents dry root yield and total biomass at final harvest 10 months after planting. Compared with zero phosphorus, the application of 100 kg ha^{-1} P increased yield by 40%, 39% and 32% in the clones CM 523-7, CM 40 and CM 489-1, respectively. The clone M Col 1684 did not show response to P application and its yield at zero P was similar to that of the high yielding clone CM 489-1 indicating its tolerance to low-P. Total biomass showed the same pattern as in root yield suggesting that differential varietal response to P is not due to different effects of fertilizer on harvest index and biomass partitioning. These data indicate the possibility of increasing both total biomass and root yield through genotype selection as well as crop management.

Photosynthesis, leaf canopy and sink-source relationship.

Figure 8 illustrates single leaf photosynthesis over time across all fertilizer treatments. Maximum photosynthetic rates for all clones were reached 4 months after planting. Significant varietal differences in photosynthesis were observed, with CM 489-1 possessing the highest average rate and M Col 1684 the lowest average rate across all measurement periods. Enhancement of leaf photosynthesis by phosphorus application was consistently observed in clones CM 523-7, CM 489-1 and CM 40. On the other hand, the clone M Col 1684 showed variable response (Fig. 9). Differences in photosynthesis due to clones or P level were

A field trial was conducted on a private farm near CIAT station at Santander de Quilichao. The experimental site was under tropical pasture grass for several years and soil-P level was about 2.5 ppm (with coefficient of variation 34%), a level much lower than the critical level required for optimum cassava growth. The experiment was laid out in a split-plot design with three replications and the following fertilizer treatments were assigned to the main plots:

(1) unfertilized

(2) 100-0-100 kg ha^{-1} NPK

(3) 100-50-100 kg ha^{-1} NPK

(4) 100-100-100 kg ha^{-1} NPK

The cassava cultivars CM 489-1, CM 523-7, M Col 1684 and CM40 were planted as subplots at a population density of 10,000 plants ha^{-1}. Sequential harvests were made every 2 months to determine the pattern of growth over time. Single leaf gas exchanges (CO_2 uptake and H_2O loss) were measured on the 5th-7th upper canopy leaves 2, 3, 4 and 6 months after planting using a portable infrared gas analyzer. Measurements were always made 0800 to 1300 h with a solar irradiance over 1000 μ mol m^{-2} s^{-1}.

Root yield and total biomass

Figure 6 illustrates fresh root yield with time after planting. The clone CM489-1 had the highest yield at any given P level and showed a significant response to P at the latest 3 harvests. Significant response to P was also noted with the early bulking clone CM 40 and the late bulking clone CM 523-7. The clone M Col 1684 did not show significant response to P. Across the four clones, application of NPK significantly increased yield as compared with unfertilized plots indicating the low fertility of the experimental site.

Figure 7 presents dry root yield and total biomass at final harvest 10 months after planting. Compared with zero phosphorus, the application of 100 kg ha^{-1} P increased yield by 40%, 39% and 32% in the clones CM 523-7, CM 40 and CM 489-1, respectively. The clone M Col 1684 did not show response to P application and its yield at zero P was similar to that of the high yielding clone CM 489-1 indicating its tolerance to low-P. Total biomass showed the same pattern as in root yield suggesting that differential varietal response to P is not due to different effects of fertilizer on harvest index and biomass partitioning. These data indicate the possibility of increasing both total biomass and root yield through genotype selection as well as crop management.

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It is known that cassava response to soil fertility is markedly expressed in changes in leaf canopy and the present data confirm such observation (Fig. 10). However, the varieties differed in their response to P level with respect to leaf canopy. The clones CM 489-1 and CM 40 showed consistent increase in leaf canopy with increase in P level whereas CM 523-7 did not show response to P. The clone M Col 1684 again showed variable response. Similar trends were observed with the number of storage roots at final harvest. Number of storage roots could be an indicator of "sink" capacity in cassava. Increasing P level resulted in higher number of storage roots in all clones at an early stage of bulking (4 months after planting) and the response persisted up to the final harvest (Fig. 11). The response was greatest in clone CM 489-1 and least in M Col 1684.

Across all varieties, the final root yield was significantly correlated with root number at 4 and 10 months after planting and with leaf area duration over the whole growth cycle (Table 4). These relationships varied among cultivars. On the other hand, final root yield was correlated with final mean root weight in clone CM 489-1 only. The additive effect of both leaf area duration and leaf photosynthesis on root yield is indicated by the improvement in correlation coefficients particularly with CM 523-7. These findings suggest that yield in cassava depends on both source and sink capacities. Although it was previously thought that cassava is not sink-limited, the sink-source effect should be carefully studied. Leaf photosynthesis might be influenced by the sink-source relation (i.e. feed-back effect). In the present studies, varietal ranking on the basis of both leaf photosynthesis and sink-source ratio (as root number/LAI) was similar (Table 5).

Response of cassava to fertilizer in Media Luna.

In Media Luna, Dept. of Magdalena, North Coast of Colombia, where cassava is produced by small farmers in limited farm area, reduction in yield has been a serious constraint in the last few years. The soil is sandy with low organic matter and nutrients contents (CIAT, Annual Report 1988). The lack of "fallow system" due to pressure on land and the absence of fertilizer application were major causes for reduction in cassava yield. In 1988-1989 growing season, a field trial was established in "La Colorada" to test the response of cassava to fertilizer application. The trial consisted of 14 clones arranged in a split-block design with four replications in which half of the blocks remained unfertilized and the second half received 50 kg ha^{-1} of N, P and K in two splits 30 and 60 days after planting. The compound fertilizer 15-15-15 NPK was used. Twenty five stakes per plot were planted on the flat, after being treated with fungicide solution, in 1 x 1 m arrangement.

Data of fresh and dry root yield and top fresh weight are presented in Table 6. As an average of all clones tested, the application of 50 kg ha^{-1} NPK significantly increased root yield and top biomass. The average increase due to fertilizer application was 46%, 47% and 44% in fresh root, dry root and top biomass, respectively. With the exception of clone SG 455-1, all clones responded positively to fertilizer application. The clone SG 455-1 did not respond to fertilizer and its fresh root yield was remarkably high (44 and 42 t ha^{-1} with and without fertilizer, respectively). The average experimental yield of 22.4 t ha^{-1} obtained without the application of fertilizer is three times greater than the average regional yield observed for the last 2-3 years. The selection of good quality planting materials and sanitary treatments of stakes prior to planting should have contributed to the better experimental yield. Also, the experimental site was under fallow and the soil fertility might has partially recovered and thus resulted in a better production as compared to that of the local farmers.

In view of the remarkable increase in yield due to application of moderate amount of fertilizer, it is beneficial to the local farmers to adopt this practice in order to ensure both reasonable yield and sufficient planting material (stakes) with good quality. The cost of this level of fertilizer is insignificant compared with the gain in yield and the ensured planting material. Moreover, the application of fertilizer increases the vegetative growth of cassava and enables it to compete with weeds and hence reduces the time and cost required for weeding. In this case, it is advisable to apply the fertilizer in 2-3 splits after the establishment of the crop (1-3 months after planting) to avoid large losses due to heavy leaching in these sandy soils. Other crop management practices related to the control of diseases and pests that greatly improve cassava production in this region are presented in the Pathology and Entomology sections of this report.

Response of cassava to association with forage legumes.

In 1987/1988 field trials were initiated in Santander de Quilichao to investigate the response of cassava to association with some forage legumes (CIAT Annual Report 1988). Permanent ground cover with forage legumes could minimize soil loss by erosion in hilly lands where cassava is produced. The experiments were conducted in exhausted soil due to continuous cassava growing for many years. One experiment received no fertilization and in the second cassava was fertilized with 500 kg ha^{-1} of 10-20-20 NPK compound fertilizer at planting. The two clones M Col 1684 and CM 507-37 were used. Data of fresh root yield in the second growing season (1988/89) are given in Table 7. In general, cassava produced less than in the first year of establishment of the forage legumes (CIAT, Annual Report, 1988). However, the clone CM 507-37, was the highest in production in both years irrespective of the association system and fertility level suggesting its high level of vigor. This clone is known to have higher leaf canopy and more extensive fibrous root system than M Col 1684 (CIAT, Annual Report, 1985).

Compared with sole cassava in the unfertilized plots, the clone CM 507-37 yielded more in association with siratro (149%), kudzu (126%), zornia (115%) and centrosima (107%), whereas the yields were greatly reduced in association with desmodium (35%) and arachis (42%). On the other hand, sole cassava in the fertilized plots outyielded cassava in association with all forage legumes. Again, the greatest yield reduction was observed in association with desmodium and arachis. It appears that high soil fertility enhanced the growth of forage legumes and hence competed strongly with cassava, probably for soil water. The depressing effects on cassava by desmodium and arachis are notable irrespective of soil fertility and the causes underlying these effects are unknown at present. Allelopathic effect due to association with desmoidum and arachis could be one of the depressing factors in this case. The same trends have been observed with the less vigorous clone M Col 1684 irrespective of soil fertility. However, yields were reduced more in association with forage legumes. These data indicate the possibility for selecting cassava clones that can produce reasonably well in association with certain forage legumes. Nevertheless, the effectiveness of this farming system in sustaining cassava production and in controlling soil erosion in hilly regions should be evaluated over longer period.

Effect of water stress on HCN in cassava roots.

Cyanide content in cassava is a major quality constraint. Most of the cassava clones commonly used by farmers contain relatively high levels of HCN in their roots. When these roots are directly consumed as human food without adequate processing, it can cause a health problem particularly in regions where cassava represents a large portion of calory intake (e.g. Africa). Besides being controlled by genotype, the HCN level may change with environment and regimes of crop management. Water stress during root filling normally increases HCN level. Cassava is extremely drought tolerant and is as a result grown in areas where rainfall is limited and sporadic. In these circumstances good cassava-root quality with an acceptable level of HCN may be more important than yield potential.

During the 1987-88 growing season, a field trial with 8 clones was conducted at Santander de Quilichao to investigate to what extent cassava can tolerate extended periods of water stress imposed at an early stage of growth and how does this affect productivity and root quality (CIAT, Annual Report 1988). The experiments were carried out in a large field lysimeter where soil water could be controlled by convering the stressed plots by plastic sheets. At 60 days after planting, half of the experimental area ($\approx$ 1500 m^{-2}) was deprived of water for 120 days and then was allowed to recover for the rest of the growing season of five months with the aid of irrigation and rainfall. The second half of the experimental area was kept under well-watered conditions throughout the growing season. The root content of total and free hydrocyanic acid (HCN) as enzymatically determined at final harvest 11 months after planting are shown in Table 8. The clones possessed a wide range of HCN in their roots from 115 ppm in clone CM 3306-32 to 723 ppm in clone M Col 1684 under well-watered conditions. With 4 months mid-term water stress, the HCN content at final harvest ranged from 108 ppm in clone CM 1335-4 to 930 ppm in M Col 1684. Free HCN levels ranged from 1.3 ppm in CM 1335-4 to 5.3 ppm in M Col 1684 under well-watered conditions. With stress the free HCN levels ranged from 6.3 ppm in CM 1335-4 to 20 ppm in M Col 1684. With the exception of the two clones CM 1335-4 and CM 922-2, HCN content increased with water stress. Even in "bitter" clones with relatively high HCN under well-watered conditions (e.g. M Col 1684 and CM 507-37), the level of HCN increased under stress. Moreover, in some "sweet" clones with relatively low HCN under well-watered conditions (e.g. CM 523-7, CM 2136-2 and CM 3306-2), HCN level increased under stress. This finding has important implications in breeding and selecting cassava varieties that are considered "sweet" under adequate water supply. Some of these clones may become "bitter" when subjected to prolonged drought and hence become unacceptable for human consumption in regions where fresh cassava is a major source of food. On the other hand, some clones with low levels of HCN under favorable conditions can maintain these levels even when subjected to a prolonged drought (e.g. CM 922-2 and CM 1335-4). In areas where cassava is grown under limited or sporadic rain and has to endure a long period of drought (e.g. Pacific Coast of Ecuador, North East of Brazil and the Sahel region of Africa), the clones which remain "sweet" with acceptable low level of HCN under stress are useful in this case. More accessions have to be evaluated to identify clones with greatly reduced HCN level under water stress. Also, there is a need to improve the accuracy of the "picrate solution" method currently used for rapid evaluation of HCN content in cassava roots. The Cassava Utilization Section is currently addressing this problem in collaboration with other concerned institutions (See the Utilization Section report, 1989).

Screening cassava germplasm for tolerance to low-P soils at Santander de Quilichao.

Characterization of the cassava germplasm for tolerance to low-P soils has been initiated several years ago to identify clones and breeding materials that can have sustainable production in soils low in phosphorus (CIAT, Annual Reports 1986, 1987). In continuation of this effort, a new group of clones were screened during the 1987/1988 season at Santander de Quilichao. The clones were planted (15.625 plants ha^{-1}) in plots which received no phosphorus for the last 7 years or with annual application of 75 kg P ha^{-1} banded at planting as triple superphosphate. The treatments were replicated 4 times. Table 9 shows the fresh root yields and the adaptation indices of the tested clones. Across all clones, the average root yield in the low-P plots (27 t ha^{-1}) was significantly lower than yield in the adequate-P plots (38 t ha^{-1}). Yields varied widely among clones in both P treatments indicating the genetic diversity in yield potential. Among this group of clones, six were identified on the basis of their adaptation indices to be tolerant to low-P. These adapted clones were CG 913-4, CM 2177-2, CG 1370-5, CG 910-7, CM 4049-4 and CM 2174-7. The best adapted clone was CG 913-4, an advanced breeding line of CIAT, with a low-P adaptation index of 2. This clone yielded 43.9 and 46.4 t ha^{-1} without and with applied P, respectively. Such clone can be used as a breeding material for tolerance to low-P in order to develop new varieties that can have sustainable production in low-P soils where most cassava is grown. More new accessions are currently under evaluation.

LEGEND TO FIGURES

Figure 1. Relationship between 1988/1989 dry root yield and single leaf photosynthesis measured in 1986/1987 season.

Figure 2. Relationship between 1988/1989 leaf photosynthesis measured once at 4 months after planting and the 1986/1987 rates measured on 3 occassions at 4 to 6 months after planting.

Figure 3. Relationship between dry root yield and leaf photosynthesis of the 1988/1989 season.

Figure 4. Relationship between dry root yield and mesophyll conductance of the 1988/1989 season.

Figure 5. Relationship between dry root yield and intercellular CO_2 of the 1988/1989 season.

Figure 6. Response of fresh root yield to P application. 000: no fertilizer; 0P, 50P and 100P: zero, 50 and 100 kg ha^{-1} P with 100 kg ha^{-1} NK.

Figure 7. Response of dry root yield and total dry biomass to P application.
1: no fertilizer; 2, 3 and 4: zero, 50 and 100 kg ha^{-1} P with 100 kg ha^{-1} NK.

(a): LSD 5% for total biomass; (b): LSD 5% for dry root yield.

Figure 8. Single leaf CO_2 uptabke rate as an average of all fertilizer treatments measured between 2 and 6 months after planting.

Figure 9. Response of single leaf CO_2 uptake rate to P application. Treatments as in Figure 7.

Figure 10. Response of growth cycle average LAI and final bulked roots to P application. Treatments as in Fig. 7.

Figure 11. Effect of P application on number of storage root over time.

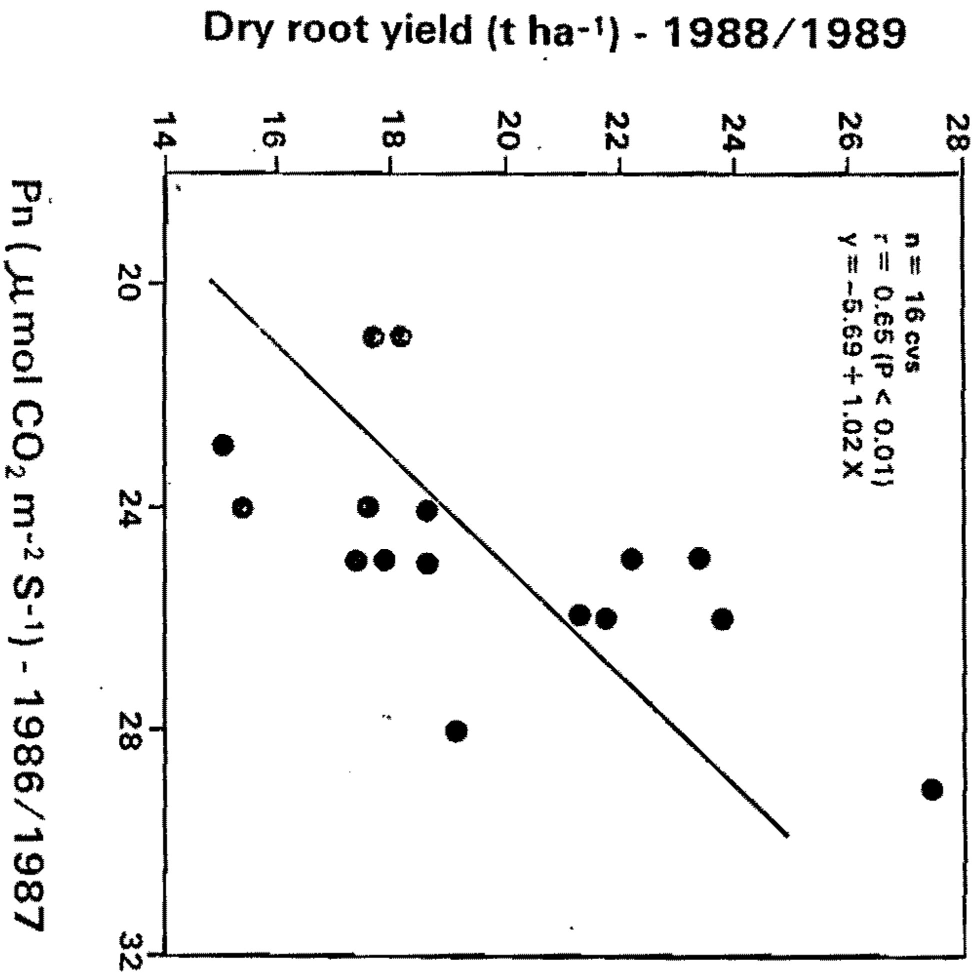
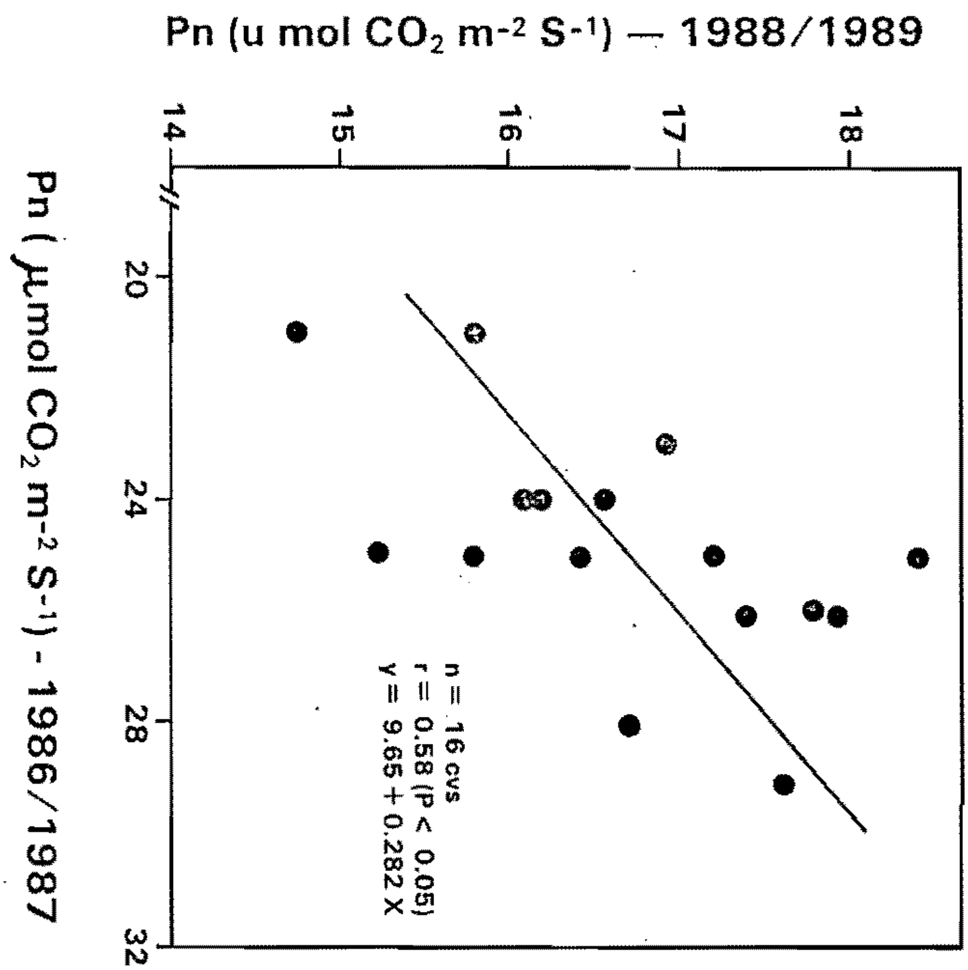
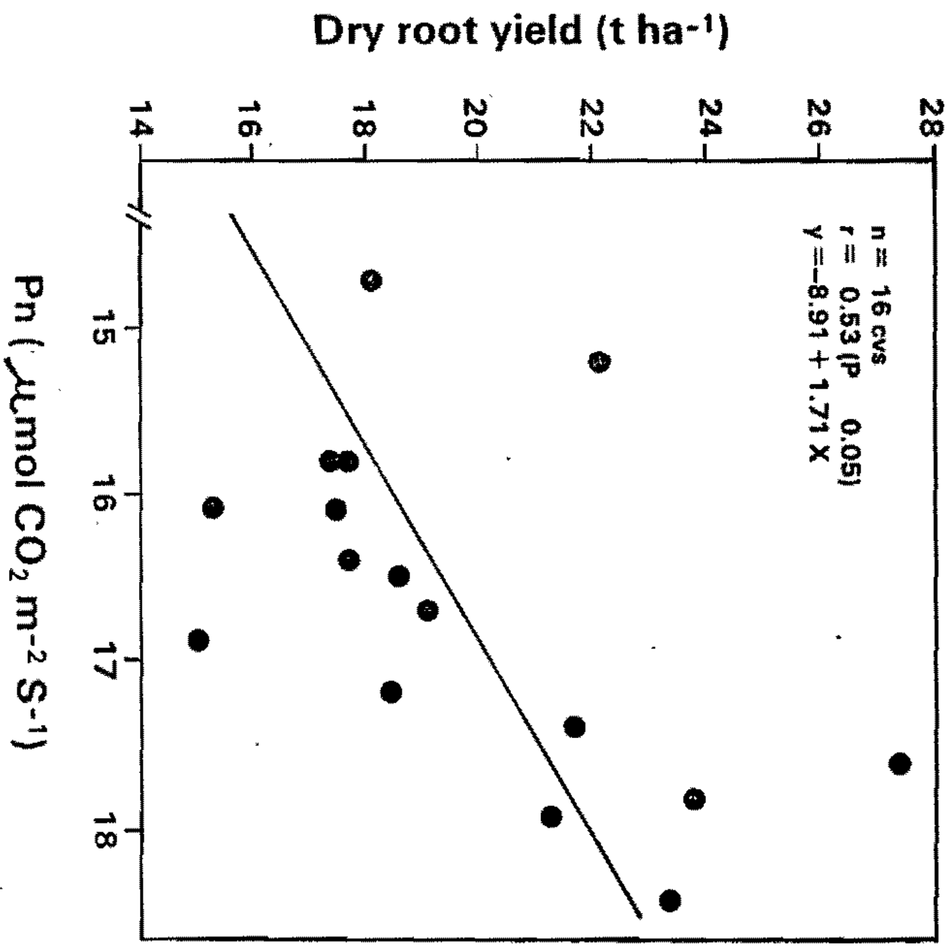

Dry root yield (t ha-1) - 1988/1989
14
16
18
20
22
24
26
28
n = 16 cvs
r = 0.65 (P < 0.01)
y = -5.69 + 1.02 X
20
24
28
32
Pn (μmol CO2 m-2 S-1) - 1986/1987

Fig. 1



Pn (u mol CO2 m-2 S-1) — 1988/1989
14
15
16
17
18
20
24
28
32
Pn (μmol CO2 m-2 S-1) - 1986/1987
n = 16 cvs
r = 0.58 (P < 0.05)
y = 9.65 + 0.282 X

Fig. 2



Dry root yield (t ha-1)
14
16
18
20
22
24
26
28
n = 16 cvs
r = 0.53 (P 0.05)
y = -8.91 + 1.71 X
15
16
17
18
Pn (μmol CO2 m-2 S-1)

Fig. 3

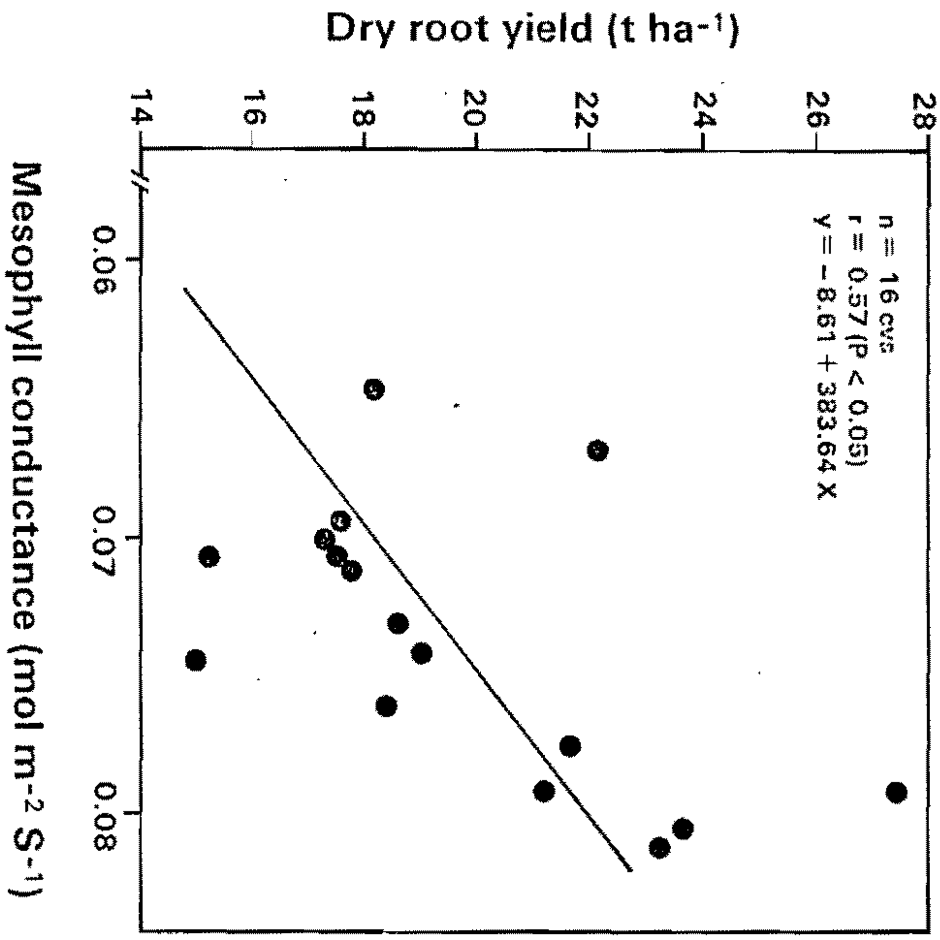

Dry root yield (t ha-1)
Mesophyll conductance (mol m-2 S-1)
n = 16 cvs
r = 0.57 (P < 0.05)
y = - 8.61 + 383.64 X
14
16
18
20
22
24
26
28
0.06
0.07
0.08

Fig. 4

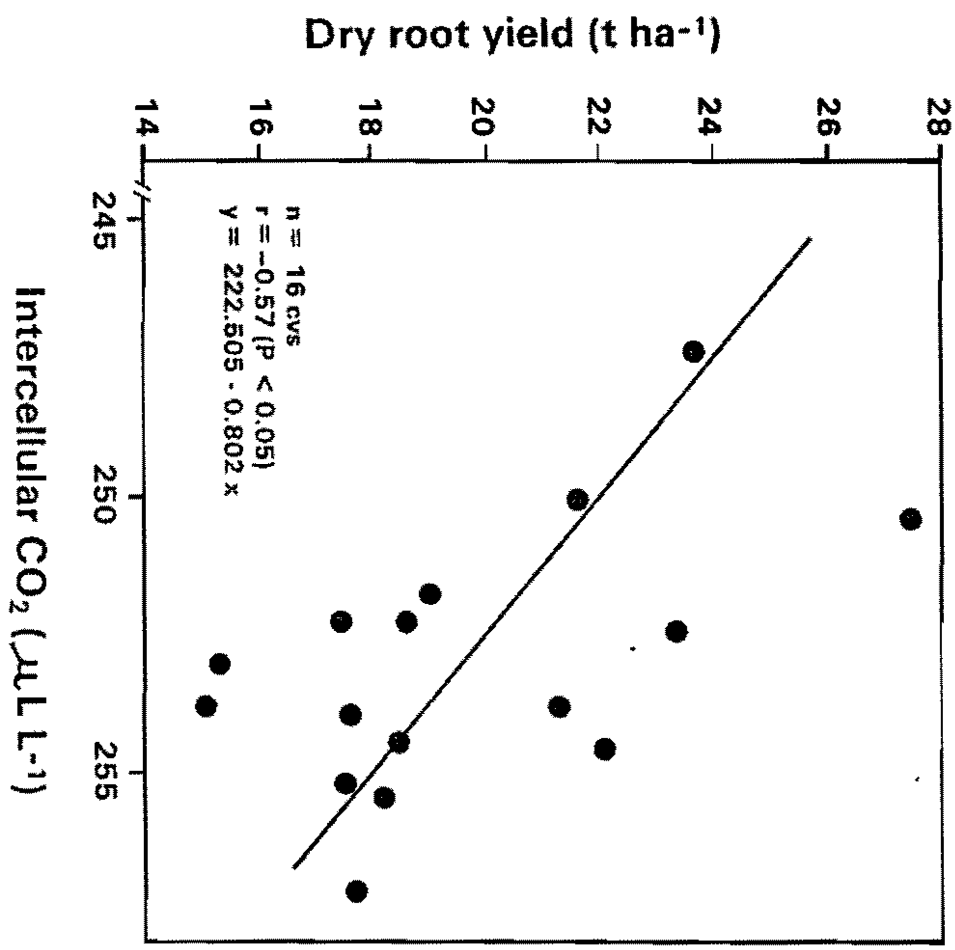

Dry root yield (t ha-1)
14
16
18
20
22
24
26
28
245
250
255
Intercellular CO2 (μL L-1)
n = 16 cvs
r = -0.57 (P < 0.05)
y = 222.505 - 0.802 x

Fig. 5

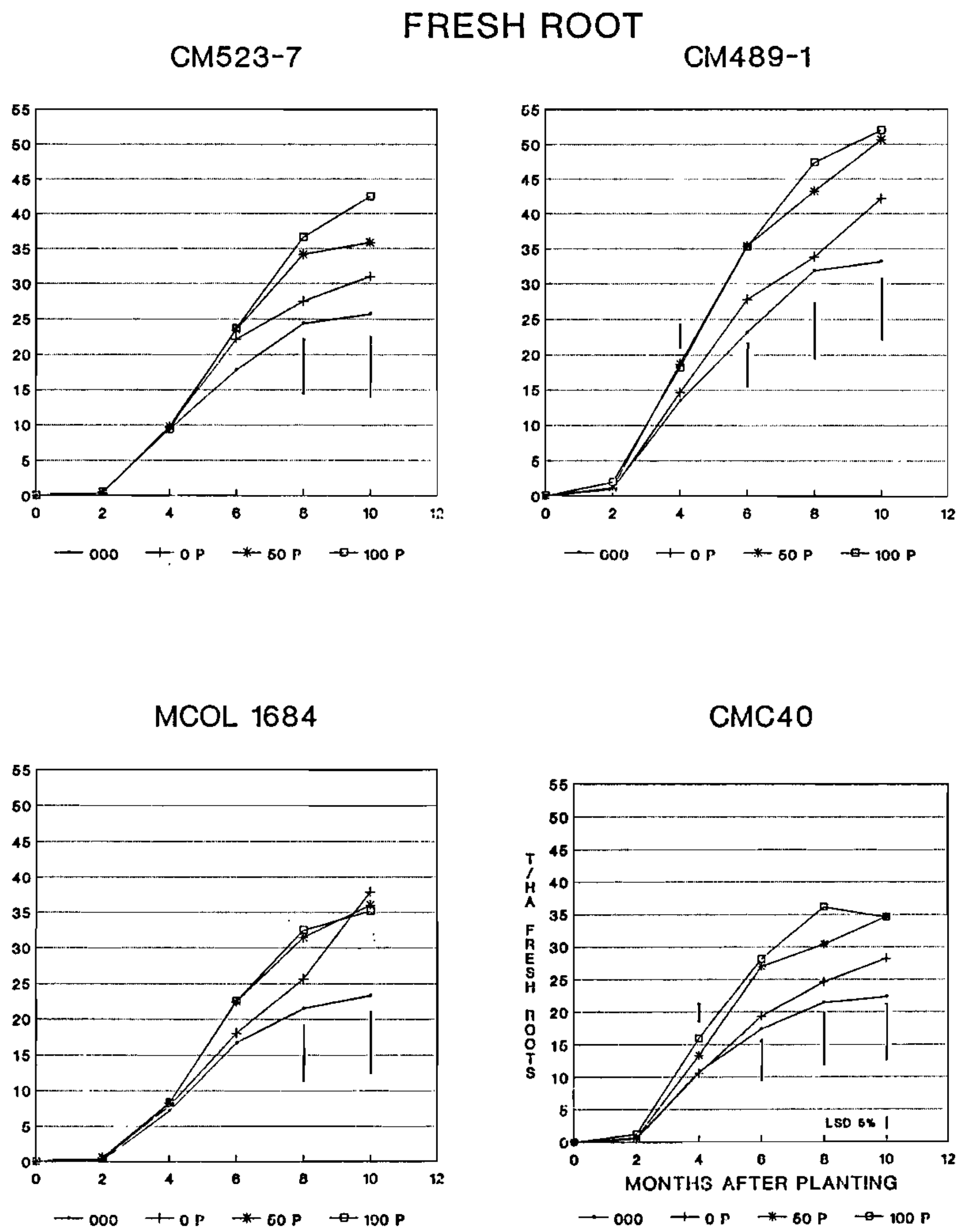

FRESH ROOT
CM523-7
CM489-1
MCOL 1684
CMC40
T/HA FRESH ROOTS
MONTHS AFTER PLANTING
LSD 5%
000
0 P
50 P
100 P

Fig. 6

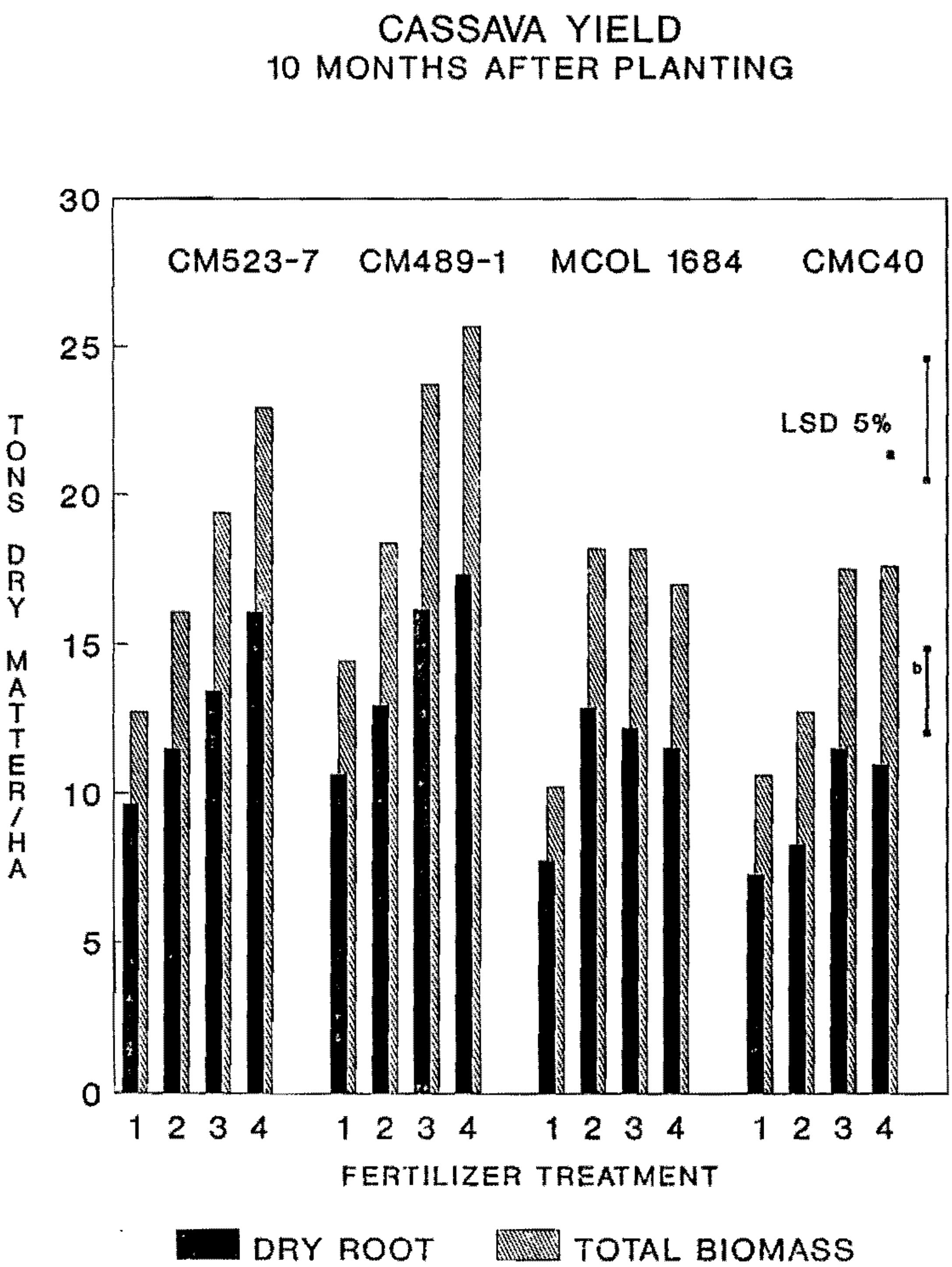

CASSAVA YIELD
10 MONTHS AFTER PLANTING
CM523-7
CM489-1
MCOL 1684
CMC40
LSD 5%
a
b
TONS DRY MATTER/HA
30
25
20
15
10
5
0
1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4
FERTILIZER TREATMENT
DRY ROOT
TOTAL BIOMASS

Fig. 7

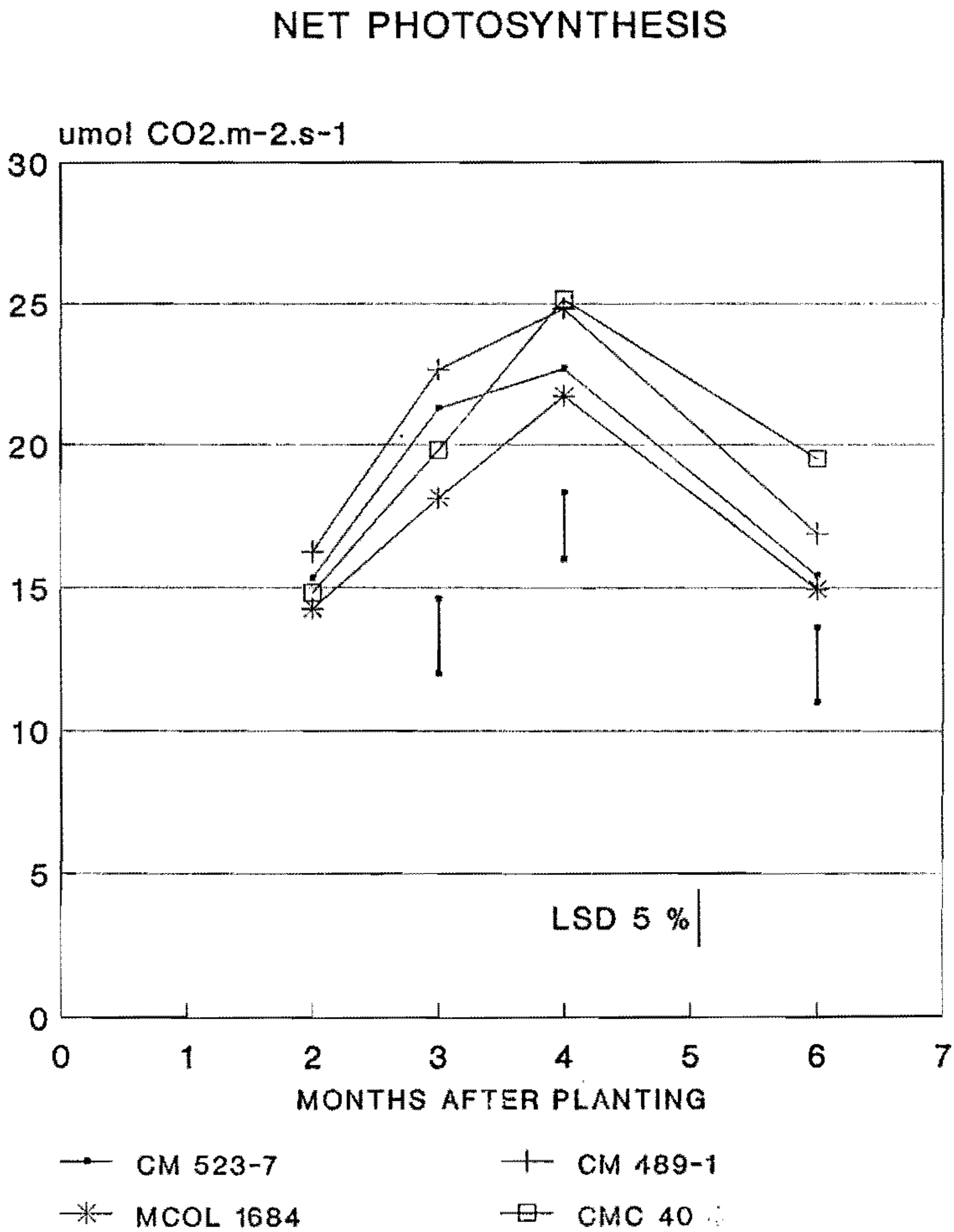

NET PHOTOSYNTHESIS
umol CO2.m-2.s-1
30
25
20
15
10
5
0
0
1
2
3
4
5
6
7
MONTHS AFTER PLANTING
LSD 5 %
CM 523-7
CM 489-1
MCOL 1684
CMC 40

Fig. 8

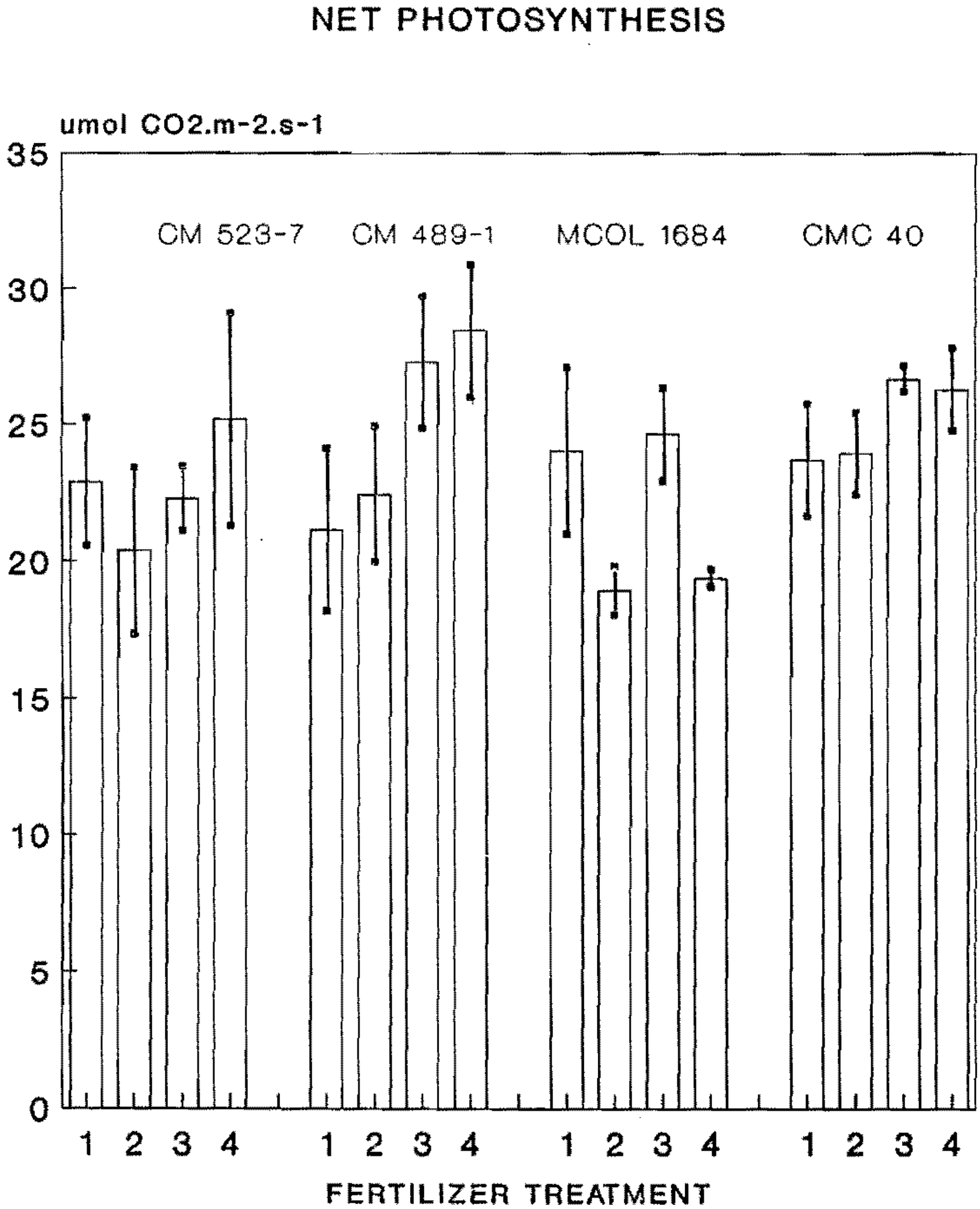

NET PHOTOSYNTHESIS
umol CO2.m-2.s-1
35
30
25
20
15
10
5
0
CM 523-7
CM 489-1
MCOL 1684
CMC 40
1 2 3 4
1 2 3 4
1 2 3 4
1 2 3 4
FERTILIZER TREATMENT

Fig. 9

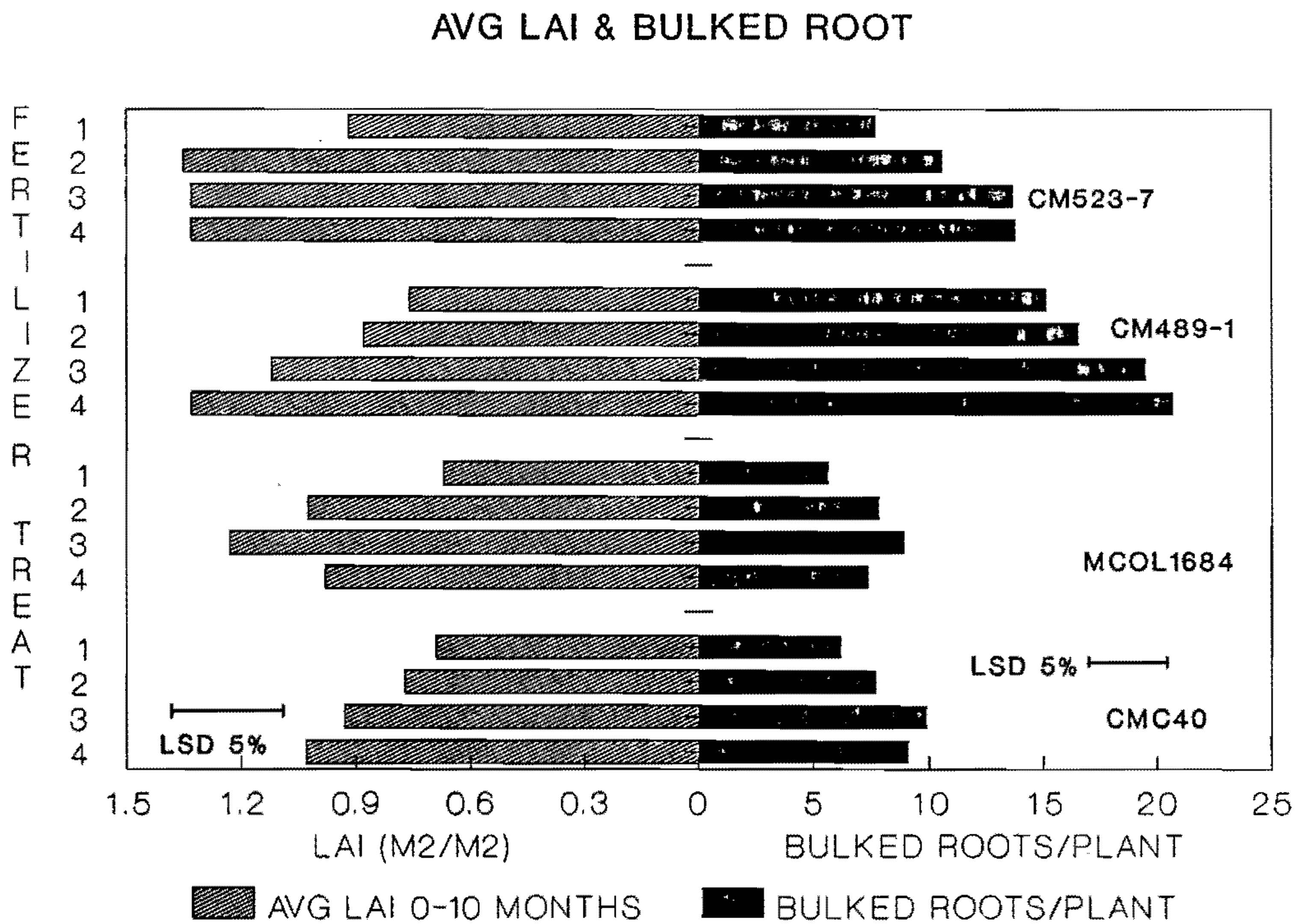

AVG LAI & BULKED ROOT
FERTILIZER TREAT
1
2
3
4
CM523-7
CM489-1
MCOL1684
CMC40
LSD 5%
LSD 5%
1.5 1.2 0.9 0.6 0.3 0 5 10 15 20 25
LAI (M2/M2)
BULKED ROOTS/PLANT
AVG LAI 0-10 MONTHS
BULKED ROOTS/PLANT

Fig. 10

BULKED ROOTS

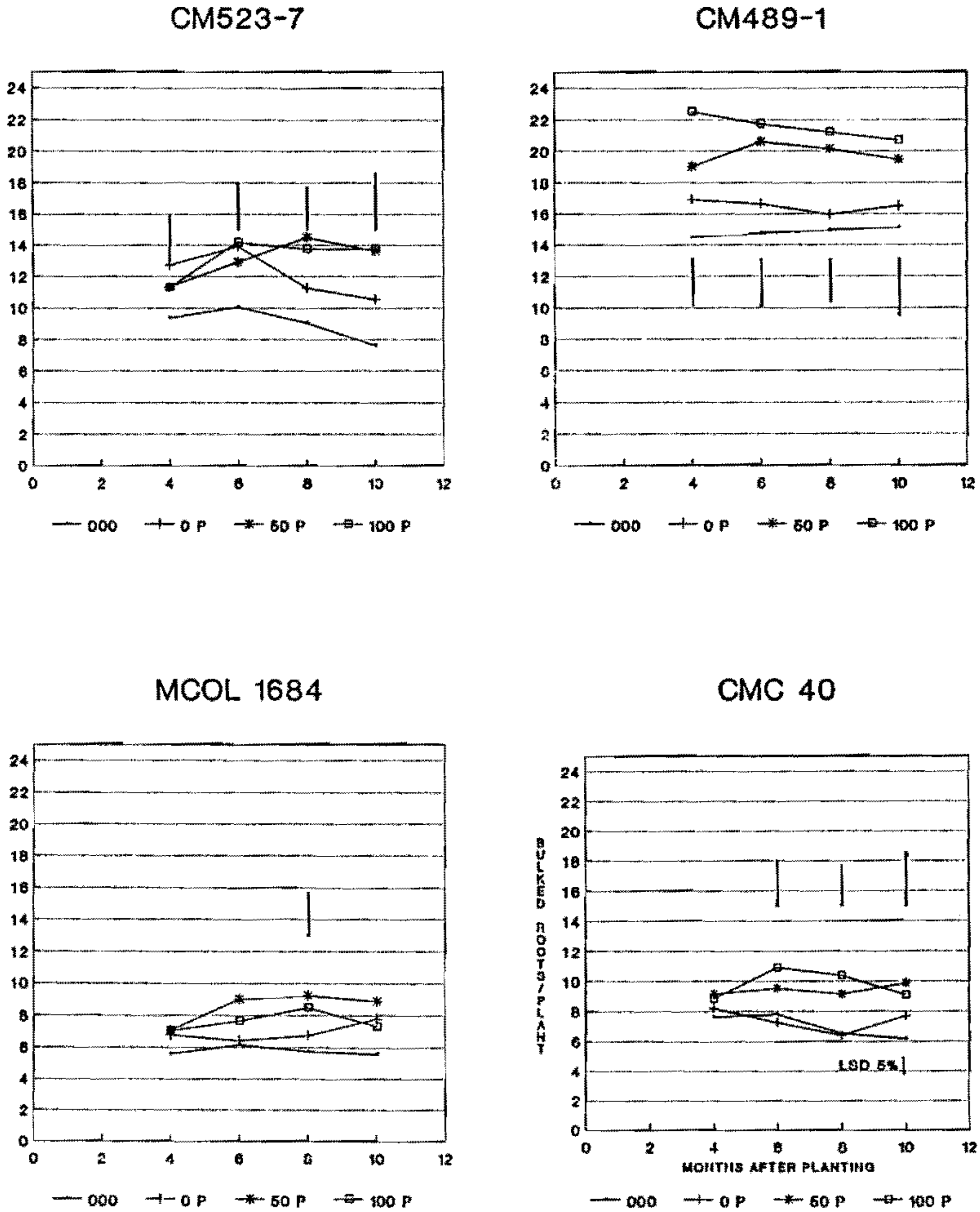


Fig. 11

TABLE 1. Root yield and leaf gas exchange characteristics of 16 cultivars grown in the Patia Valley, Cauca, Colombia, 1988-1989.

Cultivar	Dry root yield	Leaf photosynthesis	Mesophyll conductance (CO_2)	Leaf conductance (H_2O)	Internal (CO_2)
	t ha^{-1}	μ mol CO_2 m^{-2} s^{-1}	m mol m^{-2} s^{-1}		μ LL^{-1}
MCOL 1684	17.5	16.1	71	837	255
CM 305-41	21.6	17.4	78	852	250
CM 308-197	15.0	16.9	75	892	254
CM 342-170	18.5	16.5	73	836	252
CM 523-7	17.6	15.8	69	816	254
CM 922-2	23.3	18.4	81	990	252
CM 962-4	18.4	17.2	76	891	255
CM 976-15	18.1	14.7	65	759	255
CM 1015-42	17.4	15.8	70	761	252
CM 1016-34	27.4	17.6	79	879	250
CM 1022-4	19.0	16.7	74	838	252
CM 1335-4	17.7	16.4	71	887	257
CM 1797-4	23.6	17.8	80	856	247
CM 1797-8	22.1	15.2	67	720	255
HMC-1	21.2	17.9	79	930	254
MCOL 1468	15.3	16.1	71	844	253
LSD (P=0.05)	3.233	1.7	8.6	74	7.5

TABLE 2. Activity of PEP carboxylase in leaf extracts of cassava, maize and common beans. Values are means of 4 leaves ± S.D.

Species and Photosynthetic type	PEP carboxylase activitity	
	μ mol NADH/min. gfw	μ mol NADH/min. mg chl.
Maize - C_4		
cv. CIMMYT 346	14.9 ± 1.8	6.8 ± 3.55
Swan laposta C848		
Cassava - C_3 - C_4		
M Mex 59	3.2 ± 0.6	2.2 ± 1.0
MBra 534	3.0 ± 0.4	2.1 ± 1.0
M Nga 2	1.3 ± 0.1	0.4 ± 0.1
M Ven 77	2.4 ± 0.2	1.5 ± 1.0
M Col 22	2.3 ± 0.4	1.0 ± 0.6
M Col 1684	1.8 ± 0.4	0.6 ± 0.1
M Col 2264	2.6 ± 0.6	2.3 ± 1.6
M Bra 309	1.8 ± 0.4	0.6 ± 0.05
M Ven 331	1.5 ± 0.2	0.4 ± 0.2
Common Beans - C_3		
cv. Calima G 4494	0.2 ± 0.07	0.3 ± 0.1

TABLE 3. Coefficients of correlation related to dry root yield and total dry matter production 4 months after planting.

	Dry root yield 4 months n = 64	Total dry matter 4 months n = 64
Net photosynthesis at four months	0.376 **	0.313*
Avg. LAI 2,4 months	0.532***	0.740***
Net photosynthesis X Avg. LAI 2, 4 months	0.604 ***	0.750 ***
Harvest Index	0.661 ***	———

*, **, *** confidence level of the coefficient of correlation 95, 99, 99.9% respectively.

TABLE 4. Coefficients of correlation related to final dry root yield (ten months), considering separately each variety and over all varieties.

	CM 523-7 n = 12	CM 489-1 n = 12	MCol 1684 n = 12	CMC 40 n = 12	All varieties confounded n = 48
Number of storage roots 4 months after planting	0.50 n.s.	0.83 ***	0.35 n.s.	0.82***	0.67 ***
Mean storage root weight 4 months after planting	-0.23 n.s.	-0.14 n.s.	-0.35 n.s.	-0.50 n.s.	-0.40 **
Mean storage root weight at final harvest	-0.25 n.s.	0.59 *	0.49 n.s.	0.49 n.s.	-0.16 n.s.
Number of storage roots at final harvest	0.89 ***	0.72 **	0.72 **	0.73 **	0.76 ***
Avg. LAI over 10 months	0.61 *	0.806 **	0.69 *	0.790 **	0.65 ***
Avg. LAI over 10 months X Avg. net photosynthesis	0.70 *	0.811 **	0.495 n.s.	0.799 **	0.69 ***

n.s., *, **, *** confidence level respectively: not significative, 95, 99, 99.9%.

TABLE 5. Average net photosynthesis and "sink-source" ratio of four cassava clones (average over all fertilizer treatments).

	Net photosynthesis (1) μ mol CO_2 m^{-2} s^{-1}	Sink-source ratio (2) Root number/IAI
CM 489-1	20.14 A (3)	18.66 A
CMC 40	19.81 AB	9.77 B
CM 523-7	18.67 B	9.37 BC
M Col 1684	17.25 C	7.75 C

(1) Average of all measurements during growth period.

(2) The final number of storage roots/average IAI over growth period.

(3) Duncan Range Test at 95% confidence level. Values with the same letter are not significantly different.

TABLE 6. Response of cassava to fertilizer application in the sandy soil, Media Luna, Magdalena, Colombia (1988-1989). Values are means of four replications.

Clones	Fertilized (50 kg ha^{-1}, NPK) Fresh root	Dry root	Top weight (fresh)	Unfertilized Fresh root	Dry root	Top weight (fresh)
	$t\ ha^{-1}$					
CM 1223-11	42.9	13.5	17.9	23.3	6.8	8.2
CM 1533-19	37.7	10.0	26.5	21.8	5.1	17.5
CM 3306-9	28.4	10.0	18.5	19.1	6.7	15.0
CM 3320-4	32.3	9.8	30.1	19.6	5.6	15.3
CM 3555-6	33.2	9.7	27.1	21.2	6.2	16.0
CM 507-37	32.3	8.4	28.5	23.7	6.0	12.7
CM 976-15	34.9	11.6	28.6	28.8	9.7	29.4
MBra 12	32.1	8.8	23.1	23.2	6.4	21.6
MBra 191	27.6	8.0	29.7	19.2	5.7	19.9
MCOL 1468	32.6	8.0	26.7	18.6	4.1	9.9
MCOL 1684	27.0	7.1	17.1	15.0	3.9	9.3
MCOL 2057	25.7	7.2	22.9	20.5	5.8	18.6
MCOL 72	27.9	9.7	16.4	16.6	5.8	18.8
SG 455-1	44.2	14.9	27.2	42.5	14.2	24.7
LSD 5%	6.21	1.91	3.99	5.18	1.88	3.44
Average of all clones	32.8 (*)	9.7 (*)	24.3 (*)	22.4	6.6	16.9

(*) Across all clones, fertilizer application significantly increased ($P < 0.001$) both root yield and top weight. The harvest index and percentage dry matter in roots were not significantly different.

TABLE 7. Fresh root yield of cassava as affected by forage legume permanent cover in Santander de Quilichao for the second growing season (1988/89).

Cropping system	Unfertilized ($t\ ha^{-1}$)		Fertilized ($t\ ha^{-1}$)	
	CM 507-37	MCOL 1684	CM 507-37	M COL 1684
Sole cassava (Control)	17.1 (100%)	8.5 (100%)	56.2 (100%)	23.9 (100%)
Cassava/zornia	19.7 (115%)	6.8 (80%)	42.7 (76%)	16.1 (67%)
Cassava/kudzu	21.6 (125%)	7.3 (86%)	35.1 (62%)	12.6 (53%)
Cassava/centrosima	18.3 (107%)	4.3 (51%)	43.2 (77%)	12.1 (51%)
Cassava/Siratro [(1)]	25.4 (149%)	8.9 (105%)	32.5 (58%)	13.8 (58%)
Cassava/desmodium	5.9 (35%)	1.6 (19%)	17.0 (30%)	3.2 (13%)
Cassava/arachis pintoi	7.1 (42%)	1.9 (22%)	29.5 (52%)	8.5 (36%)
LSD 5%	5.43	2.64	11.54	4.46

(1) Siratro canopy showed partial deterioration in the unfertilized experiment as compared to other legumes.

TABLE 8. Effect of water stress on HCN in cassava roots. HCN content expressed on dry root basis at 11 months after planting. Values are means ± s.d. (3 replications).

Clone	Total HCN (PPM) Control	Stress	Free HCN (PPM) Control	Strees
MCOL 1684	723 ± 165	930 ± 170	5.3 ± 0.6	20.0 ± 3.0
CM 507-37	718 ± 215	805 ± 190	4.0 ± 1.7	8.7 ± 3.2
CM 489-1	192 ± 102	354 ± 89	2.0 ± 1.0	12.0 ± 5.0
CM 523-7	195 ± 53	309 ± 51	3.3 ± 0.6	10.0 ± 3.5
CM 2136-2	162 ± 39	340 ± 90	2.0 ± 1.0	8.3 ± 3.2
CM 3306-32	115 ± 40	186 ± 35	2.3 ± 1.2	12.3 ± 4.2
CM 922-2 *	146 ± 11	155 ± 9	2.7 ± 0.6	10.0 ± 3.5
CM 1335-4 *	123 ± 21	108 ± 12	1.3 ± 0.6	6.3 ± 0.6

(*) The underlined clones maintained their low level of HCN even under a prolonged water stress of 4 months during the growth cycle. Such clones could be used in areas with limited rainfall and where cassava is a major source for human food. More screening is warranted to identify clones with greatly reduced level of HCN under stress.

TABLE 9. Root yield of cassava clones under low and adequate P level in Santander de Quilichao (1987-1988). Values are means of four replications.

Clone	Fresh root yield (t ha^{-1}) Zero P	75 kg ha^{-1} P	Low-P adaptation index (1)
MCOL 1505	25.7 (2)	41.9 (2)	1.05
CM 342-170	27.7	34.3	0.93
CM 681-2	23.2	32.1	0.73
CM 1015-16	20.9	35.9	0.73
CM 1203-13	31.4	38.2	1.17
CM 1785-6	20.2	37.6	0.74
CM 1797-4	29.9	38.6	1.12
CM 2087-101	24.6	39.1	0.94
CM 2157-1	28.3	39.9	1.10
CM 2166-6	31.4	42.5	1.30
CM 2174-7	28.3	14.6	0.40
CM 2177-2	31.3	52.2	1.59
CM 2452-5	23.9	47.5	1.11
CM 2952-3	30.2	34.7	1.02
CM 2976-1	25.0	16.9	0.41
CM 3974-1	20.5	34.1	0.68
CM 4049-4	31.8	43.3	1.34
CM 4066-2	25.1	34.1	0.83
CM 4068-2	28.1	44.5	1.22
CG 668-4	23.0	35.3	0.79
CG 910-7	30.4	45.6	1.35
CG 912-3	29.6	36.7	1.06
CG 913-4	43.9	46.4	1.99
CG 936-7	27.1	39.8	1.05
CG 959-1	27.9	35.9	0.98
CG 1370-5	32.1	49.2	1.54
CG 1403-6	21.7	48.6	1.03
SG 536-1	19.4	31.2	0.59
SG 557-6	29.2	39.8	1.13

CONT. TABLE 9.

Clone	Fresh root yield ($t\ ha^{-1}$) Zero P	$75\ kg\ ha^{-1}$ P	Low-P adaptation index (1)
SG 562-4	23.8	39.3	0.91
SG 591-3	27.1	37.6	0.99
SG 782-3	20.2	29.9	0.59
LSD 5%	6.18	7.95	-
Average of all clones	27.0 (*)	38.0 (*)	-

(*) Significantly different ($P < 0.001$). The underlined clones are considered to have a good level of tolerance to low-P as indicated by their adaptation indices. The clone CG 913-4, a new breeding line of CIAT, is the best adapted to low-P among this group, followed by CM 2177-2.

(1) Low-P adaptation index was calculated for each clone using the ratio:

$$\frac{(\text{Yield at zero P})\ (\text{Yield at 75 kg ha}^{-1}\text{ P})}{(\text{Average yield at zero P})\ (\text{Average yield at 75 kg}^{-1}\text{ P})}$$

(2) LSD 5% for clone X P = 7.03 $t\ ha^{-1}$.

SOIL EROSION AND SUSTAINABLE PRODUCTION IN CASSAVA-BASED CROPPING SYSTEMS

To ensure a sustainable agricultural production and a secured food supply to meet the increasing demand of a fastly growing world human population, conservation of our natural resources is warranted. Soils, as one of these valuable resources, have shown significant levels of degradation due to erosion and depletion of nutrients in many parts of the tropics. The level of soil degradation is further agravated when resource-limited small farmers are forced to grow their food crops on very steep lands. When these steep lands are stripped off of their natural vegetation they become prone to severe erosion by heavy rainfall. Cassava is a small farmer crop and plays important role as a food source both in rural sectors and urban poor communities. Although cassava is not recommended to be grown in hillsides with slopes greater than 10%, a significant portion of cassava production occurs in these areas. In these erosion-prone steep lands, certain regimes of soil and crop managements have to be adopted to avoid large losses of the top soil through erosion. The Cassava Program have been emphasizing the importance of studying soil erosion problems in cassava-based cropping systems and has conducted research on production managements effective in minimizing soil erosion. This research has led to identifying some useful production practices that can sustain a reasonable level of cassava production and in the same time reduce soil erosion (CIAT Annual Reports 1985-1988). Applying moderate levels of fertilizer to cassava alone or intercropped with other crops, planting in contour ridges and in combination with live barriers of pasture grasses all have proved to be effective practices in producing high yields of cassava as well as in controlling soil erosion. To further extend this research effort and to augment the practical and agronomical aspects with more fundamental information concerning climatic and edaphic factors involved in soil erosion, a collaborative research project was initiated in 1987 between the cassava program at CIAT and the University of Hohenheim, Federal Republic of Germany. A Ph.D. student (Ludger Reining) from Germany spent two years with the Cassava Physiology section and conducted field research both at Santander de Quilichao and Mondomo area on cassava production systems in relation to soil erosion. His annexed report summarizes data obtained in the last two years that would certainly improve our understanding of soil erosion problems in general and of cassava-based cropping systems in particular. We do hope that such useful collaborative research efforts between CIAT and concerned national and international institutions would continue in the future.

Short report on soil erosion studies conducted from March 1987-April 1989 at Santander de Quilichao and Mondomo, Departamento Cauca, Colombia. (by Ludger Reining, University of Hohenheim, FRG).

1. Introduction.

Soil erosion studies in cassava-based cropping systems were conducted during the 1987/88 and 1988/89 cropping seasons. The treatments were as follows:

1- Cleantilled fallow (control)

2- Cassava planted on flat land

3- Cassava planted on contour ridges

4- Cassava planted on down slope ridges.

5- Cassava intercropped with grain legumes

6- Cassava planted on flat land with contour grass strips

7- Cassava planted in local minimum tillage system "cajuelas" in association with native grass.

(For detailed description of treatments and set up of trials, refer to CIAT, Annual Report, 1988).

Three replications were established at the CIAT-Station in Santander de Quilichao on land with 7-13% slope, 2 repetitions at Mondomo with 13-20% slope. Collectors to monitor both runoff and eroded soil were installed at the lower end of each plot. The planted plots of treatments 2-7 were adequately fertilized. To obtain information on rainfall characteristics rain gauges with a monthly recording period were placed at each site.

2. Rainfall characteristics

Though the long term means of precipitation with 1809 mm at Santander de Quilichao and 2133 mm at Mondomo seem to be sufficient to expect reasonable yields from cassava, the rainfall distribution is an obstacle to agricultural production. Even during the rainy seasons rainstorms can be followed by dry spells of several weeks, as it happened in April, 1987. Maximum intensities were recorded with 21 mm in 7 minutes (180 mm/h) on April 4, 1988 in Santander and with 11 mm in 3 minutes (220 mm/h) on August 19, 1988 in Mondomo. The biggest amount of rain during a single storm was recorded in Santander on 10 & 11.11.88

with 109.3 mm in 7 hours. This storm also had the highest value of kinetic energy with 2864 MJ mm/hha. In Mondomo the biggest rain yielded on November 29 & 30, 1988, 85.3 mm in 7.5 hours with a kinetic energy of 2135 MJ mm/hha.

In Santander de Quilichao rainfall was 1458.1 mm during the 1987/88 cropping season and 2416.8 mm in the 1988/89 season whereas the long term mean (average of 22 years) is 1809 mm. In Mondomo 1498.4 mm of rain fell in 1987/88 and 2376.6 mm in 1988/89 with a mean (average of 16 years) of 2133 mm. Data show that rainfall conditions were quite similar at both sites during the period of investigation (See Figs. 1-4).

3. <u>Erosivity and soil loss</u>

The effects of the tested cropping systems and tillage practices on soil erosion are shown in Figs. 5-10 as cumulative values. The soil losses of both sites are presented in Table 1.

The applicability of 11 erosivity indices was tested for soil loss from cleantilled fallow plots (treatment 1) of 11 m x 22 m The correlation coefficients of the calculated indices are presented in Table 2.

According to Wischmeier and Smith (1978) a rain storm is regarded as erosive when it yields more than 12.5 mm. This empirical threshold was not always supported by investigations on the erosivity of rainfall in other regions of the world, especially in the tropics. Schwertmann

(1981) found that storms with more than 10 mm of rain caused erosion in some parts of West Germany. Hudson (Morgan 1986) introduced the KE-25 index, stating that under the climatic conditions of Zimbabwe only rain with intensities higher than 25 mm/h caused erosion. LAL (1976) found that the AIm index, the product of the amount of erosive rainfall (A) and its maximum 7.5 minute intensity (Im) explained best the quantity of eroded soil, though this index has the disadvantage of ignoring the kinetic energy of rainfall. However, the investigations in Santander de Quilichao and Mondomo have shown that the ability of a storm to cause erosion depends on other factors besides the amount of rain. In Mondomo, for example, a storm of 11.5 mm caused slight erosion on November 22, 1988, whereas a storm of 20.9 mm on March 27 & 28, 1989, did not produce any soil loss. Besides the intensity and the kinetic energy of a respective storm, water contents and surface conditions (roughness, rilling) of a soil are probably very influential factors in the erosion process.

The calculation of the erosivity indices resulted in very low correlation coefficients in Santander de Quilichao and almost no correlation between the indices and soil loss in Mondomo during the 1987/88 season. Besides the limited number of samples (15 in Santander, 12 in Mondomo) the physical conditions of the soil surface were very influential. During the second season the standard plots were tilled more frequently with a rotar tiller to provide more uniform conditions by eliminating rills and soil crusts. For the second cropping season 1988/89 most of the tested erosivity indices are significantly correlated with soil erosion and the rainfactor of the USLE (Universal

Soil Loss Equation), EI30 proved to be the best. Because of the locations of the two sites it was not always possible to measure the eroded soil after each erosive storm. Therefore, if more than 1 erosive storm occurred between two sampling days the EI30-index of the biggest storm was related to soil loss. By calculating this index, which I called EI30 max, the correlation coefficients were slightly improved for both sites (Table 2). However, the differences between the data of the two cropping seasons underline the necessity to continue this type of investigation. According to Wischmeier and Smith (1978) analysis of rainfall data from 20-25 years is necessary to obtain a realistic EI30 indices.

4. Physical soil properties and erodibility

Using the known procedure described by Wischmeier and Smith (1978) to calculate the K-Factor which characterizes the erodibility of a given soil by using such parameters like grain size distribution, organic matter content and structural data did not produce reasonable K-Factors, which varied within the range of 0.080 and -0.039. This would mean that the soils of the trial sites are not susceptible to erosion at all, while soil loss actually occurred. Further analysis on physical soil properties like mineral composition, consistency limits, stability of aggregates, moisture retention characteristics etc. were done, but data still have to be evaluated.

5. Runoff

Like soil loss, runoff was measured after erosive storms on a regular basis. Unfortunately the water collecting system did not always function properly during heavy storms. Sometimes organic material entered the splitters which caused tapping and led to overflow or even with the splitters with 15 divisions it was not possible to collect all the runoff. Therefore, runoff might be underestimated. This was especially the case for the 1988/89 season. However, runoff values presented in Tables 3 and 4 are aproximations using current data and should be viewed as minimal estimates.

6. Losses of nutrients and organic matter in eroded soil

Concentrations of nutrients and organic matter in sediments are given in Tables 5-8 and the quantities of lost Ca, Mg, K, P and organic matter are presented in Tables 9-12. Treatment 1 (cleantilled fallow) presents the loss of natural soil fertility because these plots were not fertilized. High Ca-concentrations may have been caused by the material (Eternit) of which the collecting canals are made, though samples were taken carefully.

Reasonable amounts of organic matter and nutrient elements were lost to the runoff and eroded soils.

7. Yield

Cassava yields are presented in Table 13. Cowpeas of treatment 5 (TVX-1193-059D) produced an average of 0.92 t/ha in 1987/88 and 0.48 t/ha in 1988/89 in Santander de Quilichao. The same variety was very poor in Mondomo in 1987/88 with a yield of 0.19 t/ha, this because the species apparently is not adapted to the ecological conditions of the site. Therefore, beans (variety "Carioca") were planted in the 1988/89 season but a dry spell during the period of flowering led to a complete failure of the crop. Cassava yields are quite uniform with the exception of treatment 5 in Santander and treatment 7 in Santander and Mondomo. In the intercropping system (treatment 5) in Santander, cassava suffered from the competition of the grain legumes, while cassava yields of the minimum tillage treatment were apparently depressed because of the native grass competition for nutrients and water. In this treatment only the yield of the variety MCol 1522 in Mondomo was not significantly lower than those of most other treatments. This variety might be more tolerant to native grass competition.

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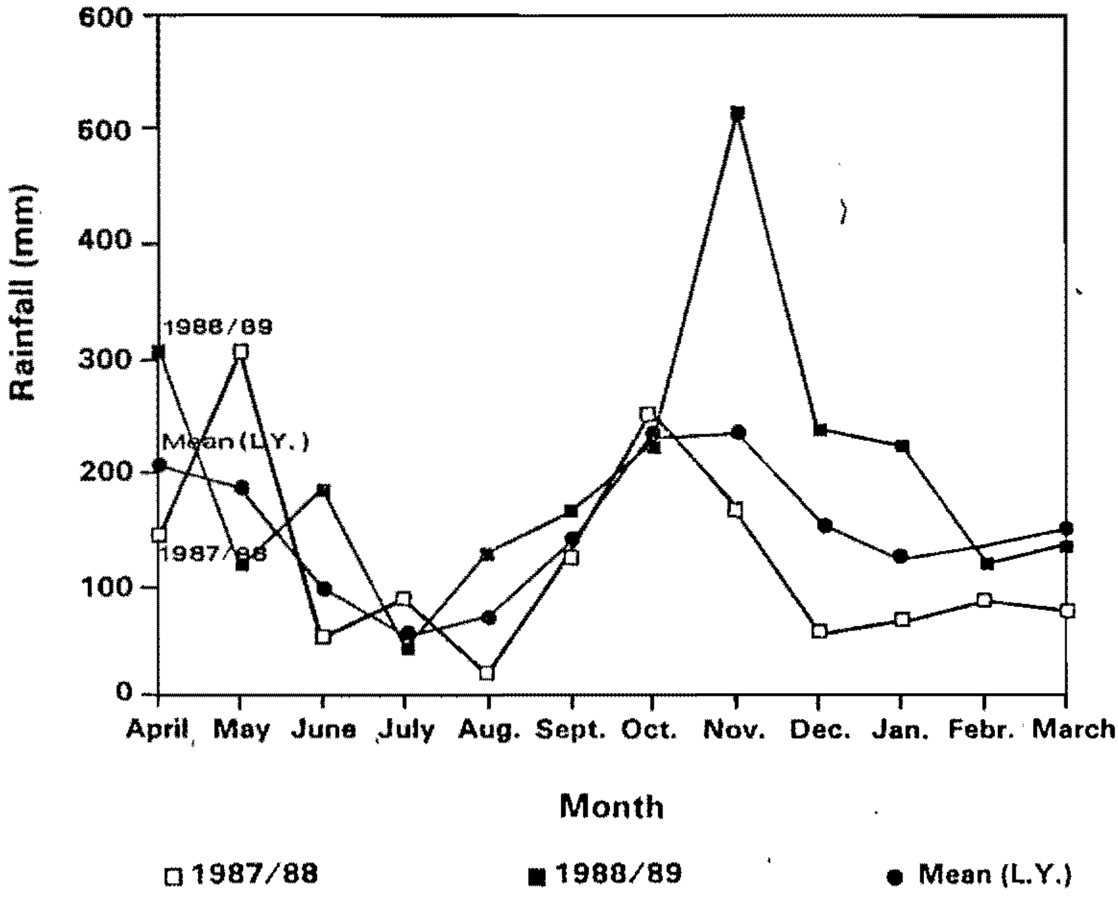


Fig. 1: Rainfall CIAT-Quilichao (mm)
1987-1989 and long year mean

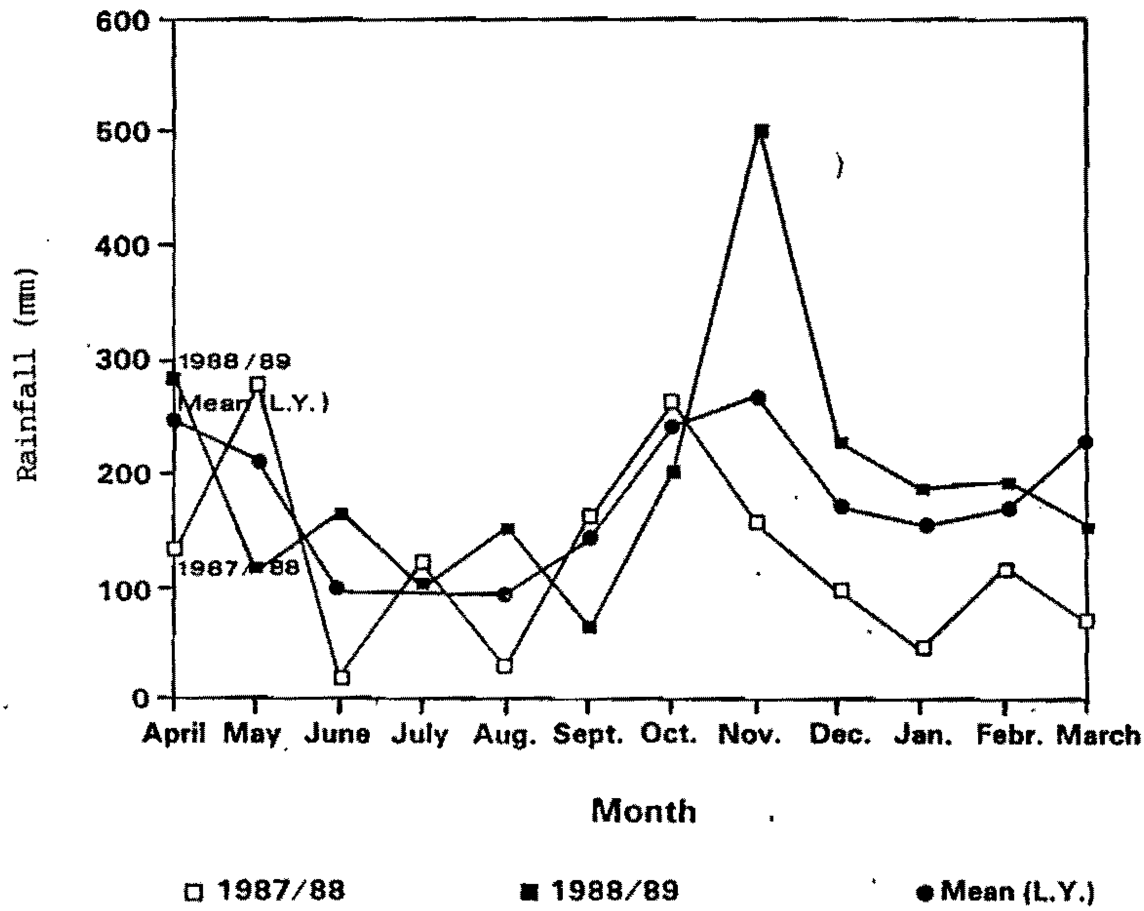
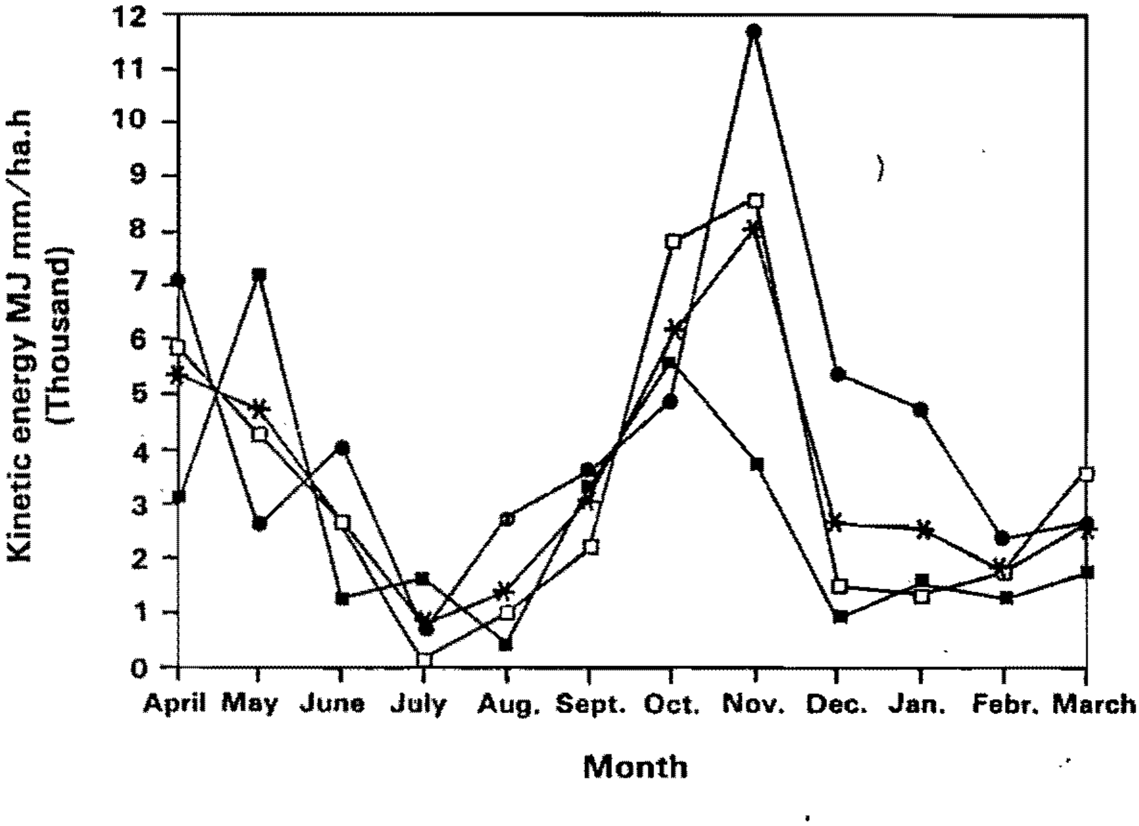
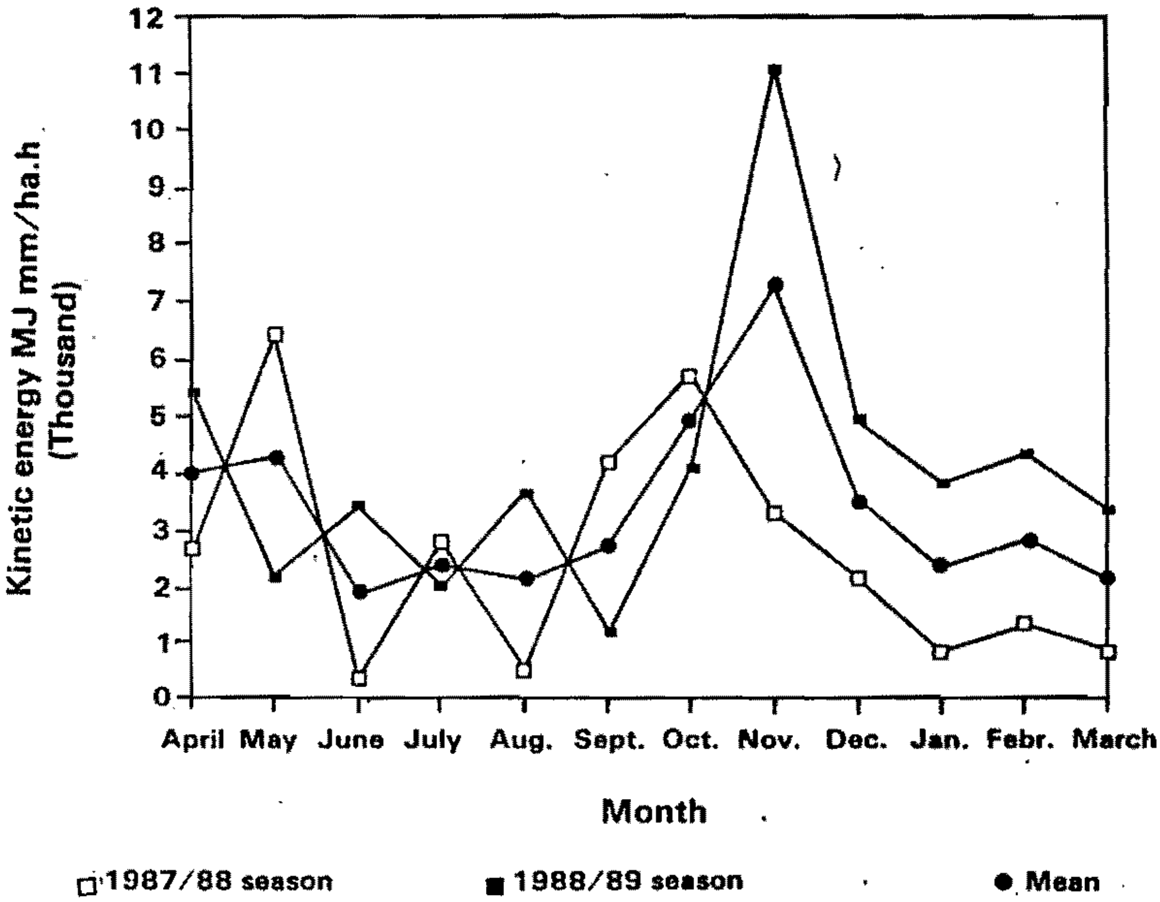


Fig. 2: Rainfall Mondomo (mm)
1987-1989 and long year mean



Kinetic Energy was calculated as: $KE = 210.3 + 89 \log_{10} I$
I = Intensity of rainfall in cm/h

Fig. 3: Kinetic Energy Rainfall CIAT-Quilichao
1986/87 — 1988/89 cropping seasons



Kinetic Energy was calculated as: $KE = 210.3 + 89 \log_{10} I$
I = Intensity of rainfall in cm/h

Fig. 4: Kinetic Energy Rainfall Mondomo
1987/88 and 1988/89 cropping seasons

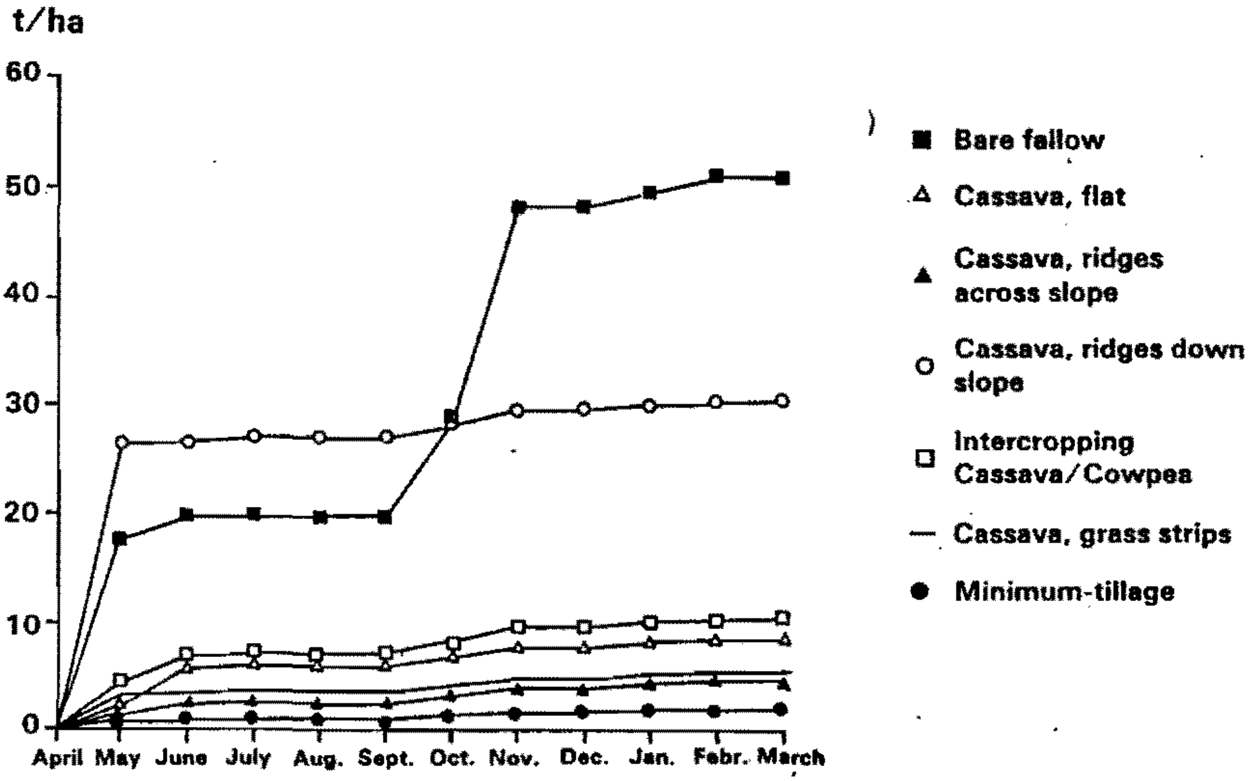


Fig. 5: Effects of different cultivation/tillage practices on soil erosion at Quilichao 1987/88 cropping cycle

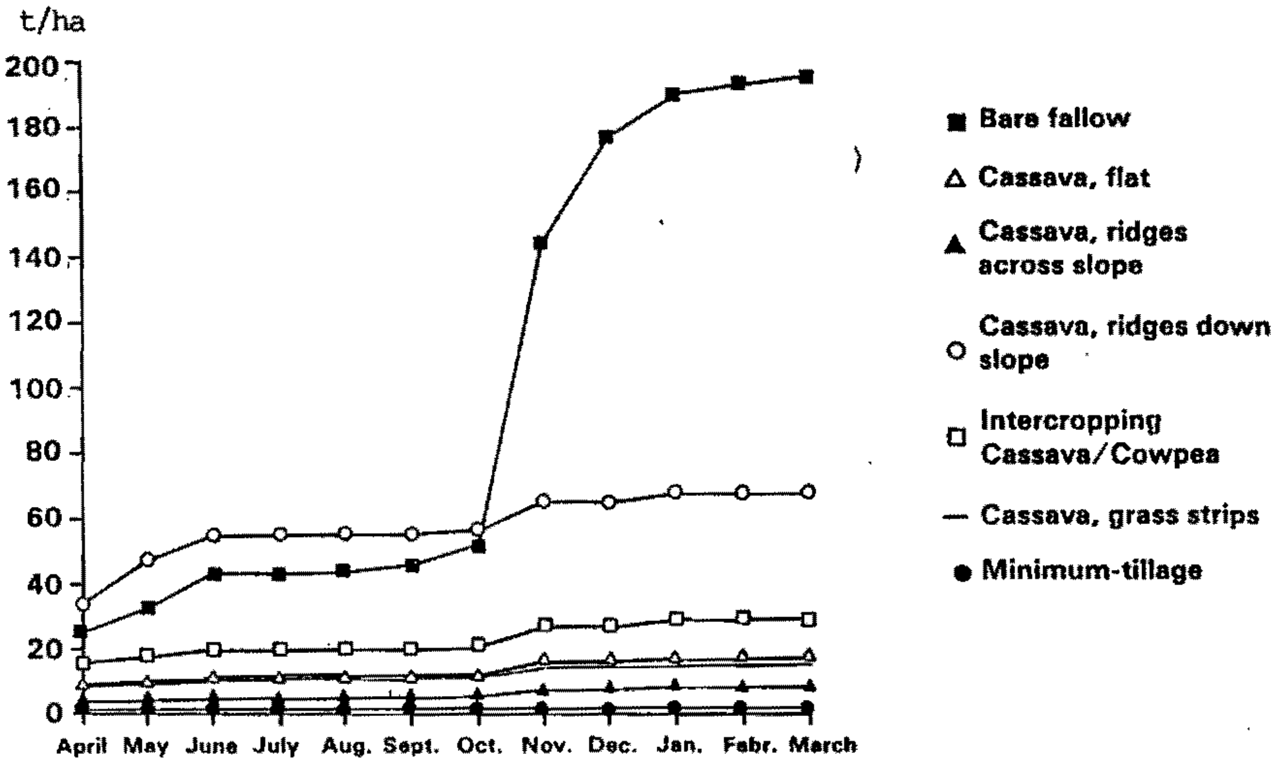


Fig. 6: Effects of different cultivation/tillage practices on soil erosion at Quilichao 1988/89 cropping cycle

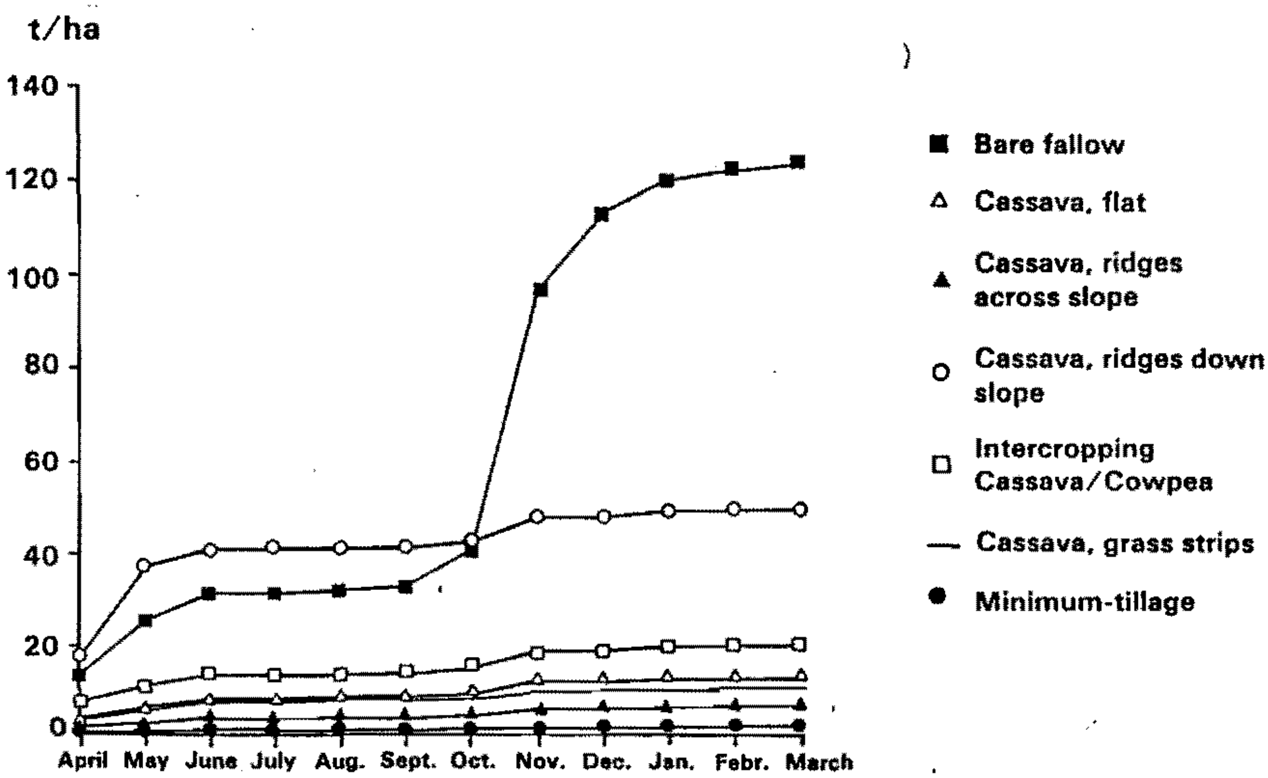


Fig. 7: Effects of different cultivation/tillage practices on soil erosion at Quilichao as an average of the 1987/88 and 1988/89 cropping cycles

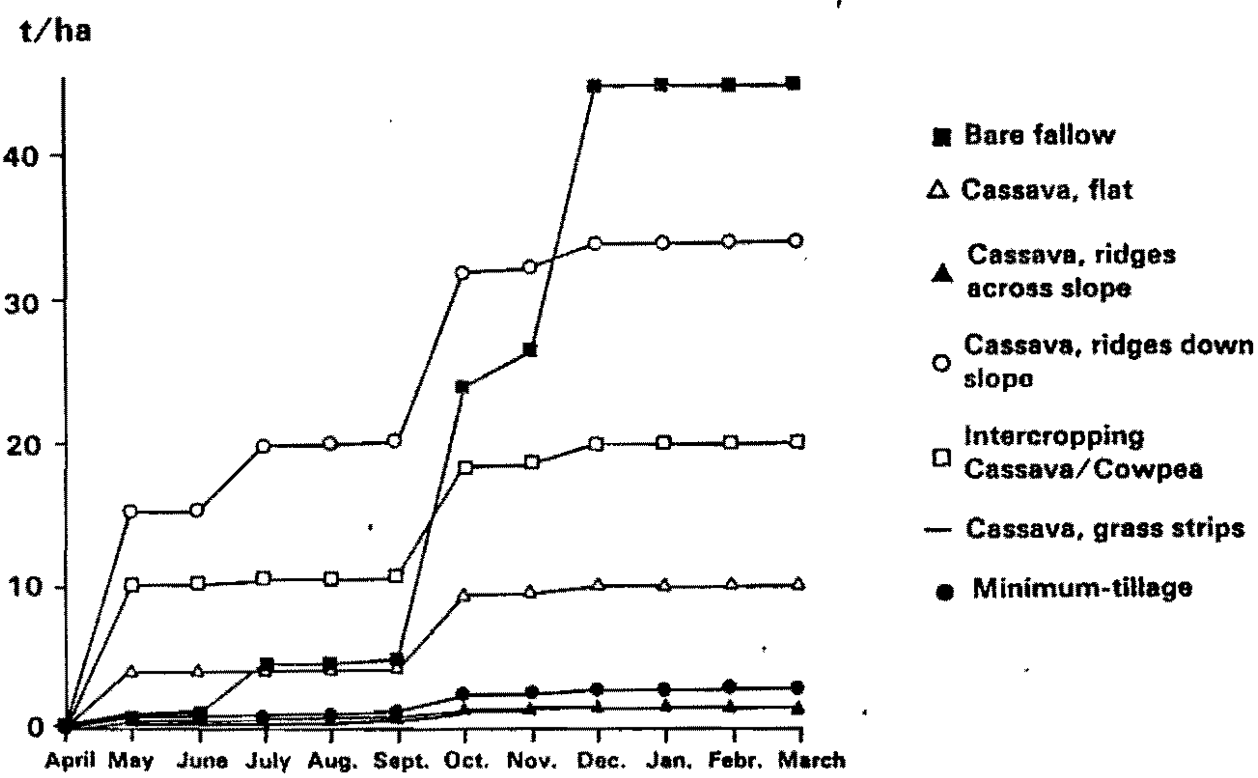


Fig. 8: Effects of different cultivation/tillage practices on soil erosion at Mondomo 1987/88 cropping cycle

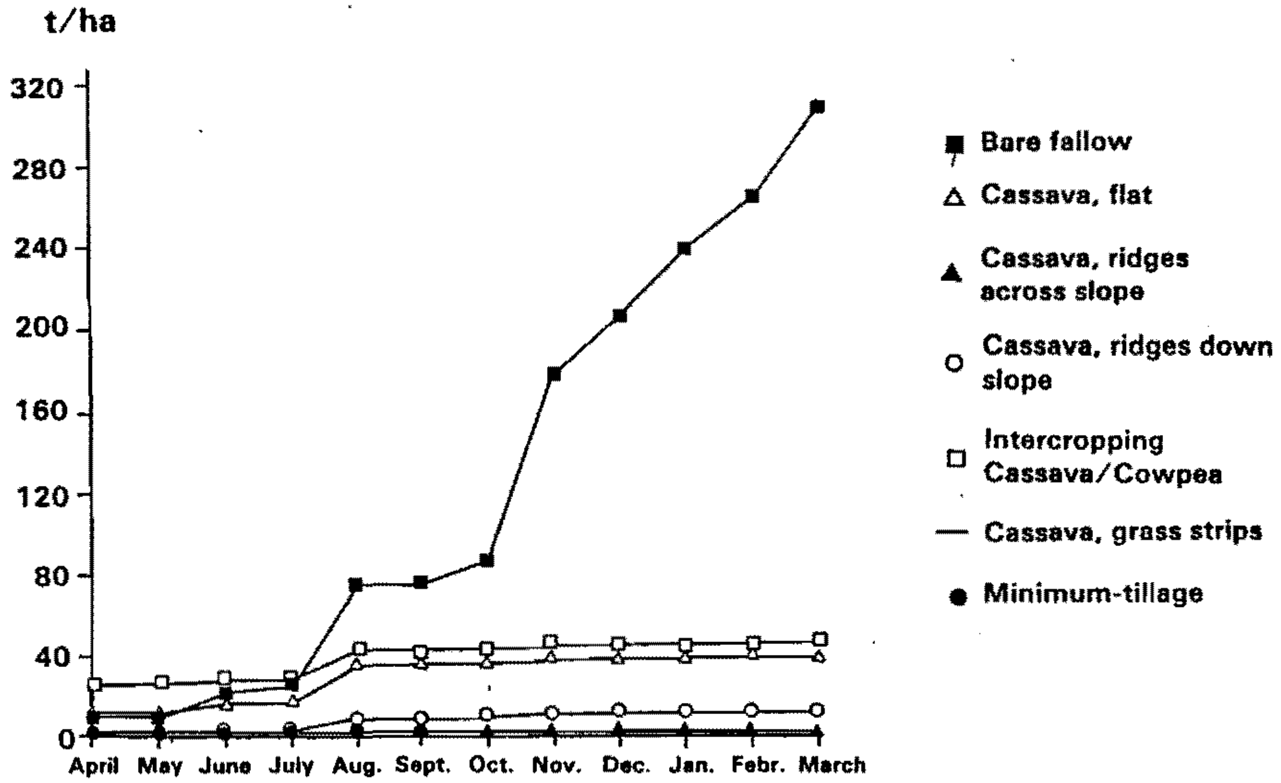


Fig. 9: Effects of different cultivation/tillage practices on soil erosion at Mondomo 1988/89 cropping cycle

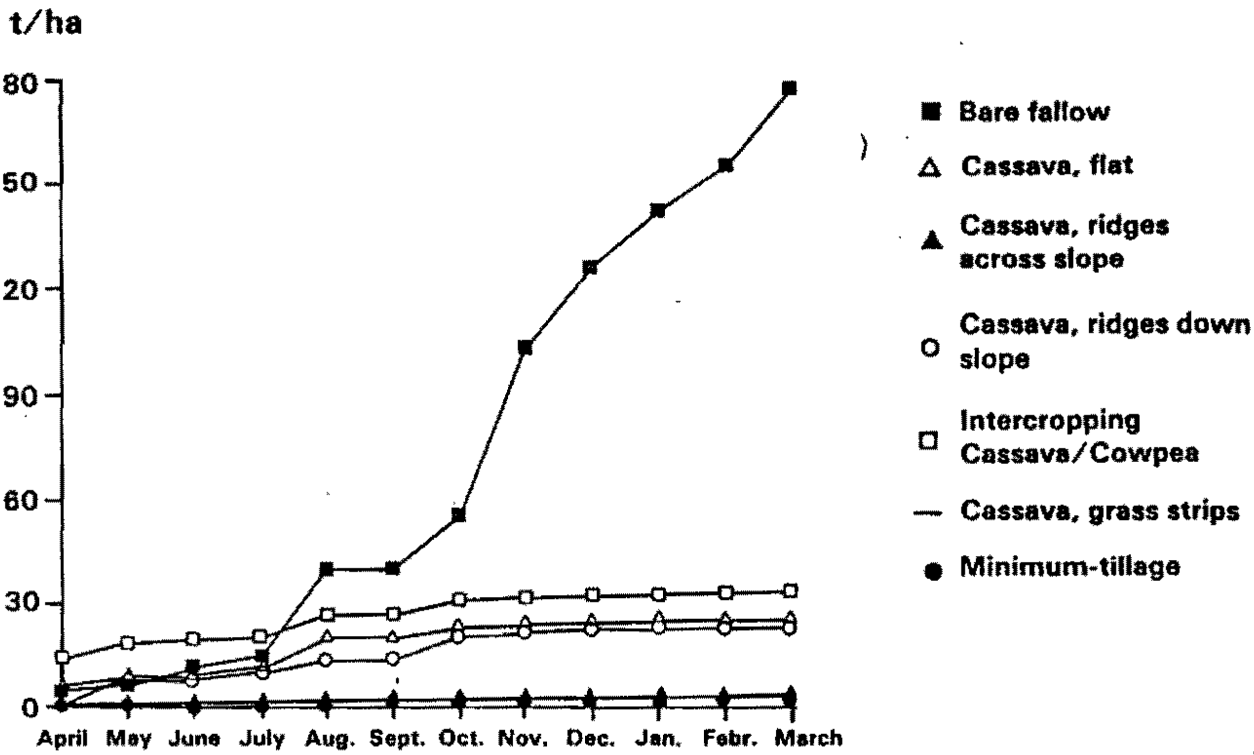


Fig. 10: Effects of different cultivation/tillage practices on soil erosion at Mondomo as an average of the 1987/88 and 1988/89 cropping cycles

TABLE 1. Soil loss during 1987/88 and 1988/89 cropping seasons at CIAT-Quilichao and Mondomo (t/ha).

Treatment	CIAT-Quilichao		Mondomo		Mean	
	1987/88	1988/89	1987/88	1988/89	CIAT-Quilichao	Mondomo
1	49.15	196.55	44.50	310.56	122.85	177.53
2	5.05	17.19	9.90	40.07	11.12	24.99
3	3.83	8.46	1.48	2.64	6.15	2.06
4	30.42	67.98	33.79	12.60	49.20	23.20
5	7.87	29.37	19.80	46.83	18.62	33.32
6	5.28	15.34	1.46	3.16	10.31	2.31
7	1.93	1.76	2.71	2.48	1.85	2.60

TABLE 2. Correlation coefficients of various erosivity indices and soil loss of treatment 1 (clean-tilled fallow).

	KE	I_{30}	EI_{30}	$EI_{30}max$	A	KE 25	I_{15}	EI_{15}	I_m	EI_m	AI_m
CIAT-Quilichao											
1987/88	0.362ns	0.555*	0.486ns	0.491ns	0.348ns	0.412ns	0.530ns	0.485ns	0.452ns	0.436ns	0.422ns
1988/89	0.398*	0.669***	0.750***	0.836***	0.290ns	0.590**	0.561**	0.730***	0.513**	0.712***	0.681***
Mondomo											
1987/88	0.054ns	-0.092ns	-0.052ns	-0.253ns	0.030ns	-0.004ns	0.060ns	-0.019ns	0.411ns	0.172ns	0.182ns
1988/89	0.564**	0.787***	0.802***	0.837***	0.480*	0.745***	0.795***	0.804***	0.786***	0.806***	0.785***

KE = kinetic energy of erosive storms

I_{30} = maximum 30-minute intensity of an erosive storm

EI_{30} = product of kinetic energy and I_{30} (rain factor of the Universidal Soil Loss Equation)

EI_{30} max = EI_{30} of biggest storm between two sampling days

A = amount of erosive rainfall

KE 25 = kinetic energy of rain with more than 25 mm/ha intensity

I_{15} = maximum 15-minute intensity of an erosive storm

EI_{15} = product of kinetic energy and I_{15}

I_m = maximum 7.5-minute intensity of an erosive storm

EI_m = product of kinetic energy and I_m

AI_m = product of amount of erosive rainfall and I_m

TABLE 3. Runoff CIAT-Quilichao 1987/88 and 1988/89 seasons.

Treatment	1987/88 mm	1987/88 % of rainfall	1988/89 mm	1988/89 % of rainfall
1	86.2	5.9	163.4	6.8
2	63.1	4.3	183.4	7.6
3	78.4	5.4	147.3	6.1
4	139.7	9.6	262.7	10.9
5	89.8	6.2	248.1	10.3
6	65.3	4.5	155.6	4.9
7	108.7	7.5	179.3	7.4

TABLE 4. Runoff at Mondomo 1987/88 and 1988/89 seasons.

Treatment	1987/88 mm	1987/88 % of rainfall	1988/89 mm	1988/89 % of rainfall
1	75.2	5.0	130.3	5.5
2	41.4	2.8	210.1	8.8
3	32.2	2.1	110.2	4.6
4	123.0	8.2	180.7	7.6
5	69.6	4.6	247.4	10.4
6	49.6	3.3	230.9	9.7
7	62.4	4.2	158.8	6.7

TABLE 5. Concentration of nutrients and organic matter in eroded soils at CIAT-Quilichao 1987/88.

Treatment	Ca	Mg	K	P	OM
	——	me/100 gr soil	——	ppm	%
1	3.82	0.40	0.19	4.9	6.4
2	6.73	0.84	0.25	10.6	6.1
3	7.13	0.68	0.29	26.7	5.5
4	5.75	0.79	0.23	13.3	5.9
5	6.50	0.78	0.27	14.1	6.0
6	7.45	0.74	0.26	14.5	5.7
7	8.54	0.59	0.30	6.7	5.1
(n = 42)					

TABLE 6. Concentration of nutrients and organic matter in eroded soils at CIAT-Quilichao 1988/89.

Treatment	Ca	Mg	K	P	OM
	——	me/100 gr soil	——	ppm	%
1	0.39	0.08	0.10	4.4	6.1
2	5.11	0.54	0.20	16.7	6.6
3	6.07	0.52	0.21	13.2	5.8
4	4.76	0.52	0.19	16.5	6.1
5	4.72	0.55	0.23	25.0	6.2
6	6.22	0.63	0.23	17.3	6.2
7	9.15	0.57	0.29	7.2	5.5
(n = 21 for Ca, Mg, K, P, n = 15 for OM)					

TABLE 7. Concentration of nutrients and organic matter in eroded soils at Mondomo 1987/88.

Treatment	Ca	Mg	K	P	OM
	—	me/100 gr soil	—	ppm	%
1	1.96	0.15	0.14	3.5	6.1
2	6.50	0.50	0.26	9.6	5.9
3	8.72	0.57	0.29	5.6	6.0
4	4.03	0.73	0.23	12.9	6.1
5	4.64	0.53	0.26	18.3	6.1
6	8.53	0.54	0.27	5.4	5.7
7	6.22	0.41	0.20	6.5	5.5
(n = 26)					

TABLE 8. Concentration of nutrients and organic matter in eroded soils at Mondomo 1988/89.

Treatment	Ca	Mg	K	P	OM
	—	me/100 gr soil	—	ppm	%
1	0.67	0.06	0.09	3.3	5.9
2	5.25	0.49	0.26	11.6	6.1
3	8.36	0.59	0.26	10.3	6.9
4	5.44	0.40	0.23	13.9	6.6
5	6.36	0.96	0.33	18.1	5.8
6	9.20	0.67	0.35	11.9	7.0
7	7.43	0.67	0.28	12.6	6.1

(n = 18 for Ca, Mg, K, P, N = 12 for OM)

TABLE 9. Losses of organic matter and nutrients in eroded soils at CIAT-Quilichao 1987/88.

Treatment	Ca	Mg	K	P	OM
			kg/ha		
1	37.63	2.39	3.65	0.241	3.146
2	6.81	0.52	0.49	0.054	308
3	5.47	0.32	0.43	0.102	211
4	35.05	2.92	2.74	0.405	1.795
5	10.25	0.75	0.83	0.111	472
6	7.88	0.48	0.54	0.077	301
7	3.30	0.14	0.23	0.013	98

TABLE 10. Losses of organic matter and nutrients in eroded soils at CIAT-Quilichao 1988/89.

Treatment	Ca	Mg	K	P	OM
			kg/ha		
1	15.36	1.91	7.69	0.865	11.990
2	17.60	1.13	1.34	0.287	1.135
3	10.29	0.53	0.69	0.112	491
4	64.85	4.30	5.05	1.122	4.147
5	27.78	1.96	2.64	0.734	1.821
6	19.12	1.18	1.38	0.265	951
7	3.23	0.12	0.20	0.013	97

TABLE 11. Losses of organic matter and nutrients in eroded soils at Mondomo 1987/88.

Treatment	Ca	Mg	K	P	OM
	kg/ha				
1	14.48	0.81	2.44	0.166	2.715
2	12.90	0.60	1.01	0.095	584
3	2.59	0.10	0.17	0.008	89
4	27.29	3.00	3.04	0.436	2.061
5	18.41	1.28	2.01	0.362	1.208
6	2.50	0.10	0.15	0.008	83
7	3.38	0.14	0.21	0.018	149

TABLE 12. Losses of organic matter and nutrients in eroded soils at Mondomo 1988/89.

Treatment	Ca	Mg	K	P	OM
	kg/ha				
1	41.70	2.27	10.93	1.025	18.323
2	42.16	2.39	4.07	0.465	2.444
3	4.42	0.19	0.27	0.027	182
4	13.74	0.61	1.13	0.175	832
5	59.69	5.47	6.04	0.848	2.716
6	5.83	0.26	0.43	0.038	221
7	369	0.20	0.27	0.031	151

TABLE 13. Cassava fresh root yield in erosion trials at CIAT-Quilichao and Mondomo (t/ha).

Treatment	CIAT-Quilichao* CM 523-7	Mondomo ** MCOL 1522 (Algodona)	MCOL 2259 (Selección 40)
2	31.12	19.70	15.52
3	29.73	15.25	15.65
4	27.70	15.37	14.57
5	21.29	16.84	15.51
6	27.12	18.19	20.18
7	8.95	15.74	6.99
Mean	24.32	16.86	14.74
$LSD_{0.05}$	3.66	2.92	8.44

* (Mean of 1986/87, 1987/88 and 1988/89 cropping seasons)

** (Yield of 1988/89 season only, previous crop was lost due to frog skin disease).

CASSAVA BREEDING 1989

The core activities of the cassava breeding section continue to be the conservation and evaluation of the world cassava germplasm collection, genetic improvement of broad-based gene pools for adaptation to distinct edaphoclimatic regions, and collaboration with national programs through training, germplasm introductions, and consulting. All these activities are long-term responsibilities of CIAT, and are expected to occupy most of the human and material resources of the breeding section through the next decade. The present report summarizes the principal research areas and results of 1989. Additional background information may be found in previous CIAT Annual Reports.

Germplasm Management

Conservation

Present status of CIAT's germplasm collection is given in Table 1. This represents a small increase over last year, with some additional accessions from Colombia, and new hybrids being incorporated into the bank. The collection is maintained continuously in the field, and 90% of the accessions have now been transferred to *in vitro* culture, maintained under slow growth conditions. Within two years, the entire collection will be passed to *in vitro* conditions.

The concept of a core collection is being studied for the case of cassava. A core collection as applied to cassava would involve identification of a subset of the total collection (on the order of 10% of the total), in which a high proportion of the genetic variation is represented. There is still considerable debate among germplasm specialists on the optimal means for determining components of a core collection, but frequently suggested criteria include measures of variation based on origin, morphological and biochemical descriptors, and agronomic traits such as pest and disease resistance, adaptation and quality.

While the identification of a core collection would not imply discarding any accessions, it would provide a manageable set of clones for detailed studies of the genetic variation in the crop. This is especially important for traits which are difficult or costly to evaluate. By concentrating first on a core collection, researchers can extrapolate to the whole of the crop's genetic diversity at considerable savings in time and money. There is of course some risk that potentially important rare genes may not be included in a core collection, and this risk must be balanced against other considerations.

Characterization

Over the last two years, the breeding section in collaboration with the Biotechnology Research Unit, has been characterizing the germplasm collection for electrophoretic patterns of esteraze isozymes. This class of isozymes has resulted, among 28 tested, the most polymorphic and has excellent resolution of bands (Figure 1). By the end of 1989, almost half of the collection (1950 accessions) was characterized.

The information will be used for several purposes, including duplicate identification, study of patterns of genetic variation, and correlations with characteristics of agronomic potential. First priority will be given to duplicate identification, using combined morphological and biochemical criteria. This work will begin in early 1990.

Some preliminary observations on the patterns obtained to date are probably indicative of patterns within the world germplasm of cassava. There is a wide range among countries on the frequency of bands. The extreme rarity of some bands (e.g., bands 12 and 17) shows the need for a very careful analysis on the basis of a range of criteria in the definition of a core collection, in order to include the highest possible degree of variation.

Based on isozyme patterns alone, 688 distinct genotypes were found among the 1950 accessions evaluated. Of these, 378 patterns were unique. The two patterns representing the largest number of accessions (35 each) were those showing presence of bands 3, 11 and 23; and 11 and 23. Clones showing the same electrophoretic patterns are not neccessarily duplicates: it means only that they are identical at the relatively few loci represented by the esterase genes. In order to identify duplicates, electrophoresis data will be used in conjunction with morphological descriptors.

Band frequency appears to differ depending on the origin of the materials, indicating possibilities of studying evolutionary patterns in cassava on the basis of electrophoretic patterns. Table 2 illustrates the frequency of 18 of the 23 bands evaluated, by groups.

Apart from the use of isozymes for germplasm bank characterization, the technique has been used in several studies of varietal identification. As one example, on Colombia's north coast region, the variety known as Venezolana is the most commonly grown. However, there has been some suspicion on the part of both farmers and local researchers that the variety may actually be a mixture of similar clones. One indication that this may be the case was the observation of differences in branching habit of

Venezolana on different farms. Since Venezolana is being officially multiplied and distributed, ICA asked CIAT to compare Venezolana accessions showing different branching habit, using isozyme analysis. Stakes were taken from plants showing early, intermediate and late branching. Electrophoretic patterns were analyzed for four isozyme systems ($\alpha\beta$-esterese, diaphorase, $\alpha\beta$ phosphatase, glutamic oxalic transaminase) and from two types of tissue (root tips and shoots). For all systems and for both types of tissue, there were no differences observed among the materials of different origins. While this is not conclusive evidence that the Venezolanas showing different branching habit are the same clone it strongly suggests that this is the case. Differences in branching habit are probably due to sensitivity of the clone to micro-environmental differences. Further studies are being carried out to look at branching habit when Venezolana from different sources and of different habit are grown together under uniform conditions.

Exchange

One of the services CIAT offers as a global repository for cassava germplasm is the return of accessions to countries of origin. Loss of material in the country of origin or need for introducing virus indexed material are two of the common motivations for this type of exchange. During 1988/89, significant parts of the collection from Peru (256 accessions) and from Paraguay (171 accessions), were returned as virus-indexed, in vitro clones.

Gene Pool Development

General Philosophy and Strategy

CIAT has been developing and evaluating germplasm specifically adapted to the major constraints for the main edaphoclimatic zones (ECZs). Even though Colombia has a variety of conditions that are broadly similar to the different ECZs, there are always production or utilization criteria specific for a country or region. As a result, it is hard to develop clones in Colombia with direct application for the national programs. Selected clones for particular ECZs are used as parents to generate progenies in controlled crosses or/and polycrosses. Segregating progenies are screened by national programs for the in situ selection of adapted materials.

The connection between breeding at the national program level and population improvement done at CIAT is the interchange of both germplasm and information. Particularly important for our breeding program is to obtain feedback on the average progeny performance and the number of selections from each progeny. With that information, breeders at CIAT headquarters can make informed decisions on parents to use in future crosses, and the possibility of recycling clones that may not have been selected under Colombian conditions. That is particularly relevant for the subtropics (ECZ 6), since similar conditions cannot be found in Colombia. Centralizing breeding for the subtropics in a representative area in southern South America is now being considered.

An ideal breeding scheme for cassava would include the development of progenies at CIAT and their subsequent, evaluation in different regions of the world, within the same ECZ (i.e., for ECZ 1: Colombian north coast, northeast Brazil, semi-arid Africa, and northeast Thailand). With the information on average performance, parental materials maintained at CIAT could be selected for recombination, and the production of families for the following cycle. Other promising materials can be evaluated and incorporated into the population improvement scheme at any time. The strong collaboration with national programs (e.g., Brazil), and at the regional level (e.g., semi-arid Africa) that is being developed, will open the possibility for such an approach in the future. That will allow the orientation of our breeding activities toward obtaining germplasm adapted to a range of conditions within the same ECZ, and with suitable variability for allowing selection for specific local traits.

Genetic variability is being introduced into national programs as clones (in vitro or virus-indexed stakes) or as botanical seeds. The former strategy allows for the maintenance of the genetic integrity of a clone (important when there is a balance of good traits in a clone), but it carries the risk of pathogen transfer. Shipment of seeds, on the other hand, allows for the introduction of a broader range of genetic variability, from which specifically adapted genotypes can be selected under the particular growing conditions of a national program. This approach requires well developed facilities since it involves a number of steps before reaching the level of yield trial, and the handling of a large number of genotypes. Generation of genetic variability by controlled crossing or polycrosses has been the base of our breeding program and the cooperation with national programs. A brief report on the advances made within each particular gene pool in Colombia, and advances at the national program level for specific countries, is presented here.

Lowland tropics with low to intermediate rainfall and long dry season (Edaphoclimatic Zone 1)

Media Luna (Magdalena) is considered the principal selection site for ECZ 1. Breeding materials are evaluated there, from F_1C_1 up to advanced yield trials. El Carmen (Bolivar) is the secondary selection site for ECZ 1. Progenies selected in Media Luna are evaluated, starting at the preliminary yield trial level. This year, hurricane Joan affected both planting seasons, and reliable data could not be gathered from El Carmen.

The ideotype that is sought for ECZ 1 includes the combination of good plant type, high root yield, high dry matter, and adequate levels of disease and insect resistance. It is usually hard to get clones approaching dry matter levels of the local check Venezolana (M Col 2215). This year at least one elite clone fell within non-significant difference in terms of dry matter content, with respect to M Col 2215, in both seasons (Table 3). Due to the high yield potential of advanced materials, all of the top 10 yielding clones produced significantly higher amounts of dry matter per hectare than the check. HCN levels, determined by the colorimetric method, are usually higher than the check's readings. Some elite clones have intermediate levels, but combining even lower HCN levels and higher dry matter will continue as a primary objective for this zone.

Lowland tropics with acid soil savannas, and high rainfall (Edaphoclimatic Zone 2)

Most of the breeding activity for ECZ 2 is being conducted now at the ICA - La Libertad experiment station, near Villavicencio. A replication of the observational trial is still maintained at Carimagua for selection under heavy pressure from bacterial blight (CBB) and superelongation disease (SED). As was expected, disease pressure at La Libertad is increasing: susceptible checks consistantly have high scores (highly affected) for CBB, SED and anthracnose. This fact, in addition to the potential for cassava development in the "piedemonte", is proving that the movement of the program to La Libertad will soon produce considerable benefits. Selections from ECZ 2 conditions are often adapted also to the humid tropics (ECZ 3). Since germplasm development in the Colombian Amazon was discontinued, national programs within ECZ 3 usually receive progenies and/or elite clones from ECZ 2.

There are several good advanced clones, with a superior combination of characteristics with respect to the check M Ven 77 (Table 4). Three advanced clones are being put into consideration for future release by ICA. As in previous seasons, clone CM 2766-5 fell within the first 10 high yielding clones. Its ability to produce well under different conditions results in an almost ideal genotypic reaction to different production conditions. Clone CG 165-7 has consistantly appeared within the best clones for ECZ 2, but its eating quality has left it outside ICA's consideration for release. However, it could be an important candidate for industrial purposes. Segregating progenies from ECZ 2 have also proved to do well in other regions with similar disease and pest problems (e.g., Paraguay).

Middle altitude tropics (Edaphoclimatic Zone 4)

Even though it has relativily less importance than ECZs 1 or 2, breeding efforts at CIAT headquarters have generated several promising clones. Significantly higher dry matter yield per hectare, with similar or lower levels of HCN, than the local check (HMC 1) has been obtained (Table 5). Screening for resistance to thrips and mites is stressed at CIAT-Palmira. A good indication of the success obtained in selecting resistant clones to these pests is the fact that, even though the susceptible spreader rows are completely affected by the pests in the advanced yield trials, few clones reach higher than intermediat levels of infestation.

Tropical highlands (Edaphoclimatic Zone 5)

Expansion of the genetic base of the highland gene-pool has been the main concern over the last years. From a massive screening of germplasm accessions, only two new entries appeared to be well adapted to highland conditions, with high yield potential and adequate levels of resistance to Phoma, the most important disease.

Relatively slow progress has been achieved trying to incorporate genes from lowland clones in crosses with adapted highland clones. Since germplasm from other ECZs can be considered as highly exotic to growing conditions in the highlands, germplasm introgression can be attempted through 3-way crosses, or other types of crosses that result in a smaller percentage of exotic germplasm than two-parent crosses. A major thrust of the next several cycles for the ECZ 5 gene pool will be to incorporate resistance to CBB, an important constraint in some highland cassava-growing areas.

A summary of results of harvests of advanced yield trials in 1989 are given in Table 6. While a few years ago few clones exceeded the local check (M Col 1522) in yield, many new hybrids now combine high yield and good root quality. Important target areas for this gene pool are the Andean zone and the highlands of East Africa.

Subtropics (Edaphoclimatic Zone 6)

Generation of genetic variability for the subtropics has been approached by crossing local varieties for the region and clones from the ECZ 2 gene pool as a source of CBB resistance; or crosses among parental materials from ECZ 2. Preliminary data from Paraguay showed a net superiority in root yield with respect to local checks. The introduced materials also presented promising resistance to CBB. However, none of these first generation selections has proved to have eating quality acceptable for Paraguayan standards. Extensive evaluation of national germplasm collections in subtropical regions and a centralized evaluation of subtropical germplasm will reveal the most suitable clones to use in our crossing schemes, and their principal weaknesses. At the moment, materials are selected based on their importance in terms of area planted, and the main reported problems for cassava production in the subtropics. Breeding for subtropical conditions will acquire considerable dimensions with CIAT's support to the activities being developed in southern Brazil.

Overview of Activities in Selected National Programs - Latin America

Paraguay

In spite of deficiencies in both human and material resources, cassava breeding research in Paraguay has expanded modestly in recent years. Their central breeding activity is the evaluation of the local germplasm collections. There are three collections maintained in Paraguay at the moment: a) the national collection established at Choré between 1983 and 1986 in collaboration with CIAT and IBPGR; b) about half of the national collection established at Caacupe; and c) the local collection made by SEAG (Capitán Miranda). From the latter collection, ten clones were selected (based on yield and area planted commercially), and are being evaluated in on-farm trials. One clone, Meza-i, not widely grown in Paraguay, has good yield potential combined with moderate resistance to CBB. It is being included as part of the recommended technology by the cassava project.

Extensive evaluation of the national collection could help detect clones combining desirable characters and that were previously not grown in large areas. This task will certainly have short-term priority over a massive introduction and screening of segregating progenies sent by

CIAT. Part of the national collection was received from CIAT *in vitro*, and is being maintained and multiplied at IAN, in order to get enough planting material to compare "clean" and "unclean" material from the same entries. Yield advantages of virus-free materials could be determined in that way.

Colombia

Cassava varietal development work in Colombia this year was highlighted by pre-release seminars by ICA for six new clones of CIAT origin -- three for the Atlantic coast region (low rainfall; long dry season), and three for the eastern savannas (high rainfall; acid soils; heavy disease pressure). Five of the six clones are the result of hybridization made between 1980 and 1982, and one (CM 523-7), from a cross made in 1975.

The clones for the Atlantic coast region were selections resulting from collaboration between CIAT and ICA-CRI El Carmen in Bolivar Department. The three clones were selected on the basis of good yield potential, high dry matter, good eating quality, resistance to principal pests and diseases in the region, and good plant type (Table 7). Final selection was based largely on trials planted in farmers' fields. During 1988/89, fourteen trials were planted on farm, managed by farmers, and evaluated with farmer participation at harvest. These data give solid support to the probable acceptability of the clones for the region.

The varietal development work in the savannas has also been a close collaborative work between CIAT and ICA. The principal selection has been at two ICA experiment stations: Carimagua in eastern Meta Department, and La Libertad in western Meta, in the piedmont area. The clones selected for this region are also characterized by high yield, good eating quality, and resistance to local pests in diseases, principally bacterial blight and superelongation disease (Table 8).

Mexico

Subsidies on sorghum in Mexico continue to act as a strong disincentive for development of a viable cassava industry. Over the past few years production in Tabasco state in officially sponsored projects has remained at 500 - 1000 ha, with production destined primarily for silage or dried chips for pig rations. Nevertheless research continues on the crop within INIFAP, with the expectation that economic realities will eventually bring pressure for reducing subsidies on sorghum and seeking alternatives to escalating grain imports.

In 1988, three hybrids of CIAT origin, selected from seed introductions in the early 80s, were identified as promising and planted in multiplication/pre-commercial plots at two sites. They will be planted in validation plots at the end of 1989, with release expected next year. On average the three hybrids (CGM 1322-12, CMM 4051-1 and CGM 1311-1) have shown a 27% yield advantage over the selected variety "Sabanera" which at present occupies most of the cassava area in Tabasco.

In the Yucatan peninsula, INIFAP has recently begun research on cassava near Campeche. A large potential market exists for balanced rations for the pig industry. At present, however, the subsidies on sorghum and lack of an appropriate technology mitigate against rapid development of a viable cassava industry. INIFAP is taking a longer view, and has begun research on varieties and agronomic practices for the region. Initial trials showed clearly that the technology developed in Tabasco is not suitable to the Yucatan peninsula, with large differences in climate and soils. Research is concentrated on variety evaluation, which began with introduction of the Mexican germplasm collection, and was followed by introductions from CIAT. The latter are in a multiplication phase and will be planted in yield trials next year.

Panama

IDIAP has maintained a continuous flow of germplasm introductions from CIAT since 1982, both as in vitro cultures and segregating populations. From the earliest introductions, the clone locally named "Dayana" has continued to demonstrate superior performance and is now planted in second year validation trials and commercial multiplication plots. In first year validation trials, Dayana yielded 25 t/ha, compared to 15 t/ha for the local clone Brasileña. The CIAT hybrid CM 955-2 has also been giving promising results and is included in validation trials this year.

In Panama, the recent political and economic uncertainly has been a setback to support for agricultural research in general and to the adoption of new technology by farmers. Nevertheless future demand for cassava seems assured and the inpetus this is creating for new varieties and improved agronomic practices is already evident.

Brazil

Because Brazil very probably has the world's broadest diversity of cassava germplasm, CIAT has emphasized collaborative activities which exploit this native diversity, including collection, characterization and utilization in a crossing program. Introduction of germplasm from CIAT has also been on ongoing activity since more than ten years ago.

The principal mode of collaboration has been through the cassava center (CNPMF), at Cruz das Almas, which in turn coordinates cassava research activities with state and regional institutions. A notable development in CIAT-CNPMF collaboration during 1989 has been the planning of a joint project for development of germplasm adapted to semiarid regions of Brazil and Africa. Since there are extensive climatic homologues between the semiarid areas of northeast Brazil and sub-Saharan Africa, it is hypothesized that the diverse germplasm of this part of Brazil could be well-adapted to Africa. CIAT, IITA and the CNPMF will work in a joint project to mutually benefit both Brazil and Africa with drought-tolerant, pest resistant and high yielding clones.

A parallel program is being established in southern Brazil with EMPASC in Santa Catarina state to develop varieties for the subtropics. This project will serve the southern cone of South America, Cuba, China and southern Africa.

Participatory Research on Farm

The final tests for acceptance of a new variety are in the farmers' fields and in the market place. Thus it is logical that farmers can and should contribute their experience and perspectives to breeders in defining selection criteria in all stages of selection. The application of sound social sciences theory can greatly increase the productivity of the interactions between farmers and breeders in on-farm trials.

The breeding section has been involved since 1986, jointly with CIAT's Participatory Research group, and national program scientists, in developing methodology for obtaining farmer input into selection. With experiences gained from some preliminary activities, a refined methodology has been applied this year in Colombia and in Ecuador.

The core of this methodology is capturing the farmers' reactions to the varieties being tested in a systematic manner, such that legitimate comparisons can be made across sites. The on-farm trials normally include 10-15 clones, including one or more local checks. Basic trial design (e.g., plot size and arrangement) are determined by the agronomist, but most other aspects of management are left to the discretion of the farmer, such as inclusion of an intercrop, form of land preparation, fertilization and weeding. Two harvest dates are suggested (early and normal), though this may vary with the situation.

A major objective of these trials is to provide feedback to the breeders on setting selection priorities. Without adequate interaction with farmers and consumers, breeders may miss key criteria, thus rendering otherwise good varieties unacceptable. The experiences in two distinct regions of Colombia have provided some excellent feedback to the CIAT/ICA breeding efforts.

During 1989, trials were harvested from 14 on-farm sites in the Atlantic coast region. Since several of the national program collaborators were inexperienced in the procedures, the quality of the data are somewhat variable. Nevertheless some clear results emerge, and the experience has served as a training for the technicians involved in the trials.

Table 9 summarizes the salient data from the Atlantic coast trials. The most notable aspect of these trials is that four hybrids were positively evaluated in all respects, and these four have been selected by ICA for possible release based on these as well as other data. This indicates that the criteria used by CIAT/ICA breeders has been highly compatible with those of farmers of the region. The one clear example of a clone which was rejected (CM 3306-9) demonstrated that a clone with light brown roots and/or poor eating quality will not be acceptable even if high yielding.

Trials in Cauca were managed more uniformly, since fewer scientists were involved. While some of the criteria considered by farmers in this region were similar to those of the coast (e.g., production, starch content and ease of harvest) (Table 10), others were more region-specific (e.g., root thickening, stake production and branching habit). In these trials, two introduced clones and the local variety were evaluated as good in all important criteria. Nearly all the clones were considered good in production (one of the principal selection criteria by breeders) but several had other deficiencies, especially in the aspect of root thickening. Since most of the clones were selected in the highland station at Popayan, it appears that this selection site is not entirely appropriate for the area Pescador and Morales where the trials were conducted. These results suggest that means should be taken to broaden the adaptation of clones selected for the highland ecosystem. To do this, more effort will be made, first to include a broader germplasm base in the gene pool for this zone, and secondly to evaluate material in other sites in addition to Popayan to assure broader adaptability.

Future Initiatives

During 1989 CIAT went through the process of a ten-year strategic plan. This plan contemplates major new initiatives in two areas related to cassava breeding: research on developing a viable technology for commercial cassava production from true seed; and the establishment, characterization and utilization of a wild species collection. Preliminary work has already begun in both these areas, and is expected to expand significantly in the next few years.

Table 1. Cassava accessions in CIAT germplasm collection.

Country of origen	Total accessions	Last code assigned
Argentina	16	M ARG 16
Bolivia	3	M BOL 3
Brasil	833	M BRA 930
Colombia	1893	M COL 2624
China	1	M CHN 1
Costa Rica	147	M CR 149
Cuba	74	M CUB 74
Dominican Republic	5	M DOM 5
Ecuador	117	M ECU 200
Fiji	6	M FJI 6
Guatemala	90	M GUA 92
Indonesia	51	M IND 51
Malaysia	67	M MAL 69
Mexico	101	M MEX 111
Nigeria	19	M NGA 19
Panama	42	M PAN 139
Paraguay	194	M PAR 195
Peru	406	M PER 615
Philippines	6	M PHI 6
Puerto Rico	15	M PTR 102
Thailand	8	M TAI 8
United States	9	M USA 9
Venezuela	241	M VEN 332
Hybrids ICA-CIAT	291	CM 4481-1
TOTAL	4635	

Table 2. Frecuency of $\alpha\beta$-esterase bands for different groups of cassava germplasm.

	BAND																		
GROUP	2	3	4	6	8	11	12	13	14	15	16	17	18	19	20	21	22	23	TOTAL
HMC	25.0	25.0	0.0	0.0	25.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.0	25.0	0.0	25.0	100.0	4
BRAZIL	3.8	8.3	74.9	29.9	38.7	56.5	0.0	1.9	4.1	0.0	47.7	0.3	0.4	9.2	20.3	19.3	30.2	73.3	688
COLOMBIA	29.4	35.3	17.6	31.8	50.6	71.8	0.0	22.4	20.0	0.0	22.4	0.0	1.2	22.4	5.9	49.4	4.7	80.0	85
CUBA	0.0	100.0	0.0	0.0	60.0	100.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	20.0	100.0	5
DOMINICAN REP.	0.0	60.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	5
ECUADOR	26.2	40.2	3.7	32.7	59.8	79.4	0.0	1.9	4.7	8.4	34.6	0.0	0.9	7.5	27.1	21.5	60.7	27.1	107
FIJI	83.3	50.0	16.7	16.7	33.3	66.7	0.0	0.0	0.0	0.0	66.7	0.0	0.0	0.0	16.7	50.0	0.0	83.3	6
GUATEMALA	2.4	53.0	8.4	21.7	62.7	96.4	0.0	0.0	0.0	15.7	39.8	0.0	0.0	15.7	7.2	13.3	43.4	92.8	83
INDONESIA	19.6	30.4	4.3	26.1	32.6	59.7	0.0	0.0	0.0	0.0	23.9	0.0	0.0	6.5	6.5	67.4	37.0	56.5	46
MALAYSIA	19.7	57.6	6.1	18.2	42.4	56.1	0.0	0.0	0.0	0.0	25.8	0.0	0.0	0.0	6.1	50.0	3.0	81.8	66
MEXICO	3.8	9.6	44.2	26.9	15.4	73.1	0.0	1.9	1.9	26.9	17.3	0.0	0.0	44.2	26.9	7.7	26.9	63.5	52
NIGERIA	0.0	0.0	50.0	0.0	0.0	50.0	0.0	0.0	0.0	0.0	50.0	0.0	0.0	0.0	0.0	50.0	0.0	100.0	2
PANAMA	0.0	0.0	100.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	100.0	0.0	100.0	100.0	1
PARAGUAY	8.2	2.7	56.4	53.6	78.2	26.4	0.9	0.0	0.0	0.0	69.1	0.0	0.0	55.5	20.9	0.0	39.1	68.2	110
PERU	1.4	31.1	2.9	48.3	24.4	39.2	0.0	2.4	7.7	0.0	46.9	0.5	1.4	7.2	1.9	21.1	44.0	67.9	209
PTO. RICO	0.0	0.0	60.0	6.7	13.3	53.3	0.0	0.0	0.0	0.0	6.7	0.0	0.0	6.7	26.7	6.7	26.7	53.3	15
THAILAND	0.0	12.5	62.5	25.0	50.0	75.0	0.0	12.5	12.5	0.0	25.0	0.0	0.0	50.0	37.5	50.0	0.0	50.0	8
USA	25.0	50.0	0.0	12.5	50.0	50.0	0.0	0.0	0.0	0.0	12.5	0.0	0.0	37.5	12.5	62.5	50.0	75.0	8
VENEZUELA	3.5	61.0	7.4	7.8	16.9	72.3	0.0	17.7	21.2	0.0	35.1	0.0	0.0	9.5	32.9	11.3	19.0	78.8	231
HYBR. CG	7.0	0.0	90.7	44.2	51.2	58.1	0.0	7.0	2.3	0.0	34.9	0.0	2.3	16.3	39.5	23.3	65.1	39.5	43
HYBR. CM	0.0	19.7	68.2	25.5	15.9	51.0	0.0	7.6	16.6	0.0	33.1	0.0	0.6	21.0	22.3	47.1	26.8	54.1	157
HYBR. SG	16.7	0.0	72.2	22.2	77.8	55.6	0.0	0.0	0.0	0.0	33.3	0.0	0.0	22.2	33.3	16.7	11.1	83.3	18
HYBR. SM	0.0	0.0	100.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	1

Table 3. Performance of ten high yielding clones and two checks (M COL 2215 and M COL 1505) at Media Luna (ECZ 1); seasons A and B.

Clone	Fresh root yield (t/ha)	Dry Matter (%)	Dry root yield (t/ha)	Harvest index	HCN (1-9)[1]
1989 A					
CG 1355-2	23.4	34.6	8.1	0.67	8.5
CM 3372-4	22.1	32.6	7.2	0.65	7.0
CM 4362-5	21.2	30.8	6.6	0.74	7.0
CG 910-3	21.0	34.0	7.2	0.70	7.0
CM 4209-3	20.6	36.1	7.4	0.69	7.5
M Bra 589	20.2	30.8	6.2	0.57	8.0
CM 4362-6	20.1	33.5	6.8	0.70	7.5
SM 374-2	18.8	32.8	6.2	0.65	8.0
CM 4362-9	18.0	33.7	6.1	0.67	5.5
CM 3845-2	17.4	30.3	5.3	0.68	7.5
M COL 2215	5.0	37.0	1.9	0.50	6.0
M COL 1505	6.6	34.2	2.2	0.56	6.0
TOTAL MEAN	12.3	33.7	4.1	0.62	6.8
1989 B					
CM 4042-2	16.6	28.5	4.7	0.54	7.5
CM 4052-2	15.8	27.6	4.4	0.49	8.5
CM 4388-1	15.7	27.0	4.3	0.52	7.0
CM 1785-6	14.1	26.4	3.7	0.57	7.5
CM 4063-6	13.4	26.4	3.5	0.49	8.0
M Bra 99	11.8	25.9	3.1	0.41	8.5
CM 2976-1	11.8	23.9	2.8	0.52	6.0
CG 1413-3	11.8	26.3	3.1	0.45	8.0
CM 5428-1	11.7	23.2	2.7	0.41	8.5
SM 306-9	11.2	27.0	3.0	0.38	8.5
M COL 2215	1.2	28.0	0.4	0.21	5.5
M COL 1505	3.5	24.0	0.8	0.20	7.5
TOTAL MEAN	8.0	26.2	2.1	0.39	7.5

[1] 1 = very low; 9 = very high

Table 4. Performance of ten high yielding clones and the local check (M VEN 77) at La Libertad (ECZ 2); season A y B.

Clone	Fresh root yield (t/ha)	Dry Matter (%)	Dry root yield (t/ha)	Harvest index	HCN (1-9)[1]
1989 A					
CG 165-7	31.9	28.2	9.0	0.60	6.0
CM 2766-5	30.0	22.9	6.9	0.63	2.8
CM 2772-3	27.5	22.4	6.2	0.55	3.0
CM 3380-7	26.8	28.5	7.7	0.51	5.5
SM 301-3	26.3	26.8	7.1	0.52	8.0
SG 104-264	25.1	27.7	7.0	0.60	6.0
CM 3401-2	24.8	25.1	6.2	0.52	6.5
SG 104-283	24.5	29.6	7.3	0.59	8.5
SG 250-3	24.0	26.4	6.4	0.54	6.5
CM 4402-4	23.8	29.5	7.0	0.57	2.5
M Ven 77	22.8	23.4	5.4	0.54	9.5
TOTAL MEAN	22.5	26.7	6.0	0.53	4.8
1989 B					
SG 695-9	30.0	33.4	10.0	0.59	5.0
CG 165-7	27.3	34.4	9.4	0.53	8.5
CM 2166-6	26.7	34.6	9.2	0.59	4.5
CM 5253-1	26.5	37.9	10.1	0.57	7.0
SM 494-2	26.4	35.0	9.3	0.57	6.0
CG 1139-2	25.9	34.5	8.9	0.53	5.5
SM 343-1	25.4	34.3	8.7	0.54	5.5
CM 2766-5	24.9	34.6	8.7	0.53	5.5
M Bra 97	24.9	35.3	8.8	0.48	6.0
CG 1367-1	23.2	34.9	8.1	0.48	6.0
M Ven 77	13.8	32.5	4.6	0.41	5.5
TOTAL MEAN	20.4	34.7	7.1	0.48	6.0

[1] 1 = very low; 9 = very high

Table 5. Performance of ten high yielding clones and a local check (HMC 1) at Palmira (ECZ 4); season A and B.

Clone	Fresh root yield (t/ha)	Dry Matter (%)	Dry root yield (t/ha)	Harvest index	HCN (1-9)[1]
1989 A					
CM 4864-1	38.6	34.9	13.5	0.53	7.0
CM 305-4	31.0	35.0	10.8	0.54	6.0
M Cub 32	30.7	38.7	11.9	0.54	3.0
SG 779-9	30.4	32.7	10.0	0.61	8.0
CG 912-9	29.5	34.6	10.2	0.58	7.0
CM 4344-1	29.3	38.8	11.4	0.60	5.0
CM 3924-2	28.7	38.1	10.0	0.40	6.5
CG 996-6	28.1	39.7	11.2	0.57	3.5
CM 4169-1	27.7	32.5	9.0	0.44	4.5
SG 582-3	27.7	35.4	9.9	0.63	7.5
HMC 1	24.9	36.5	9.1	0.44	4.0
TOTAL MEAN	18.6	34.5	6.5	0.42	6.3
1989 B					
SG 756-7	43.3	39.0	16.9	0.63	5.5
CG 913-4	43.2	35.4	15.3	0.65	6.5
CM 4042-4	42.4	39.2	16.6	0.68	4.5
CM 1203-13	41.3	37.0	15.3	0.75	3.0
SG 731-4	41.2	40.6	16.7	0.73	2.5
CG 1450-4	39.6	39.5	15.6	0.70	5.5
CG 1287-5	37.9	37.8	14.3	0.65	7.0
CM 2976-1	37.1	36.7	13.6	0.65	8.5
CM 3199-1	36.3	36.8	13.4	0.70	4.0
CM 1286-7	36.3	39.8	14.4	0.67	4.5
HMC 1	35.1	32.7	11.5	0.63	4.5
TOTAL MEAN	30.7	36.4	11.2	0.61	5.4

[1] 1 = very low; 9 = very high

Table 6. Performance of ten high yielding clones and a local check (M COL 1522) at Popayan (ECZ 5); seasons A and B.

Clone	Fresh root yield (t/ha)	Dry Matter (%)	Dry root yield (t/ha)	Harvest index	HCN (1-9)[1]
1989 A					
CG 402-11	42.5	30.1	12.8	0.58	4.0
CG 481-3	38.9	34.2	13.3	0.53	3.0
CM 4488-4	36.1	32.7	11.9	0.42	5.5
SG 638-6	35.9	33.3	12.0	0.51	5.5
CG 1118-121	35.8	35.4	12.7	0.50	3.5
CG 501-2	34.1	36.4	12.4	0.48	4.0
CG 1231-3	33.4	31.6	10.6	0.56	5.5
SG 427-64	32.6	37.4	12.2	0.43	7.0
SG 520-16	32.3	34.0	11.0	0.46	3.0
SG 501-1	29.3	37.0	10.8	0.46	5.0
M Col 1522	23.2	28.0	6.5	0.40	4.0
TOTAL MEAN	26.3	33.1	8.8	0.46	4.3
1989 B					
M Bra 405	16.9	34.5	6.0	0.56	5.5
CG 1118-89	16.2	32.8	5.3	0.55	4.0
CG 502-1	15.0	34.9	5.4	0.66	2.0
M Col 2261	14.8	34.0	5.0	0.48	4.0
CG 501-16	14.8	34.7	5.2	0.46	4.0
CG 501-18	14.4	37.0	5.3	0.47	5.5
SG 424-19	14.1	31.6	4.5	0.50	3.5
CG 406-6	13.7	32.8	4.6	0.50	4.0
SG 898-15	13.4	30.6	4.2	0.39	5.5
SG 432-1	13.3	31.4	4.1	0.50	2.5
M Col 1522	11.0	31.6	3.5	0.38	5.5
TOTAL MEAN	8.3	31.4	2.7	0.38	5.2

[1] 1 = very low; 9 = very high

Table 7. Principal traits of three new clones and a check for the eastern savanna region of Colombia. Data from advanced yield trials and regional trials.

Trait	Clone			
	CM 523-7	CM 2177-2	CM 2766-5	M VEN 77 (check)
Root yield (t/ha)				
Mean	20.1 (75)	24.6 (20)	26.8 (25)	14.0 (47)
Maximum	44.2	40.0	41.6	28.7
Root D.M. (%)	36.0 (75)	34.6 (20)	30.7 (25)	29.7 (47)
Reaction to pests and diseases				
Thrips	I	R	I	S
Green mite	I	R	I	S
Bacterial blight	R	R	R	R
Superelongation	R	R	R	R
Diplodia	S	R	S	S

Table 8. Principal traits of three new clones and checks for the Atlantic coast region of Colombia. Data from advanced yield trials and regional trials.

Trait	Clone				
	CG 1141-1	CM 3306-4	CM 3555-6	M COL 1505 (check)	VENEZOLANA (check)
Root yield (t/ha)					
Mean	20.3 (9)	18.1 (9)	15.9 (9)	14.9 (14)	11.5 (25)
Maximun	41.3	40.0	25.9	31.7	29.9
Root D.M. (%)	37.5 (9)	38.4 (9)	34.2 (9)	33.5 (14)	35.5 (25)
Reaction to pests and diseases					
Thrips	R	R	R	I	I
Green mite	R	R	I	I	S
Diplodia	R	S	R	R	S

Table 9. Comparison between key farmer criteria of varietal acceptability and agronomic evaluations for nine clones evaluated in 14 on-farm trials in the Atlantic coast region of Colombia in 1988/89.

CLONE	FARMER EVALUATION CRITERIA[1] PRODUCTION	STARCH CONTENT	ROOT COLOR	EASE OF HARVEST	FLAVOR	EATING QUALITY	OVERALL ACCEPTANCE	RESEARCHER EVALUATIONS DRY MATTER (%)	ROOT YIELD (t/ha)
CG 1141-1	G	G	G	G	G	G	G	37	24
CM 3306-4	G	G	G	G	G	G	G	38	19
CM 3555-6	G	G	G	G	G	G	G	33	24
CM 3306-9	G	G	I	G	G	P	P	36	22
CM 523-7	G	G	G	G	G	G	G	36	22
CM 1355-2	G	G	G	G	-	P	-	-	27
CM 3372-4	G	G	-	G	-	P	-	33	12
VENEZOLANA (local check)	G	G	G	G	-	G	-	36	13

[1] Subjective evaluation by farmers as good (G), intermediate (I) or poor (P) for given criteria. Missing data indicate that a given criterion was not mentioned by farmers.

Table 10. Comparison between key farmer criteria of varietal acceptability and agronomic evaluations for ten clones evaluated in 13 on-farm trials in the mid-altitude regions of northern Cauca Department in 1988/89.

	FARMER EVALUATION CRITERIA[1]							RESEARCHER EVALUATIONS	
CLONE	PRODUCTION	ROOT THICKENING	STARCH CONTENT	STAKE PRODUCTION	EASE OF HARVEST	BRANCHING HABIT	ORDER OF PREFERENCE BY FARMERS	DRY MATTER (%)	ROOT YIELD (t/ha)
HMC 53	G	G	G	G	G	G	1	35	15.0
M COL 1522 (local check)	G	G	G	G	G	G	2	37	16.0
CG 487-2	G	G	G	G	G	G	3	40	14.0
CG 501-18	G	P	G	G	P	G	4	40	14.0
ICA 76 x 40-3	G	P	G	G	G	G	5	36	11.0
M COL 113	G	P	G	G	P	G	6	33	9.5
CG 354-2	G	P	G	G	G	G	7	38	8.0
CG 358-3	G	P	G	G	P	P	8	39	10.0
CG 406-6	G	P	G	G	P	G	9	37	12.0
CG 401-6	P	P	P	G	P	P	10	38	9.5

[1] Subjective evaluation by farmers as good (G) or poor (P) for given criteria.

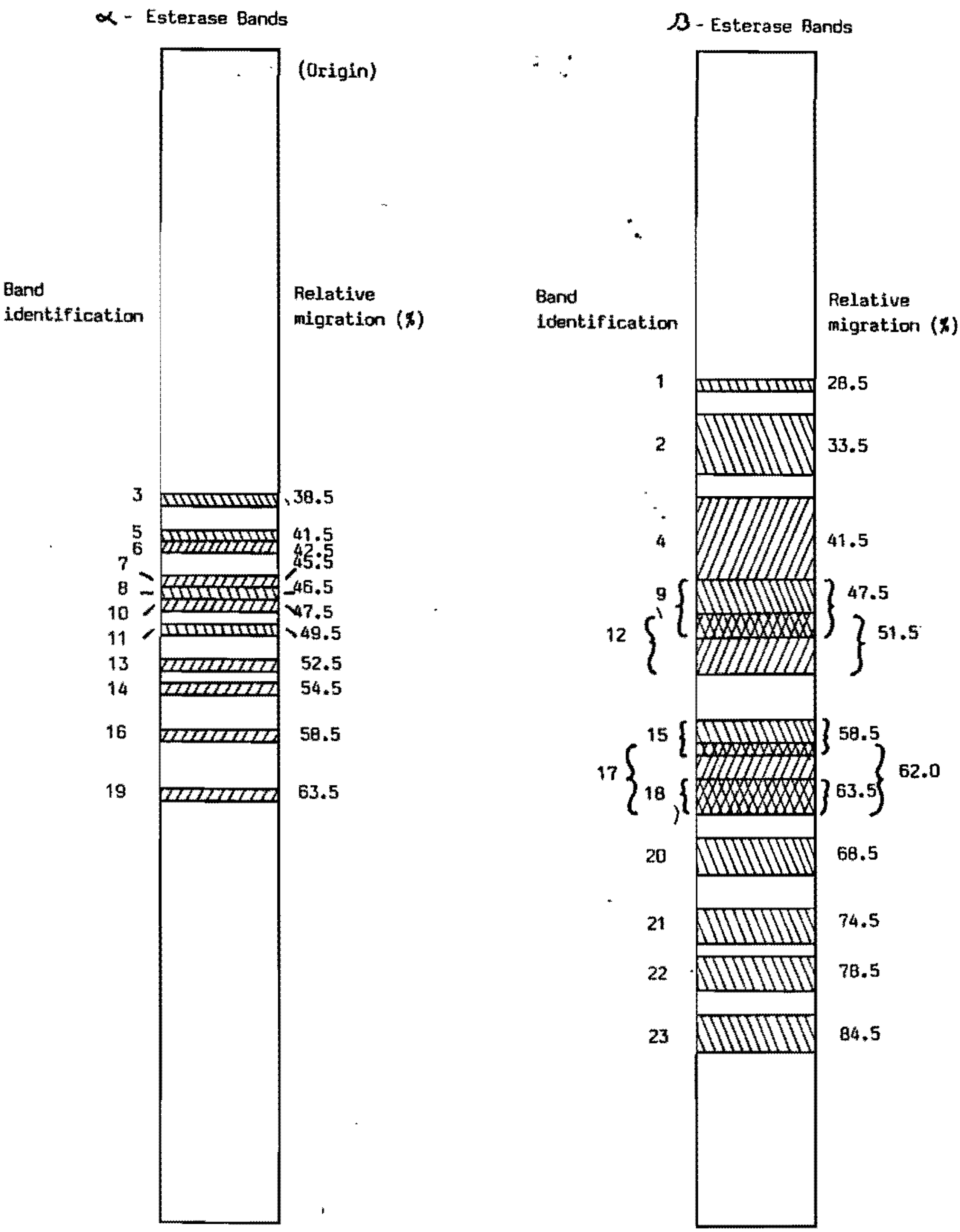


Figure 1. Relative size and migration of bands resulting from electrophoresis on polyacrilimide gels of αβ-esterase isozymes extracted from root tip tissue of cassava.

The critical economic and political situation of Panama, altered the research plans for 1989, particularly the on-farm research efforts. Only four experiments were planted this cropping season in Ocu. In addition, four pre-production plots with the best available technology were also planted. In spite of this situation, most of the activities in the Rio Hato Experimental Station are very close to normal. In Rio Hato, trials on cassava germplasm and a more controlled type of field research is conducted.
A technical recomendation to improve cassava production in Ocu have been recently released by the Cassava Group for comments by the rest of IDIAP personnel. This is the first "teck pack" available for cassava in Panama and one of the few produced by IDIAP in the last years. The pre-production plots mentioned above are largely based on the technology proposed in this publication.

3.- In the North Coast of Colombia, a group of research and extension personnel from diverse agriculture institutions have been organized. This group is composed of approximately 25-30 persons that meet regularly to coordinate cassava-related activities in the North Coast (Departments of Cordoba, Sucre, Bolivar and Atlantico). The Agronomy Section in close collaboration with the "Programa de Cultivos Multiples" of ICA organized this Group back in 1985 with the purpose of improving the relevance of the on-farm cassava research in the Region. The activities of the Group are many, but the evaluation with farmers of improved cassava cropping systems; trials with new cassava germplasm; the production of better cassava planting material and farmer´s problem identification, are among the most important of these activities. This year the Group published the first set of papers on cassava research in the North Coast and a second set of papers is in the process of edition. A characterization of cassava/yam production systems was also published this year. The Group also participated actively in the first Workshop on Diagnostic of Root Crops Production Systems held in Cartagena which was a CIAT/CIP/IITA joint training activity. Some members of the Group also participated in the training of scientist from other countries that are sponsored by CIAT.
Several methodological issues of on-farm research are frequently discussed in the Group and many of the experimental design used today in farmer´s field have been previously tried in the region by CIAT´s staff.
The Agronomy section participate every year in the planning and evaluation of research with cassava in the Region.

4.- The Ceara project in Brazil is a relatively new activity for the Cassava Program. The Agronomy section assisted EPACE scientists in the formulation of a survey to characterize cassava production systems in each of the microregions where the project built drying patios. The survey was designed to better identify production constraints faced by farmers and available technology to improve cassava production in Ceara. The preelimirary visits helped to design a network of field trials that Brazilian scientists resposable for the project are presently implementing. The network was organize after several meetings with research and extension personnel that participate in the Project.

ANNUAL REPORT 1989

AGRONOMY SECTION - CASSAVA PROGRAM

INTRODUCTION

During 1989, the Agronomy Section of the Cassava Program carried out two main activities: **Outreach**, primary in Latin America within the context of Integrated Cassava Projects, and **Cropping Systems Research**, both in the countries and in the CIAT's Station at Palmira. The outreach activities are briefly summarized in this annual report, before results on cropping systems research are presented with more details.

A.-Outreach

This year most of the activities were concentrated in Paraguay, Panama, the North Coast of Colombia and Brasil.

1.- In Paraguay several base line studies for cassava production, utilizacion and commercialization were finished and are presently in the process of been published. Notable among them are the results of the study about commercialization of cassava in the country. Also a document including data on cassava/animal production systems from farms of the target areas of the project, was made available in the country. The Agronomy Section collaborated this year in the analysis of data and interpretation of most of these base line studies aimed to better characterize cassava production systems in the Sub-tropics. Special attention is placed on the training of national scientists during this analysis activity.
For the first time in Paraguay, the Extension Service have produced a comprehensive technical recomendation to improve cassava production which is based on results from on-farm research. This technical recomendation is particularly suited to the Department of Ybicui.
Based on the new technology developed by the Extension Service plus the existing technical knowledge, several pre-production trials have been implemented with farmers to further validate the improved technology. These pre-production trials are serving at the same time as demonstrative plots for farmers.

2.- In Panama, the experiences accumulated in the last four years of cassava activities are being documented in a single publication. This document will serve as a starting point for a second phase of the Panamenian cassava research and development project.

1.-ON-FARM RESEARCH

1a.= Intercropping new maize cultivars with cassava in the North Coast of Colombia.

The testing of new released maize materials to assess its ability to compite with cassava and inversely the effect of these maize cultivars on the performance of cassava, should be an important part of the on-farm research activities in areas where these two species are intercropped.
In the last three years, an experiment has been continously carried out in the North Coast of Colombia in coordination with ICA, to test new released maize cultivars in association with cassava.
Recently released improved varieties of maize are planted in alternate rows with the cassava var. "Venezolana" (M Col 2215).
Cassava/maize alternate rows are planted at 1.2m apart. Cassava is planted at 1.0m on the row while maize is planted on the row at 0.5m (3 plants/hill). A split plot design with cropping systems (monocrop and association) as main plots and maize cultivars as subplots. This year the experiment was planted in a total of 10 localities (farms) in the Departments of Cordoba, Sucre, Bolivar and Atlantico. Two repetitions were planted at each farm. The maize varieties V-156; V-109; V-258; V-106; V-155 and the "Criollo" were tested. Cultivars V-155 and V-258 had never been tested before in association with casava. Based on previous results from monocrop maize experiments, the var. V-258 was tested with cassava only in Cordoba and Sucre while the var. V-106 was tested only in Bolivar and Atlantico.

Last year´s cropping season in the North Coast, was characterized by very heavy rainfalls inmediately after the planting period. This unusual heavy rainfall plus relatively high temperatures, resulted in a vigorous initial growth of maize. This strong early development of the maize, negatively affected the growth of the intercropped cassava. In spite of the favorable conditions for initial maize growth, the period near harvest was also of heavy rainfall, causing lodging and ear rots, that resulted in lower that expected maize yields.
It is known that cassava is very susceptible to competition in its early stages of growth, so its yields in intercrop were relatively low this year. In addition, the heavy rainfall resulted in high incidence of root rot pathogens that further reduced yields.
On a global analysis most of the cassava variables recorded resulted highly significant different between localities. Also the factor "cropping system" that compares the performance of the two species in association and in monocrop, resulted significantly different for most of the analysed variables. In a general analysis, the influence of the different maize varieties on the performance of the var."Venezolana" intercropped was not statistically significant. Results from previous years indicated that improved maize varieties tended to yield significantly more than the criollo and at the same time, these

The field trials were designed to evaluate with farmers the best available technology to improve cassava production. Each farmer´s association that operate a drying patio will also be responsable for managing at least one pre-production trial.

B.- Research

The objective of the research conducted by the Agronomy section is the development of improved cassava-based cropping systems for specific agroecological areas of Latin America. This objective is achieved by the Section through on-farm research, technology validation and support research.
The on-farm research is conducted in close collaboration with national institutions of Latin America. Due to obvious geographical reasons, a "hands-on" approach is possible only in the North Coast of Colombia. In other countries, the approach is rather of collaboration in the analysis of production problems, design of research, design of field experiments, assistance in statistical analysis of experimental results and others.
For practical reasons the activities could be divided into three groups: 1) **Development of Better Cassava Production Systems** for a specific area of Colombia (North Coast) within the context of a Integrated Cassava Production, Utilization and Commercialization Project. This site-specific situation serves as a model to develop appropiate methodology for field research in support of a cassava-based rural development project. Particular emphasis is put on methodological issues that call for discussions with local scientists. This methodological emphasis lead to the organization of the above mentioned Group of scientist in the North Coast. It is expected that the methodology developed here will be applicable elsewhere in Latin America as well. 2) **Validation with Farmers of Improved Cassava** Technology. This activity is also conducted on farms, but the main objective of this type of research is that results could serve as a feedback mechanism to research. The Validation of technology under a set of different ecological and socio-economic circunstances is not a regular activity of national research/extension institutions. From this last point of view, Validation is also a methodological issue, but as previously stated, the main emphasis is now on feedback to research institutions. 3) Support Research. Under this heading all the research done either on Experimental Stations or in farmer´s fields but that is conducted under more controlled conditions is included. The results of this research help scientists to better understand some relevant aspects of the relationships between crops and crops and their environments.

For the purposes of this annual report, the results from four of the experiments included, correspond to what have been classified as on-farm research. They correspond to numerals 1a to 1d in the text. The three following experiments reported correspond to Technology Validation with farmers and are numered 2a to 2c. Lastly, three experiments that correspond to Support Research are included in numerals 3a to 3c.

The average yield for maize in this experiment (including all the varieties and cropping systems) was 2.7 ton/ha which is below the yield obtained in previous years under experimental conditions with farmers. The average yield for sole crop maize was 3.0 ton/ha and for intercrop with cassava "Venezolana" was 2.4 ton/ha. This difference in cropping systems for maize, was higly significant for a value of 20% of cv.
Improved maize varieties performed better than the regional in all the localities. There were significant differences between improved maize varieties in sole crop in terms of yields as well. Only the regional variety was significantly different from the rest in the case of intercrop with cassava. These differences can be appreciated in Table 3

Table 3. Yields (ton/ha) of different maize varieties in sole crop and associated with cassava in the North Coast of Colombia. 1988.

Maize varieties	Sole crop	Associated with cassava
V-156	3.4a 1/	2.5a
V-109	3.2a	2.4a
V-258	2.9ab	2.4a
V-155	3.3 b	2.6a
Regional	2.4 c	2.1 b

1/ Figures followed by the same letter are not significantly different according with Duncan's multiple range test (0.05)

A highly significant (0.01**) interaction between localities and maize varieties was registered, this means that the relationship between maize and cassava will remain site-specific across the North Coast if improved varieties become more widely used in the region. This fact also implies the need to ecologically regionalize this type of research in order to optimise cassava/maize yield at each sub-region in the region. A significant interaction (0.05*) between locality x cropping system x maize variety further confirm this fact from the point of view of the maize.

The relationship between maize and cassava yields can be observed in Table 4 . This table only includes the Departments of Sucre and Cordoba, where the lowest and highest yields for cassava were obtained, respectively.

improved maize varieties allowed cassava to yield more in terms of aerial part biomass and fresh roots than the yield obtained when it was intercropped with the "criollo" maize.
Casava plant height, the weight of it aerial part and the number of cassava plants/ha were significantly affected by the locality. These last two variables were also significantly affected by the cropping system. There was also a significant interaction between locality and cropping system for these two variables. This result indicates that cassava does not perform in the same manner in association in all the different environments and furthermore that management of the association by the different farmers, affect this relationship. The number of cassava plants/ha was higher in monocrop than in association with maize. This effect has to be added to the competition with maize to explain the reduction of cassava yield when intercropped.
Due to root rot loses, values of cv were above 30% for most of the variables recorded this year. Althougt the same tendency in yields than in previous years was observed, the differences in yields of the cassava var. "Venezolana" in monocrop as well as in association with different maize cultivars were no statistically significant. Table 1

Table 1. Yields (ton/ha) of cassava in intercropp with different maize varieties. Average of 10 localities. 1988

Maize varieties	Aerial weight	Marketable roots	Monocrop
V-156	14.0	6.8	10.5
V-109	13.6	6.9	11.3
V-258/106 1/	13.8	6.2	11.8
V-155	13.1	5.6	11.9
Regional	10.7	5.0	11.7

1/Average of var. V-258 and V-106.

As mentioned above this was an exceptionally unfavorable year for cassava production in the North Coast of Colombia. On average, the highest yields were obtained in Cordoba and the lowest in Sucre. Table 2.

Table 2. Marketable yield (ton/ha) of fresh roots cassava intercropped with different maize varieties in Cordoba and Sucre. Average of two farms in each Department. 1988

Maize	Cordoba		Sucre	
varieties	Intercropped	Sole crop	Intercropped	Sole crop
V-156	9.3	14.0	4.2	6.7
V-109	12.4	13.9	3.5	9.8
V-258	11.1	16.3	3.9	8.5
V-155	11.1	18.2	2.4	9.1
Regional	11.1	15.3	3.6	9.5

The experiment was harvested in only six localities (farms). In the rest of the localities some repetitions were lost for causes that could not be attributed to the effect of treatments.

On a global analysis of the six localities there were no locality effect on cassava yield in terms of weight of marketable size roots. Considering the average yield of all the cassava varieties, including sole crop and association with maize, there were significant differences between varieties. M Col 22 outyielded the rest of the varieties and the local "Venezolana" resulted in the lowest yield.

There was also a significant difference between varieties in sole crop, but this difference was not present when the yields of the same varieties in intercrop were compared. Table 5.

Table 5. Yield in marketable fresh roots (ton/ha) of different cassava varieties in sole crop and associated with the maize variety V-156.

Varieties	Sole crop	Associated with maize	% Reduction	Average
M Col 22	25.4a	12.4a	51	18.9a 1/
M Col 72	20.0 bc	11.0a	45	15.5 b
CM 681	18.8 cd	10.3a	45	14.2 bc
CM 962-4	20.5 b	11.8a	42	16.1 cd
Venezolana	16.3 d	9.9a	39	13.0 d

1/ Figures followed by the same letter are not significantly different according to the Duncan's multiple range test (0.05)

Maize in sole crop yielded significantly more (2.9 ton/ha) than did maize in association with the different cassava varieties (2.3 ton/ha). Maize in sole crop showed no difference in the check plots, but this lack of difference was expected from plots with the same variety.

To the contrary of the past years, during this cropping season, the cassava varieties did not affected differently the maize that was intercropped with them. Table 6.

Table 4. Yiels (ton/ha) of different maize varieties in sole crop and associated with cassava in Cordoba and Sucre. North Coast of Colombia.

Maize varieties	Cordoba		Sucre	
	Sole crop	Associated	Sole crop	Associated
V-156	2.5	1.7	3.8	3.3
V-109	2.7	1.9	3.3	3.3
V-258	2.9	2.4	3.2	3.0
V-155	3.0	2.2	3.0	2.6
Regional	1.4	1.0	3.2	2.8

In Cordoba where the highest yields of cassava were obtained, the reduction in maize yields due to the intercrop with cassava were more evident than in Sucre.

1b.- Performance of different cassava varieties as sole crop and in association with the maize var."V-156" in the North Coast of Colombia.

In the past, most of the regional trials with cassava in the North Coast of Colombia, were conducted in sole crop. Since cassava is seldom cultivated as sole crop, most researchers working in the region agreed that promising genetic material should be tested, before release, for its ability to grow in intercrop with maize .
After analysing several past years results of regional trials, four cassava varieties were selected for high yield. These varieties are being tested for the past two years in farmer's fields for its ability to grow in intercrop with maize. A single maize variety "(V-156") was selected for intercrop with the different cassava varieties. V-156 is widely cultivated in the region, and perform rather uniformily across localities. The cassava varieties selected were: M Col 22; M Col 72; CM 681 and CM 962-4. The local cultivar "Venezolana" is used as check.
In addition to the varieties selected for this experiment, there are at least three other improved cassava varieties recommended for the North Coast, but no sufficient data are available now about their performance in intercrop with maize.
The same spatial arrangement used for the experiment on maize varieties was used for this experiment with cassava varieties. Rows of cassava were interplanted at 1.2m with rows of maize. Cassava was planted at 1.0m on the row while maize was planted at 0.5m. A split plot design with cropping systems (sole crop or association) as main plots and varieties as subplots was used. Two repetitions/farm were planted and most of the crops management after the planting, was the responsability of each farmer.

reduced tillage on cassava are largely lacking. It is known though that many farmers operating in steep lands do not prepare the soil before planting cassava or prepare the soil only in the site where a stake is planted.

If the cost of a possible reduction in yield due to no land preparation is lower than the cost of renting a tractor, some farmers may adopt the no-tillage technology for cassava production with significant reduction in the costs of production. Several studies have been conducted with maize under no-tillage conditions with positive results in many instances. However information about the performance of cassava under no-tillage is largely lacking. Moreover information about the performance of a cassava/maize intercrop under no-tillage seems inexistant.
In addition to possible economic benefits,no-tillage could alsso improve the general soil condition in the long range.

To test the effect of soil preparation on the performance of cassava and maize intercropped, an experiment was conducted with three farmers in two departments of the North Coast. Each farmer or locality, managed four repetitions of the 2 treatments. One treatment was mechanized soil preparation down to a deep of aproximately 25cm, and the other was soil with no preparation. The lots selected for the experiment had a similar history of cultivation, with cassava/maize cultivated previously on the lots for at least 4 consecutive years. The cultivar "Venezolana" and the variety "V-156" of cassava and maize, respectively were used. The two species were planted in alternate rows 1.2m apart. On the row, cassava was 1.0m apart and maize 0.5m with 3 plants/hill.
Results from this first experimental year are summarized in Table 7.

Table 7. Yields of cassava and maize (ton/ha) under two soil preparation treatments in three localities of the North Coast of Colombia.

Locality	Soil Preparation Treatment			
	----Cassava----		----Maize----	
	Tillage	No-tillage	Tillage	No-tillage
1	12.3a 1/	12.7a	2.6a	1.2b
2	14.7a	15.4a	1.7a	1.7a
3	11.2a	9.0a	1.9a	1.4b

1/Figures followed by the same letter in the row and for the same crop, are not different according with the Duncan´s Multiple Range Test (0.05)

On a global analysis there was no significant effect of soil treatments on the yield of cassava in terms of marketable fresh

Table 6. Yields of maize(ton/ha) cv."V-156" as sole crop and intercropped with differnt cassava varieties.

Cassava Var.	Sole crop	Intercropped with cassava	Average
M Col 22	2.9	2.2	2.5
M Col 72	3.0	2.4	2.7
CM 681	2.8	2.2	2.5
CM 962-4	3.0	2.3	2.6
Venezolana	3.0	2.4	2.7
Average	2.9	2.3	2.6

1e.- Effect of two soil preparation methods on the performance of cassava and maize cultivated in association.

Land clearing and soil preparation are among the most labor and capital intensive cultural practices to produce cassava. Land clearing is spread over time and due to the specificity of each case, it is very difficult to calculate its costs and its overall influence on cassava total production costs. Given the restricted economic capacity of the mayority of farmers, the limited available information about better technology and the difficulties for testing new technology for land clearing,the development of improved technology for this activity is rather difficult. However, for soil preparation methods, the design and test of better technology is somehow easier.
After land clearing, soil preparation is done either manually or mechanized in most of the fallow-based production systems of cassava. At present in many regions of Latin America, plowing and harrowing with a wheel tractor, particularly in flat lands, are common cultural practices. These soil preparation practices are repeated year after year in almost exactly the same manner with negative consequences mainly for soil structure.
The cost of land preparation is among the highest in terms of cash for cassava production, particularly in the case of rented tractors that is very common practice among low resource farmers.
On rainfed conditions, soil preparation is done at the same time troughtout a cassava producing region. The demand to hire tractors is very high at this particular moment in the cropping season that coincides with the onset of the rainy period. Since the number of tractors in a given region is generally very limited, several farmers end up preparing soil too late in the season, or not preparing it at all. The advantages of early planting to obtain good yields are well known to farmers, but many of them are forced to plant late in the season due to the difficulties encountered in hiring tractors.

Minimun tillage and/or no-tillage have been tested with several crops with diverse results, but information about the effect of crop in a completely random block design with three repetition/farm in three deparments of the North Coast.

Results of this experiment are presented in Table 8. None of the recorded variables was affected by the origin of the planting material. This demonstrates that the quality of the planting material obtained from cassava that was cultivated as sole crop and cassava cultivated in association with maize, is not significantly different. The performance of the cassava plants from where stakes were obtained was within the range of the average yields for the region.

Similar results were obtained last year with the same experiment. If these results are repeated in the next year it could be concluded that at least the quality of the planting material is not affected by the intercrop with maize. Since it is already known that the quantity of stakes is affected by intercrop, the ability of the farmer to select stakes out of the available planting material from intercrop is more critical than in other situations.

Table 8. Effect of the intercrop with maize on the quality of planting stakes of cassava.

Origin of planting material	Variables recorded		
	Plant Height (m)	Aerial Part Weight (ton/ha)	Marketable roots Weight (ton/ha)
Monocrop	1.79a 1/	8.20a	17.32a
Intercrop	1.73a	8.00a	16.56a

1/ Figures followed by the same letter are not significantly different according with the Duncan´s multiple range test.

Since planting material selection seems to be so critical for succesfull cassava production, the following experiment about selecton of planting material by farmers, was designed with the same cassava variety.

2.-TECHNOLOGY VALIDATION

roots. There was however, a significat difference in terms of maize yield due to the effect of soil treatments. Maize cultivated with soil preparation yielded significantly more than the maize cultivated with no soil preparation.

There was also a strong locality effect for most of the variables analysed. Moreover a 75% possibility of interaction between locality and maize yield with only 11.5% CV called for a separate analysis of variance at each locality. This locality analysis showed that at farm two, the effect of land preparation was less evident for maize yield than at the rest of the localities. Also a highly significant difference for maize yield at locality 1 with a non significat difference for the cassava that was intercropped with this maize was also evident after this locality analysis.
No data on weed incidence between treatments have been obtained during this first year. Farmers were instructed to maintain the experimental plots exactly as they maintain their commercial plots. Weed incidence, if different between treatments, will probably influence the choice of the best soil preparation practice, due to the high cost of of weeding which is characteristic of cassava production in intercrop.

1d.- Influence of the intercrop with maize on the quality of the planting material of cassava cv. "Venezolana".

Intercropping cassava with maize significantly reduce the total weight of the aerial part of cassava and consequently the amount of planting material available for the next cropping season. Selecting stakes from plants that yield less both in terms of fresh roots and aerial biomass could negatively affect yields of cassava in the subsequent cropping seasons.
In addition to a possible build up in virus incidence and decreasing soil fertility, the constant use of seeds coming from plants that were intercropped the previous season, could be another reason for the constant decreasing yields that is a characteristic of cassava production in certain areas of the world.
The intercrop could affect the planting material in terms of quality and quantity or both.
To test the influence of intercrop with maize on the quality of the cassava planting material, an experiment was conducted with five farmers in the North Coast of Colombia. Cassava stems were selected from the central part of experimental plots with cassava sole crop and cassava in intercrop with maize. These stems were stored separately in the same manner for less than 60 days in each farm until the next planting season.
Stakes prepared from each of the two groups of stems were randomly selected for planting. These two lots of stakes were planted in sole

Table 9. Influence of the origin and selection of planting material on the performance of cassava in the North Coast of Colombia.

Type of planting material 1/	Variables recorded Plant height (m)	Aerial weight (ton/ha)	Marketable Roots (ton/ha)
Farmer by Farmer	1.9a 2/	8.8a	16.3a
Farmer by CIAT	1.8a	8.3a	15.8a
CIAT by CIAT	1.8a	9.0a	17.2a

1/Farmer by farmer= farmer´s seeds selected by the farmer. Farmer by CIAT= farmer´s seeds selected by CIAT´s staff. CIAT by CIAT= CIAT´s planting material selected by CIAT´S staff.

2/ Figures followed by the same letter are not statistically different according with the Duncan´s multiple range test.

It seems that at least some farmers, have sufficient knowledge about proper stakes selection for better yields. Under these circunstances a "farmer to farmer" rather than a "extension agent to farmer" squeme is more adequate to transfer this type of technology in the North Coast of Colombia.

2b.- Effect of seed treatment on the performance of cassava in farmer´s fields of the North Coast of Colombia.

Stake desinfection previous to planting, is actually included in most of the technical recomendations for better casava production in diferent regions of the world. However in the mayority of the countries, particularly in Latin America, no validation of this technology in farmer´s field have been done. Theoreticaly, stake desinfection is important to sustain or improve production in areas where soil pathogens negatively affect yields. The role of stakes protection is not very clear where the inoculum potential of the soil is low or unknown.

In four departments of the North Coast of Colombia, namely Cordoba, Sucre, Bolivar and Atlantico, small farmers do not protect their cassava planting material althought this practice is common for yam production and the chemical products are easily available and frequently used in the farm for other purposes.

To validate with farmers the technology recomended by the extension service for stake protection, an experiment was designed and conducted for two years with farmers´s participation in the management of the experiments.

For the cropping season that begun in 1987, stakes from a single source of planting material were randomly divided in two lots at

2a.- Effect of selection of planting material on the performance of cv."Venezolana" in the North Coast of Colombia.

Good selection of planting material have been pointed out as a key factor for a succesful cassava production. Lack of sufficient good quality planting material or ignorance on behalf of the farmer (or both) are probably the main reasons for planting poor quality stakes on any given year.

To study the influence of seed origin and selection of plant material on cassava yields, this experiment was conducted in the North Coast: for the first treatment (FxF), six farmers were asked to select from their available seed what they considered "good seed". For the second treatment (FxC), CIAT's agronomists selected what they considered "good seed" from the farmer's available planting material. For the third treatment (CxC), CIAT's agronomists selected seed from a field exclusively planted in the North Coast by CIAT with the purpose of providing "good seed" for experimental purposes. For the first and second treatment the seed was different among localities. In the third treatment the seed was from a single origin.
The three treatments were arranged on a completely random block design with three repetitions in each of 6 farms.

There was a marked effect of localities on each of the analysed variables. This was expected since ecological conditions, management and seeds from treatments FxF and FxC were different among localities. But for the rest of the variables no significant differences were found between treatments as shown on Table 9.

No difference in terms of weight of marketable fresh roots was registered for the three treatments. This means that farmers are capable of selecting good planting material if this material is available. Since farmer's planting material selected by CIAT's agronomists was equally good in terms of yield than the CIAT's seeds, the quality of planting material available to the farmers that year, was of a very high standard.

Since CIAT's planting material selected by CIAT's staff did not perform better than the rest of the treatments,the purposeful planting of cassava, exclusively to serve as seed will not be always an advantage in terms of yield, at least for some farmers. This is an important consideration in the planning and implementation of any cassava seed program for small farmers. A cassava seed program could help to solve the occasional problem of lack of sufficient planting material on a given cropping season and locality, but the quality of the planting material produced by such program should outperform the available plant material at farm level to motivate farmers to participate in any collaborative seed program.

Table 10. Total above-ground weight (ton/ha) and population (plants/ha x 1000) of cassava produced with farmer´s stakes and stakes produced by researchers.

Sources of planting material	Total weight of above ground material	Number of pl/ha
Farmer	11.8 a 1/	8.0 a 1/
Researchers	13.1 b	8.2 b

1/ Amounts followed by the same letter are not statistically different according to Duncan´s multiple range test

Table 11. Fresh weight of commercial and total roots of cassava (ton/ha) produced from farmer´s stakes and stakes produced by researchers.

Sources of planting	Commercial roots	Total roots
Farmer	12.9 a 1/	16.9 a 1/
Researchers	13.0 a	17.5 a

Amounts followed by the same letter are not significantly different according with the Duncan´s multiple range test.

Table 12. Yields (ton/ha) in terms of fresh weight of commercial and total roots from cassava planted with treated and no-treated stakes.

Stakes treatment	Marketeable Roots	Total Roots
Treated	13.0 a 1/	17.4 a
Non-treated	12.8 a	17.0 a

Amounts followed by the same letter are not significantly different according to the Duncan´s multiple range test.

The results of this experiment demostrate that farmer´s decision to plant cassava stakes with no chemical treatment is basically correct, at least in the short range and from the point of view of yields/ha. It is also evident that technical recomendations should be validated under farmers conditons before releasing them to the extension services. In this particular case of stakes treatment, a more site specific identification of prevalent soil pathogens could help to better select the chemicals for stakes treatment.

each farm. The chemical treatment was applied to one of the lots, while the rest of the seeds served as check. The Extension Service recomendation was largely based on CIAT's research results. It consisted of 3 gr of Benlate; 3gr of Manzate and 2cc of Malation in 200 l/water. The seed used was a uniform source of reasonable good quality planting material of the cultivar "Venezolana" (M Col 2215) that researches had selected for use in field experiments. Two repetition/farm were planted in 16 farms of the four Departaments. All the cultural practices, except the seed treatment were conducted by the farmers in exactly the same way they manage their commercial plots.
During the 1988 cropping season,the experiment was slightly modified to include another variable which was the source of stakes. Two sources of stakes were used: a similar source as the previous year and the stakes that farmers had selected for their commercial plots and were ready for planting. Farmers were asked to select stakes from their own planting material for this experiment. Each lot of planting material was then further divided in two lots, one of which received the seed treatment, while the other served as check. A split plot experimental design was used. Main plots were the sources of stakes and subplots the chemical treatment to the seed. Three repetitions/farm (localities) were used this year in eleven farms.
During the 1987 cropping season, no statistical difference was registered in terms of yield of fresh roots, between treated and non treated planting material. The difference in yield in favor of plants that received stake treatment was between 1.5-3.0 ton/ha considering an average of all the localities.

In 1988 differences between farms (localities) were highly significant for most of the variables recorded. The increase in the number of repetitions in each locality, allowed for one extra degree of freedom to better identify the effect of localities. These differences among localities were expected because in addition to diverse ecological conditions, each farmer managed his plots differently.

The effect of sources of stakes was significantly different in terms of weight of the aerial part and number of plants/ha. Table 10. The stakes that researches had selected for their experiments resulted in higher yields of fresh roots than the stakes that farmers had available for planting that particular season. However this difference in weight of fresh roots was not statistically significant in an overall analysis. Table 11.

For the factor stakes treatment, no statistical difference for any variable-including fresh root weight- was registered between treated and non-treated planting material. Table 12. This was true both in an overall analysis and in a localitry by locality analysis. The same results were obtained grouping the localities by each of the four Departments.

On a global analysis that considers farm as localities no differences in yield were recorded at harvest between treatments. But as expected, significant differences were obtained between localities for most of the variables. Treatments 1 and 2 that correspond to the best available technology for stems storage did not differ significantly from farmer´s practices. There was no difference either between the yields of plants comming from seed that was stored and from plants comming from fresh stakes. Table 13.

Table 13. Differences in plant height (m) number of harvested plants/ha and yields (ton/ha) after planting cassava from stakes stored in three different methods and from fresh stakes.

Storage method 1/	Plant height	Number of plants	Weight of aerial part	Weight of commercial roots
Improved 1	1.79a 2/	7666a	12.5a	17.4a
Improved 2	1.70 b	7666a	10.7a	18.0a
Farmer	1.74 b	7639a	11.4a	17.6a
Check (fresh)	1.92a	7800a	12.2a	18.4a

1/ Improved 1= Good quality stems,vertically store in the shade and tips immerse on mud; Improved 2= Same as above, but stems desinfected with insecticide and fungicide previous to storage.

2/ Figures followed by the same letter are not significantly different according with Duncan´s Multiple Range Test(0.05).

On Table 14, a partition of results by locality is summarized averaging the data for improved technology and comparing them with the farmer´s storage method and with fresh material.

Table 14. Yields (ton/ha) of marketable roots from cassava planted with stakes stored using improved technology and stakes stored with the farmer´s methods.

	Yields		
Farms	Improved technology 1/	Farmer technology	Fresh planting material
1	16.9a 2/	17.3a	16.1a
2	18.9a	17.7a	20.3a
3	15.8a	15.4a	16.5a
4	19.4a	19.4a	19.9a

1/ Average of the recommended improved technology.
2/ Figures followed by the same letter are not different according with the Duncan´s Multiple Range Test (0.05)

8e.- Storage of cassava stakes under farmer's conditions in the North Coast of Colombia.

To store cassava stems for planting next season is a practice common to many farmers. Farmers rarely relay on a single method to have good quality planting material available for planting after a dry season. In fact many farmers leave a piece of land with a standing crop rather than store stakes.

Storage of planting material is done in many different ways according with farmer's preferences and abilities. Under these circumtances, is very difficult to identify a single method common to all farmers to serve as check for an experiment.

Many research institutions (CIAT among them) have conducted studies trying to improve current farmer's practices for storing stakes. Most of the technical recomendations to preserve the planting material in good conditions for germination, focus on procedures to avoid water losses during the storage period. Storage under shade, covering the planting material with leaves, adding water periodically, immersing the tip of the stakes in mud, etc are all practices aimed to avoid water loss.

To validate with farmers the available technology to store stakes in comparison with the commonly used methods in the region, an experiment was begun in the dry season (January-March) of 1988 in the North Coast of Colombia. Four farmers that usually store stakes were selected for this experiment. Four treatments were selected: 1) Store rather long and healthy stakes vertically with the lower tips immerse in mud, cover them with leaves and leave them standing under the shade of a tree. 2) Same as above, but the stakes are treated previous to the storage with a mix of insecticide and fungicide.
3) Store in the same way as the farmer. This treatment varied from farm to farm, but in general the tip of the stake was not immersed in mud and the general care both for stake selection and during the procedures for storage was much less than in the treatments 1 and 2. They were all stored in shaded places and the stems were covered with plant material. Two of the farmers stored stakes horizontally. These three storage treatments were compared in terms of yield and other variables, with the fresh seeds that all the farmers have maintained in the field for planting that year. This treatment of fresh material (4) was also slighly different across farms, since the quality of the planting material differed among farmers, althougth they all grow and store the variety "Venezolana".
The storage period was from 75 to 110 days and from the stored stems and fresh material, planting stakes were randomly selected to plant three complete blocks on each farm with the four treatments arranged completely random. Farms were analysed both individually and considered as localities.

As expected there was a marked difference in the yield of improved and traditional maize cultivars. Improved maize cultivars averaged 4.0 ton/ha while traditional cultivars yielded only 1.5 ton/ha. In terms of maize yield, there was no significant difference whether it was intercropped on the same row or in alternate rows with cassava. This means that regardles the spatial arrangement of the maize, its interaction with cassava remains the same. Any of the two spatial arrangement used for intercrop in this experiment can then be used in the future in CIAT's Station to test maize cultivars in intercrop.

The average yield of the two traditional maize varieties was similar in intercrop and in the two monocrops checks used. The opposite was true for the improved varieties that yielded significantly more in sole crop-particularly at the high planting density-than in association with cassava (Table 15). This lack of difference between the yield in association and in sole crop is probably the reason why the traditional varieties of maize are rarely cultivated as sole crop. On the contrary, and compared with their yield in association with cassava, almost two tons of more maize were obtained with the improved cultivars when they were grown as sole crop at high plant densities.

Table 15. Yields of traditional and improved maize cultivars (ton/ha) intercropped with cassava and as sole crop in two plant densities.

		Sole crop (pl/ha x 1000)	
Type of maize	Intercropped	20	40
Traditional	1.55	0.94	1.95
Improved	3.56	3.03	5.44

Average yield of the cassava cultivar CMC-40 was 22.0 ton/ha of fresh roots when intercropped with maize and 29.2 ton/ha as monocrop. A statistically significant difference. This difference remained similar for cassava intercropped with maize in the same row or intercropped in alternate rows when the four different maize cultivars are considered. Comparing the yield of cassava intercropped with improved maize cultivars against its yield as sole crop, a 5.7 ton/ha difference in favor of the sole crop was registered. In the case of traditional maize varieties this difference in favor of the sole crop was 8.5 ton/ha.
The intercrop of cassava with improved maize varieties yielded more cassava and maize than the intercrop with traditional maize varieties.Figure 1.
The effect on cassava yield of intercropping with maize on the same row or on alternate rows was different according to the maize cultivar used. No statistically significant difference was observed for three cultivaras but the hybrid H-211 reduced cassava yields significantly

During this cropping season, results in terms of yields from the different storage methods practiced by the farmers, did no differ significantly from the available improved technology. If similar results are obtained in the future ón a different set of environmental conditions, it could mean that the existing technology for stakes storage at farmer´s level is sufficient to ensure good quality planting material for next season and that research efforts should be better allocated on different subjects. An improved method of storage should yield considerable more product per unit of effort than the traditional ones to be adopted by farmers. No economical analysis of these data are have been conducted, but surely the improved technology is more expensive and time consuming than the traditional methods.

3.-SUPPORT RESEARCH

3a.- Cassava intercroped with traditional and improved maize varieties.

Cassava and maize are frequently intercropped in most of the regions where these two species are grown. Worldwide cassava is probably the most common of the maize intercrops.
In Latin America, improved maize varieties are becoming more and more important among small farmers. Many of these new maize varieties have been developed for monocrop although farmers grow them in association with cassava and several other crops. Several experiments conducted in the last years under farmer´s conditions, demonstrated that improved maize varieties not only yielded more in monocrop than traditional varieties, but they also yielded more in association with cassava. Furthermore cassava intercroped with improved maize varieties outyielded cassava intercroped with traditional maize varieties.

To further investigate the relationship between cassava and different types of maize, an experiment was designed to be conducted under more controled conditions in CIAT´s Research Station at Palmira.
Two types of maize -improved and traditional- both intercropped with the cassava cultivar CMC-40 and as single crop were tested. Improved maize cultivars were the hybrid H-211 and the variety V-258. Traditional varieties were collected from small farmers fields in the Valle del Cauca. These are known as "Clavo" and "Limeno". Two maize monocrop checks were used: one planted at the same density than the intercrop and other at a population that the farmers would use in case of a more intensive single crop maize production system. The effect of spatial arrangement on the intercrop was also investigated. Cassava and maize were intercroped on the same row and in alternate rows but maintaining the same planting density.

more when intercropped on alternate row than the intercrop in the row.Table 16.

Table 16. Effect on cassava yield (ton/ha) of two spatial arrangements between cassava and maize.

Maize cultivar	Spatial arrangement	
	on the row	on alternate rows
H-211	25.9	16.3
V-258	22.7	25.0
Control (cassava sole crop)	27.5	29.0
"Clavo"	22.5	20.5
"Limeno"	22.9	21.0
Control(cassava sole crop)	30.9	29.5

This reduction of cassava yield in intercrop in alternate rows with maize hybrids has been recorded in several ocassions at CIAT's Station. Similar results have not been obtained in less favorable environments such as in the North Coast of Colombia. Further research should help to better understand this result and assest if this is a general characteristic of maize hybrids or a location and/or variety specific situation.
Land Equivalent Ratios for the experiment ranged between 1.4 and 2.34, depending on the sole crop check that was used for the calculation. Traditional varieties of maize do not always respond significantly in terms of yield to increasing plant densities. In the case of these traditional varieties only a sligthly higher plant density than the one used for the intercrop can be used for the sole crop check. In this experiment, only 0.4 ton/ha of difference in yield were obtained after the increase in population for the sole crop check of traditional varieties. This difference was 1.9 ton/ha for the case of improved varieties.
From the methodological point of view, the test of new improved maize varieties to assess their ability to compite with cassava, should include the check of maize sole crop at its optimun plant density.

These results, obtained in a different environment and under more controlled conditions in CIAT's Station, confirm the findings from the North Coast of Colombia that the cassava/maize intercrop yield more when improved maize varieties are used.
Higher than average yields for both cassava and maize are very strong arguments for farmers to decide in favor of improved maize varieties. But the high yields of the improved maize varieties are not only a consequence of a more efficient use of the available resources but also a more intense use of them, particularly soil nutrients.

For a fallow-based type of agriculture such as the one practiced by small farmers in the North Coast of Colombia, the switch from

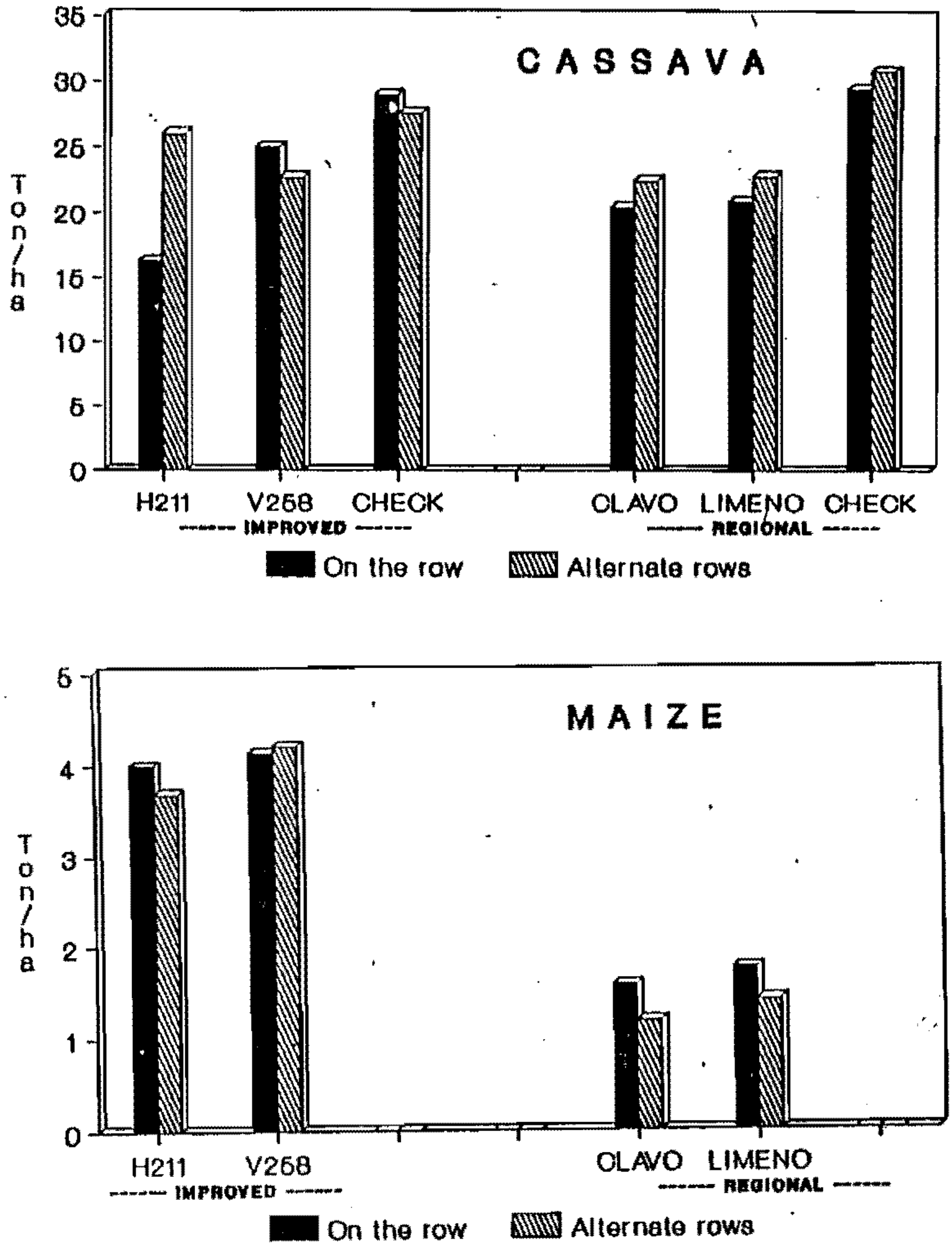


FIGURE 1. YIELDS OF CASSAVA INTERCROPPED WITH TRADITIONAL AND IMPROVED MAIZE CULTIVARS.

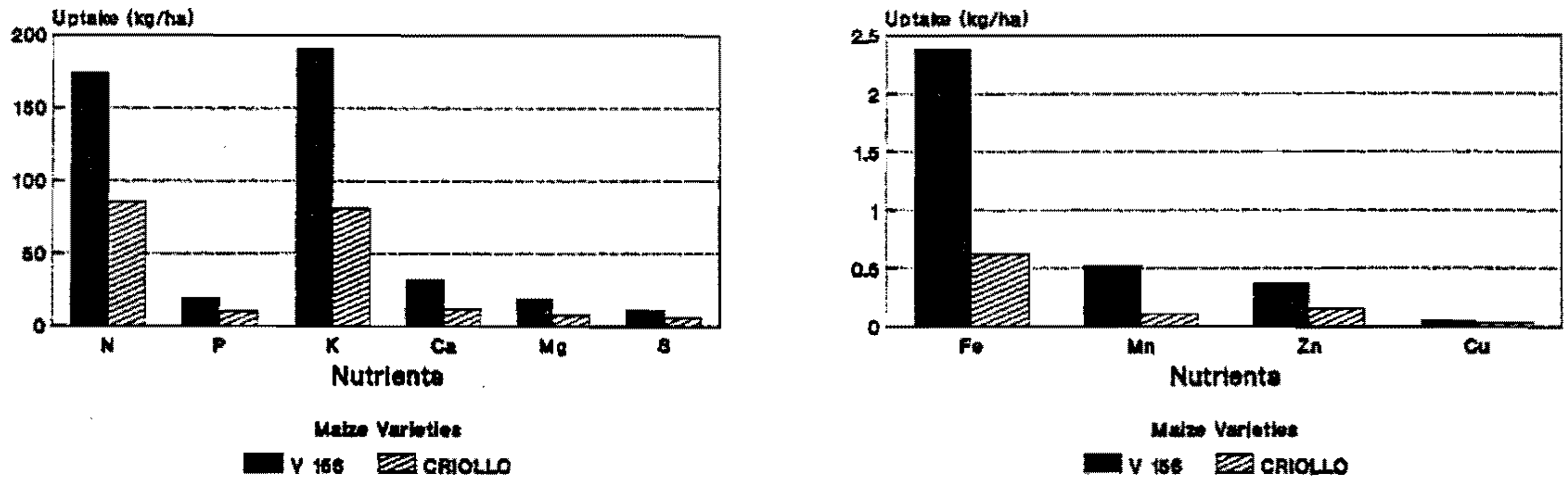


FIGURE 2. NUTRIENT UPTAKE FROM THE SOIL BY IMPROVED AND TRADITIONAL MAIZE CULTIVARS IN THE NORTH COAST OF COLOMBIA.

traditional to improved varieties of maize, will mean a more intense use of the soil nutrients and cosequently a shorter cropping phase and a longer fallow in the production cycle. In Table 17 and Figure 2 some preeliminary results from sampling plants in the North Coast are presented. The nutrients uptake by the traditional variety is much less than the uptake of the improved variety.
The use of fertilizers and some soil management practices could help to reduce the fallow period in the North Coast if improved maize varieties become more widely planted.

Table 17. Content and nutrient uptake by an improved and traditional maize variety in the North Coast of Colombia.

Nutrient	Cultivar			
	V-156		Criollo	
	Content(%)	Uptake(kg)	Content(%)	Uptake(kg)
N	2.3	175	2.5	85
P	0.25	19	0.31	11
K	2.5	191	2.36	81
Ca	0.43	32	0.35	12
Mg	0.25	19	0.22	8
S	0.15	11	0.17	6
	(ppm)		(ppm)	
Fe	311	2	181	0.6
Zn	69	0.5	33	0.1
Mn	50	0.4	46	0.2
Cu	8	0.06	9	0.03

9b.= Effect of maize and yam competition on the performance of different cassava cultivars

Results from the North Coast of Colombia and field observations at CIAT's Station, indicated that cassava yields were affected differently by its intercrop with maize and yam, depending -among other factors- on the cassava cultivar planted. To test the hipothesis of a different reaction of cassava cultivars to its intercrop with maize and yam, an experiment was designed and conducted under controlled condition in CIAT's Station at Palmira.

Seven contrasting cassava cultivars were selected for this experiment: CMC 40; CM 1223-11; CM 523-7; CM 849-1; SG 107-35; CM 1918-3 and M Ven 218. They were planted as sole crop and associated with maize at 1 pl/m2. In association with yam they were planted at .83 pl/m2. Maize in intercrop was planted at 3.3 pl/m2 while as sole crop it was planted

associated with maize. Figure 3. The ability to compete with maize is then probably a variety-related cassava characteristic.
Yields of cassava in association with yam were not significantly different among cassava cultivar with the sole exception of var. M Ven 218.
Average yield of maize (14% humidity) were reduced by 17 to 32 % when intercropped with the differnt cassava varieties. Intercropped maize yielded an average of 3.58 ton/ha while in monocrop its yield was 4.5 ton/ha. Yields of maize obtained with the different cassava varieties were not statistically different. The H-11 hybrid maize have performed similarly in other tests when intercropped on the same row with cassava.
Yams yields in intercrop with cassava were higher in average than yields obtained in yam sole crop, although the difference was not statistically significant. Yam yields obtained with the cassava varieties tested were not statistically different either.
Land equivalent ratios (LER) values of 1.31 and 1.72 for cassava/maize and cassava/yams intercrops were obtained in this experiment. This results confirm the preference for intercropping cassava, particularly in conditions of small farms like most of the cassava producing areas of Latin America.
In this experiment yam yield in monocrop was unusually low, but no explanation for this fact is available at this point. This low yield in monocrop, increased LERs values above 1.5 which is common for this crop combination.

Considering only the two cassava varieties with the highest yields,one of the non-yield variable that was significantly affected by intercrop was the number of stems/plant. In variety CM 1223-11, that drastically reduced its yield when intercropped with maize, the number of stems/plant was 2.31 in monocrop while in association with maize this number was reduced to 1.58/plant, a highly significant statistical difference (0.01**)

Variety CM 523-7, that did not reduced its yield significantly in intercrop with maize, practically maintained the same number of stems/plant in association and in monocrop. Further research should help in establishing the relationship between yield and number of stems/plant in sole crop and association with maize.

Variety CM 523-7 is one of the most vigorous in terms of fresh weight of its aerial part (11.4 ton/ha). In intercrop with maize this weight is reduced by 62%. Variety CM 1223-11 is less vigorous with 6.0 ton/ha of aerial weight. When intercropped with maize this weight is reduced by 58%. A very similar percentual reduction for the two varieties, but still on a higher level for variety CM 523-7. These results indicate that the vigour of a variety expressed in fresh weight of the aerial part, could indicate its ability to compite with maize when intercropped on the same row. The same is true for the variable weight of the planting material produced by the two varieties in monocrop and associated with maize.

both at 3.3 and 5.0 pl/m2 (near optimun for sole crop maize production). Yam was planted at .83 pl/m2 both in intercrop and in sole crop. The intercrops were arranged on the same row.

The ICA local hybrid maize H-211 and the yam cultivar "Pelado" from the North Coast of Colombia were used for the associations.
Treatments were arranged in a split plot design in which the crop combinations were the main treatments and the cassava cultivars the subtreatments. Four blocks were planted.

Considering an average of all the cassava varieties used, yields of cassava expressed as total fresh roots was significantly different (0.01**) in cassava sole crop (24.4 ton/ha) as compared with both its yield in association with maize (12.6 ton/ha) and with yam (13.7 ton/ha) for a relatively high 31.8% overall value of CV, mainly due to the yam. The variety M Ven 218 was severely affected by root rot pathogens and its average yield was only 6.1 ton/ha. There was a highly significant difference (0.01**)in terms of fresh roots yields between cassava cultivar even with the exclusion of M Ven 218. Table 18.

Table 18. Average yield of fresh roots (ton/ha) of seven cassava cultivars in sole crop and associated with maize (var. H 211) and yam (cv "Pelado").

			Cassava associated with					
Cultivar	Sole crop	(R)1/	Maize	(R)	Yam	(R)	Average	(R)
CMC 40	21.6 c 2/	(6)	13.9ab	(3)	12.2a	(5)	15.9 b	(6)
CM1223-11	30.8ab	(2)	11.2 bc	(4)	17.2a	(2)	19.7ab	(2)
CM 523-7	31.3a	(1)	20.5a	(1)	17.2a	(3)	23.0a	(1)
CM 849-1	23.8 bc	(5)	14.5ab	(2)	17.2a	(1)	18.5 b	(3)
SG 107-35	27.8abc	(3)	10.8 bc	(5)	16.8a	(4)	18.5 b	(4)
CM 1918-3	27.0abc	(4)	10.8 bc	(6)	11.6a	(6)	16.5 b	(5)
M Ven 218	9.0 d	(7)	6.5 c	(7)	2.8 b	(7)	6.1 c	(7)

1/ R= Rank
2/ Amounts followed by the same letter are not significantly different according with the Duncan´s multiple range test (0.05).

In sole crop cassava varieties yielded differently, CM 523-7 and CM 1223-11 outyielded the rest of the varieties tested. However, variety CM 1223-11 in association with maize yielded only 63.6% of its yield in sole crop and was ranked among the lowest yielder in association with maize. On the contrary, variety CM 523-7 maintained in association with maize, the high yield obtained in monocrop. Other varieties such as CM 849-1 ranked in the 5th place for its yield in monocrop, became one of the high yielder (2nd place) in association with maize. These results demonstrate that cassava varieties behave differently in sole crop and

3c:- Intercrop of cassava with two maize varieties at different maize plant densities.

Results obtained from farmer´s fields during several cropping seasons in the North Coast of Colombia, demonstrate that improved maize varieties not only yielded more in sole crop and intercropped with cassava, but they also allowed to obtain a higher yield of cassava than the traditional maize varieties.

Most of the improved varieties of maize yield more at high plant densities. This is not so for most of the traditional maize varieties. In regions where cassava and maize are frequently intercropped, farmers that adopt these improved new maize varieties do not always plant them at high plant densities neither in monocrop nor in association with cassava. If improved maize varieties yield more than the traditionals in association with cassava, then an increase in maize density will produce more maize but keeping the cassava yields higher or at the same level than with the traditional maize varieties. These will result in a general improvement of the maize/cassava association

Plant arrangement would probably influence the performance of the crops in the association. With some varieties of maize and/or cassava, farmers prefer the intercrop on the row or in alternate rows. The effect on cassava of increasing maize density will probably be different whether the plants are all on the same row or in alternate rows

An experiment was conducted in CIAT´s Station to test the performance of the cassava cultivar CMC-40 intercropped with a traditional (Limeno) and an improved (V-258) maize variety. Maize varieties were intercropped at 5 densities: 1.66; 2.49; 3.33; 4.16; and 4.99 plants/m2. Two spatial arrangements were used: intercrop on the same row (OR) and intercrop on alternate rows (AR). Cassava population was kept constant at .83 plant/m2.

Cassava as sole crop always yielded more than in association. In general, as maize plant densities increased, so increased the % yield reduction of cassava, in comparison with a constant check. With the traditional maize variety, there was a very clear negative correlation between increase in plant density and cassava yield. This was also true for the improved maize variety only in the case of the OR spatial cropping pattern. The cassava intercropped with this improved maize variety in alternate rows (AR) did not show this tendency. Table 19.

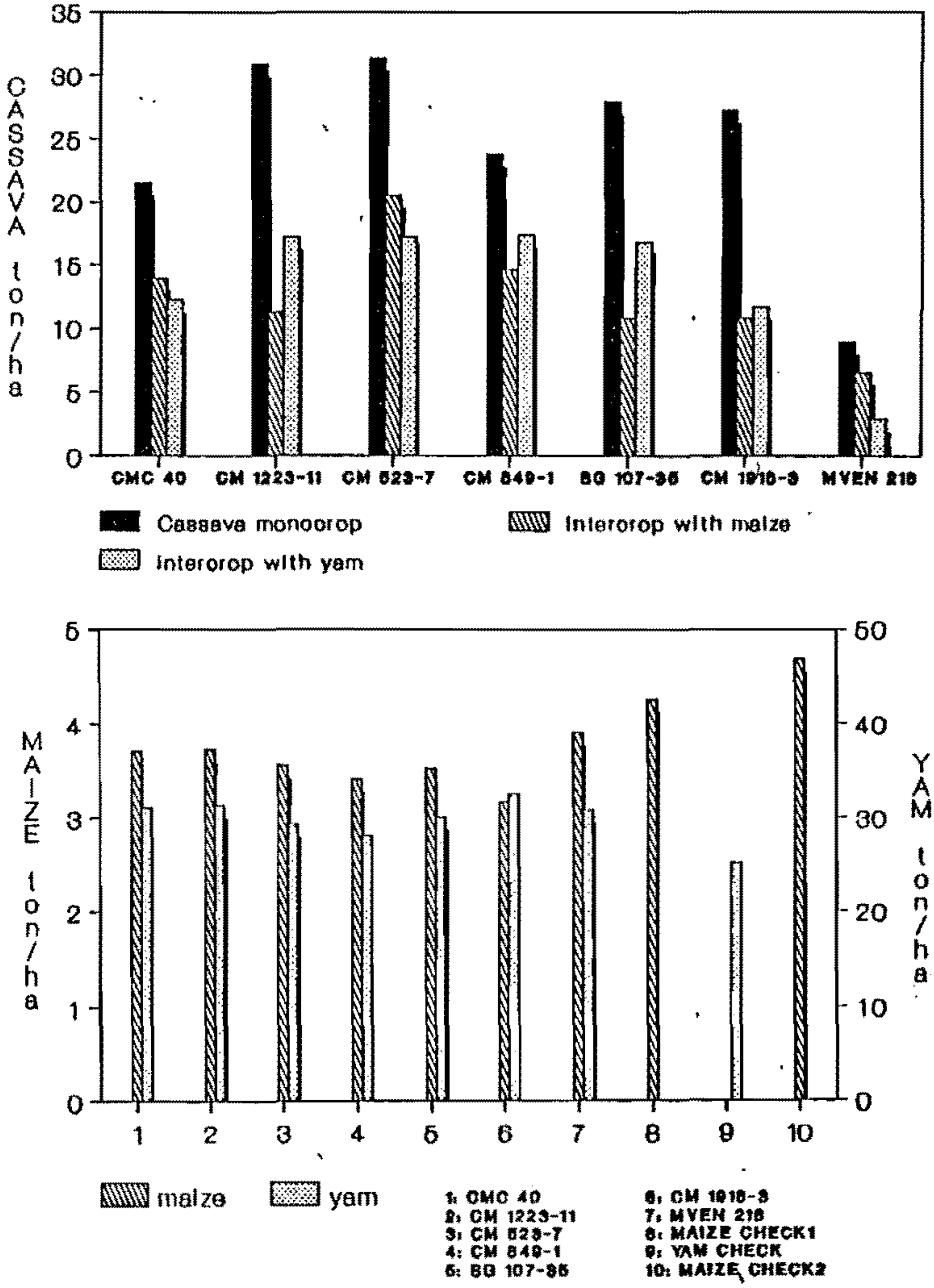


FIGURE 3. PERFORMANCE OF DIFFERENT CASSAVA CLONES IN SOLE CROP AND INTERCROPPED WITH MAIZE AND YAMS.

FIGURE 4. YIELDS OF TRADITIONAL AND IMPROVED MAIZE CULTIVARS INTERCROPPED WITH CASSAVA AT DIFFERENT PLANT DENSITIES AND CROPPING PATTERNS.

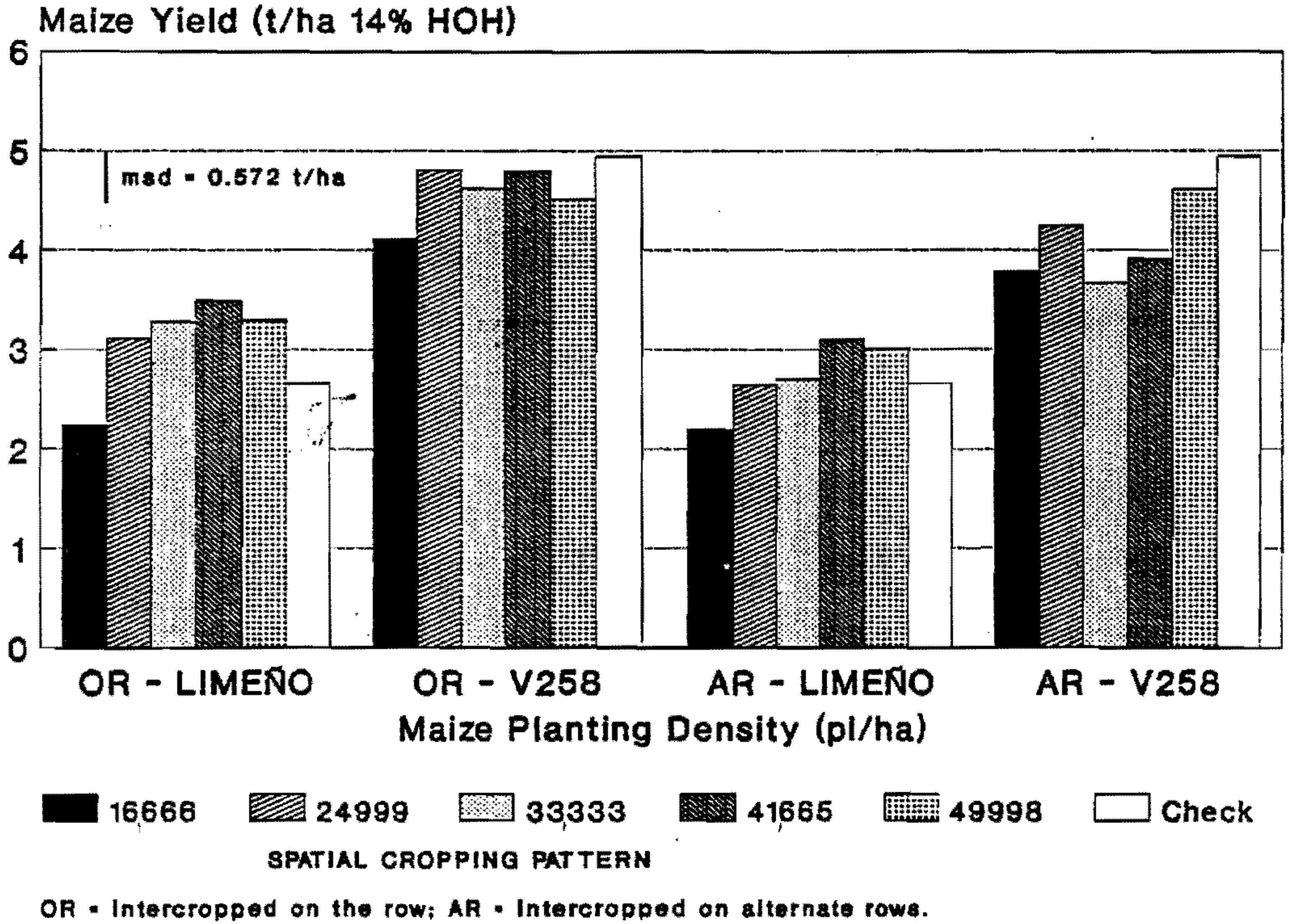


Table 19. Percentage yield reduction of cassava intercropped with two maize varieties at five planting densities of the maize.

Cropping pattern 1/	Limeno plant density x 1000 16.6	24.9	33.3	41.6	49.9
OR	28.62	39.65	51.31	59.67	65.72
AR	28.91	36.69	39.34	43.07	57.00
Cropping pattern	**V-258 plant density x 1000 16.6**	**24.9**	**33.3**	**41.6**	**49.9**
OR	22.43	37.34	54.05	59.45	67.73
AR	35.99	26.32	26.97	41.18	35.18

1/ OR= Cassava and maize intercropped on the same row; AR cassava and maize intercropped in alternate rows.

The decrease in cassava yield due to increase in maize population was less evident in the case of the improved variety V-258, particularly on the AR cropping pattern.

With regard to maize yields, the traditional Limeno variety increased its yields as the plant density was increased up to aproximately 4.16 plant/m2 , both for the OR and AR cropping pattern. The improved variety V-258 never reached the level of the check. Probably higher plant densities should have been tested for associatioin with cassava, since most of the improved varieties respond to very high plant densities. Table 20.

Table 20. Relative yield of two maize varieties at two plant densities in intercrop with cassava and compared with a check in sole crop.

Cropping Pattern	Limeno plant density x 1000 16.6	24.9	33.3	41.6	49.9
OR 1/	84.54	117.27	123.49	131.41	124.13
AR	83.03	99.66	102.73	116.86	113.24
Cropping Pattern	**V-258 plant density x 1000 16.6**	**24.9**	**33.3**	**41.6**	**49.9**
OR	83.24	97.27	93.43	97.01	91.30
AR	76.76	85.82	74.22	78.99	93.35

1/ OR=Maize and cassava intercropped on the same row. AR=Maize and cassava intercropped in alternate rows.

In Figures 4 and 5 the effect of variety, plant density and cropping pattern is represented in ton/ha.

In Figures 6 and 7 the best fit curves for maize and cassava yields are represented. With the traditional Limeno variety planted OR at a plant density of 2.5 plants/m2 is possible to obtain 3.0 ton of maize and 9.61 ton of cassava, with a AR cropping pattern, 37.0 plant/m2 of maize are needed to obtain the same yield of cassava, but only 2.82 ton of maize. For the traditional variety therefore the spatial cropping pattern has a clear influence on the performance of the maize/cassava crop combination.
With the improved maize variety the OR crooping pattern also resulted in a better general performance. With 1.69 plants/m2 it was possible to harvest 12 ton/ha of cassava and 4.2 ton/ha of maize. With the AR cropping pattern only with a 3.62 plants/m2 of maize was possible to harvest 11.2 and 3.89 ton/ha of cassava and maize respectively.

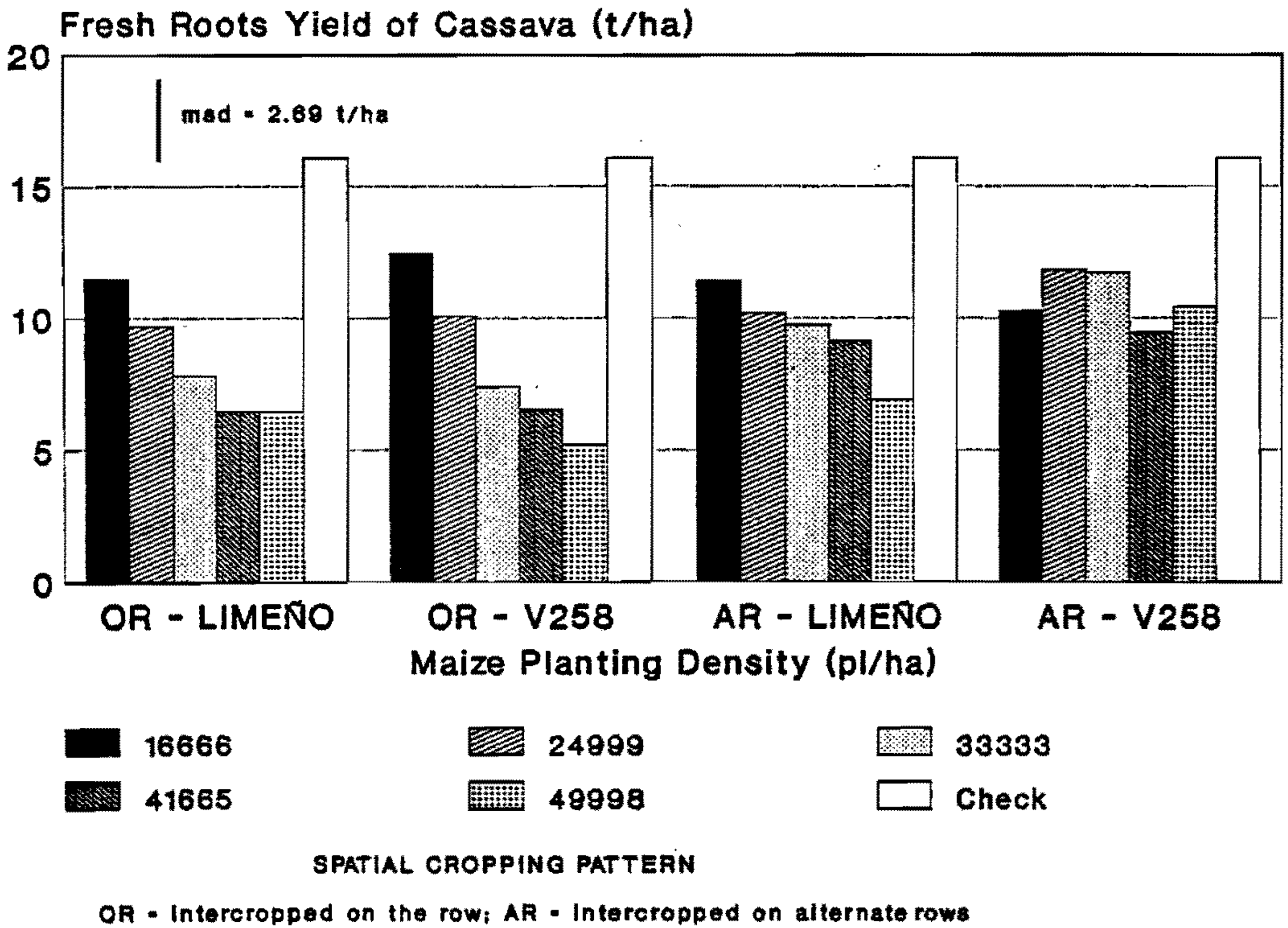
All evidence indicate that in spite of the theoretically higher requierements of the improved maize varieties in terms of nutrients, these improved varieties seem to compite less with cassava at least in the short range. This is probably related to more efficient use of light of the improved varieties, particularly during early stages of growth. This fact is represented in Figures 8 to 12. Particularly in Figures 10b, 11a, and 12a, it can be appreciated that from 55 to 65 days after planting, the light interception of the improved variety is less than the traditional. At the plant density of 3.33 plants/m2 where the difference in light interception is more evident, cassava yields are less afected by maize competition.
Less light interception in the case of the improved maize varieties allowed for a larger leaf area index in cassava at harvesting time. This is represented in Table 21.

Table 21. Leaf area index of cassava at harvesting time after being associated with a traditional and an improved maize cultivar interplanted at different desities.

Cropping pattern	Limeno plant density x 1000				
	16.6	24.9	33.3	41.6	49.9
OR	0.65	0.36	0.19	0.09	0.10
AR	0.69	0.50	0.68	0.37	0.33
Cropping pattern	**V-258 plant density x 1000**				
	16.6	24.9	33.3	41.6	49.9
OR	0.66	0.56	0.25	0.10	0.04
AR	0.77	0.82	1.01	0.56	0.61

The lesser amount of intercepted light could be one of the reasons for better yields of maize and cassava when improved rather than traditional maize varieties are used for the association with cassava.

FIGURE 5. YIELDS OF CASSAVA INTERCROPPED WITH A TRADITIONAL AND IMPROVED MAIZE CULTIVAR AT DIFFERENT PLANTING DENSITIES OF THE MAIZE AND CROPPING PATTERN.



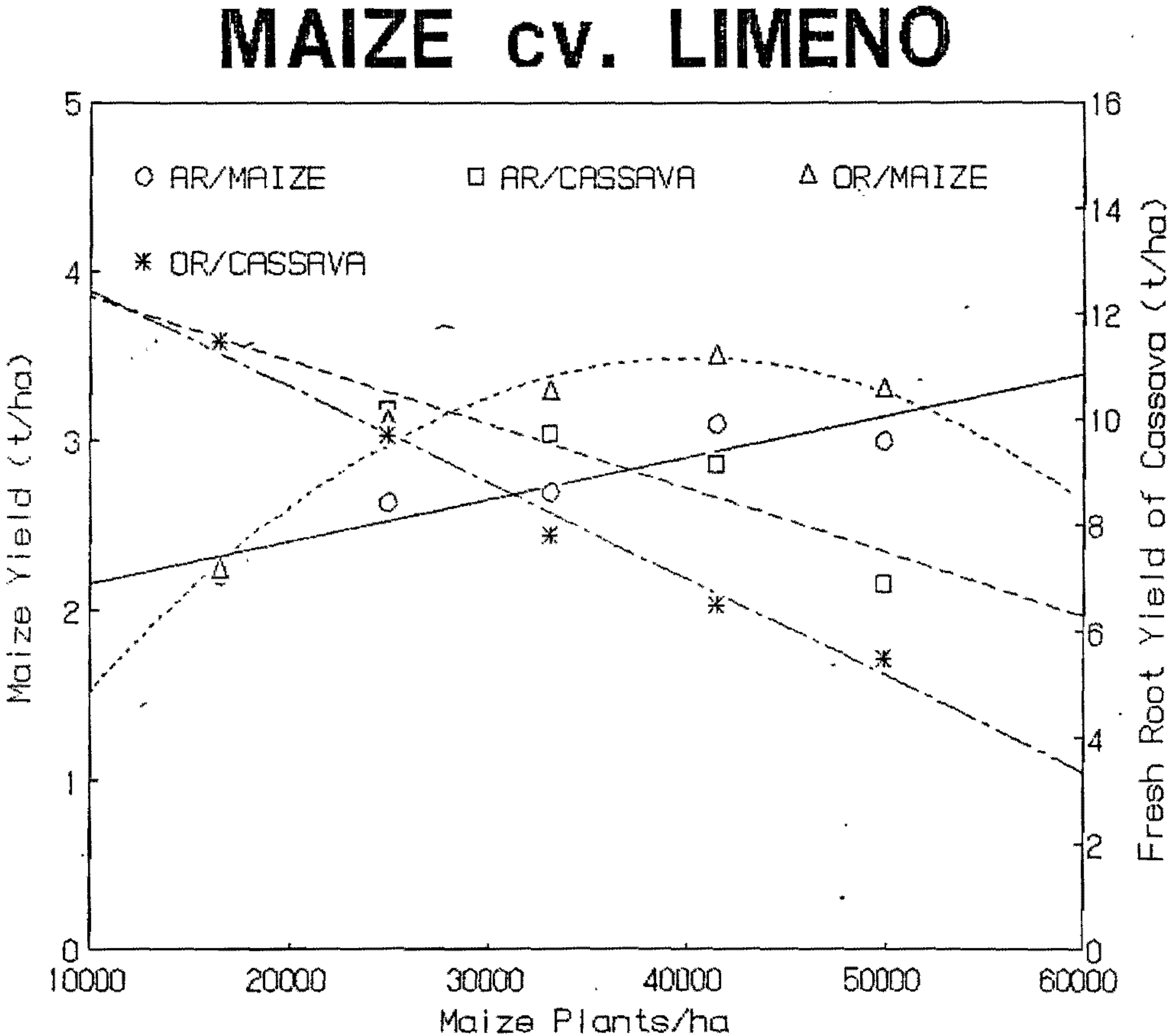


FIGURE 6. YIELDS OF MAIZE AND CASSAVA INTERCROPPED IN DIFFERENT CROPPING PATTERNS. TRADITIONAL MAIZE VARIETY.

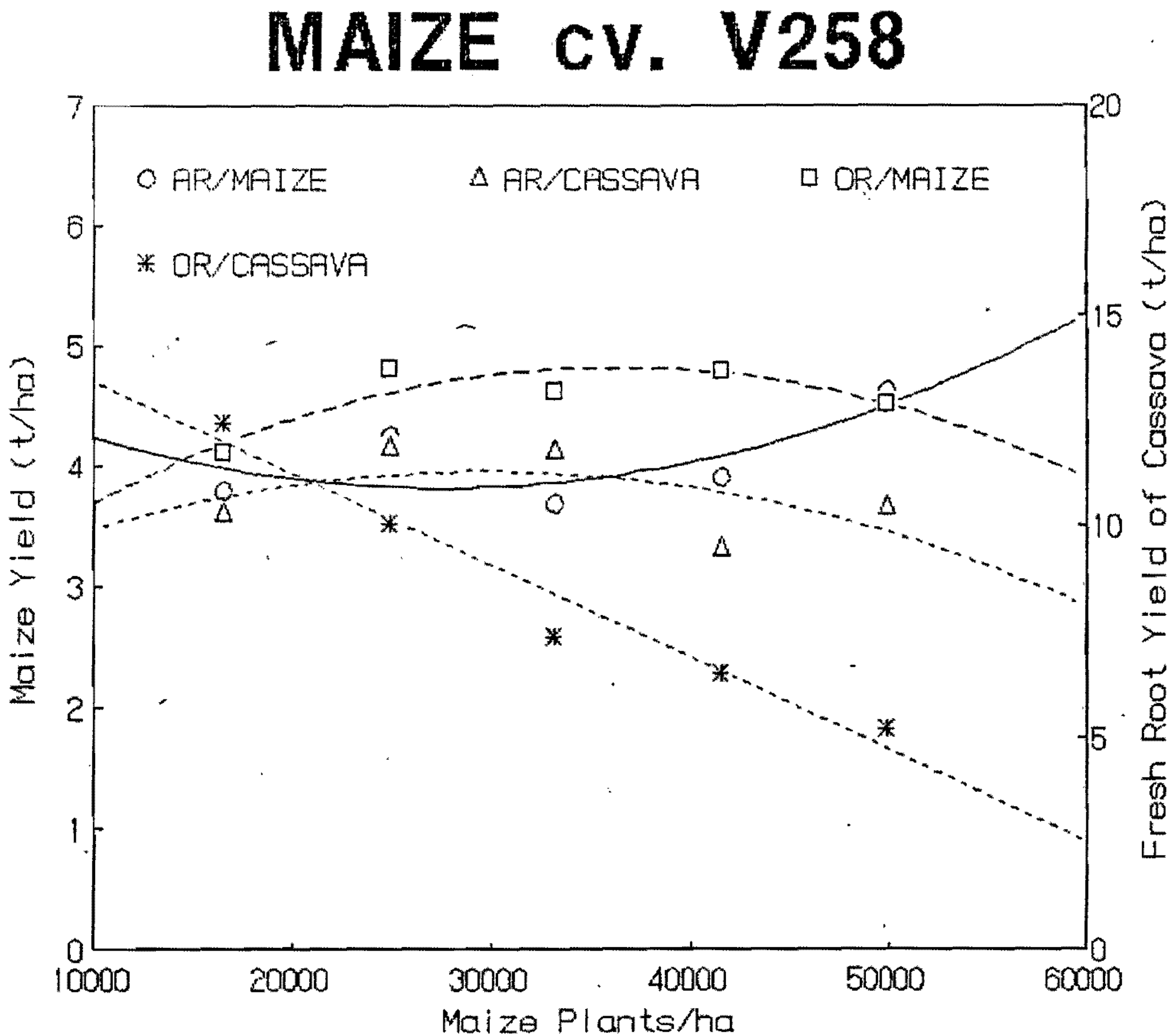


FIGURE 7. YIELDS OF MAIZE AND CASSAVA INTERCROPPED IN DIFFERENT CROPPING PATTERNS. IMPROVED MAIZE VARIETY.

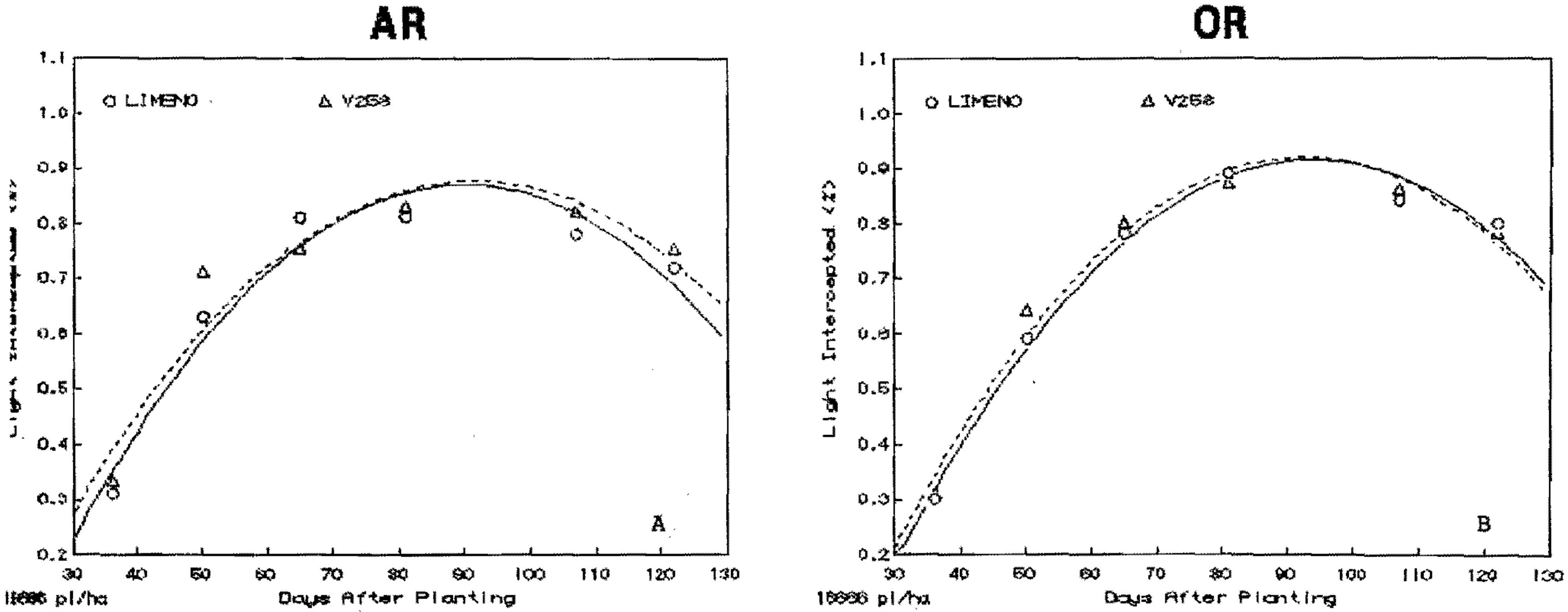


FIGURE 8. LIGHT INTERCEPTION OF A TRADITIONAL (LIMENO) AND AN IMPROVED (V-258) MAIZE VARIETY AT A PLANTING DENSITY OF 1.6 PLANTS/M2. A) INTERCROP ON ALTERNATE ROWS B) INTERCROP ON THE ROW.

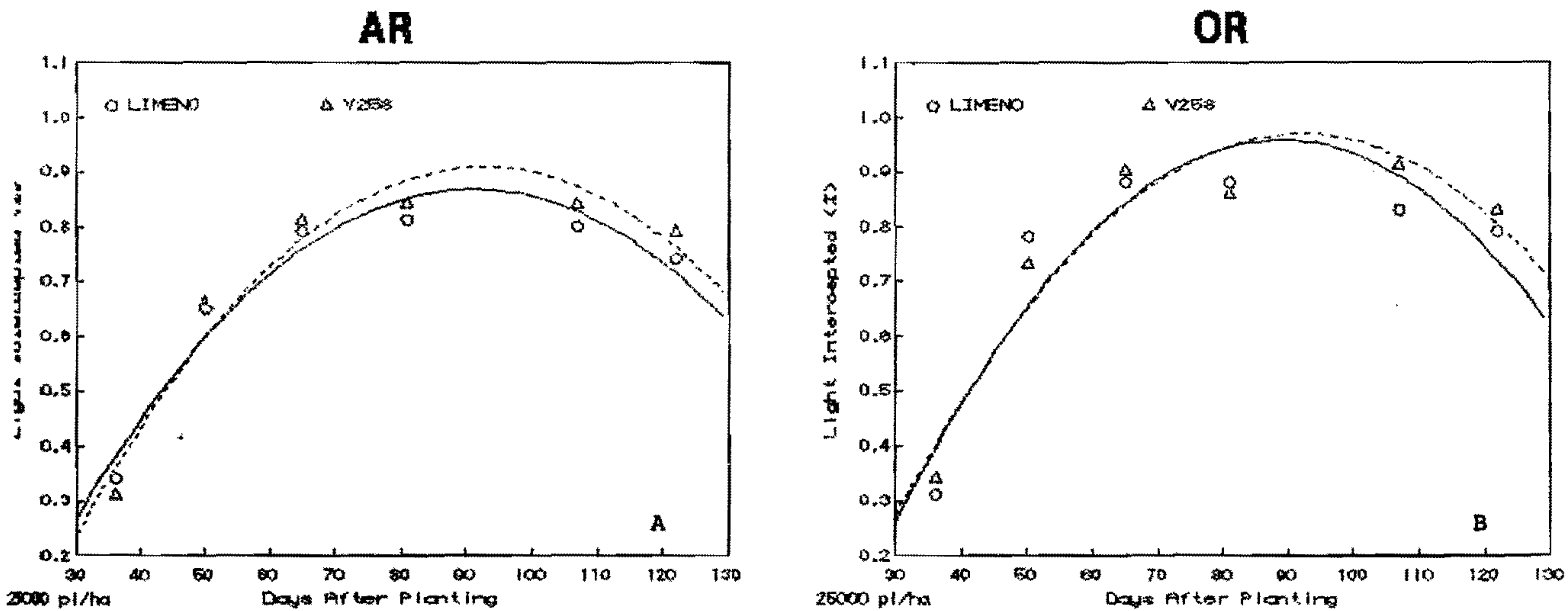
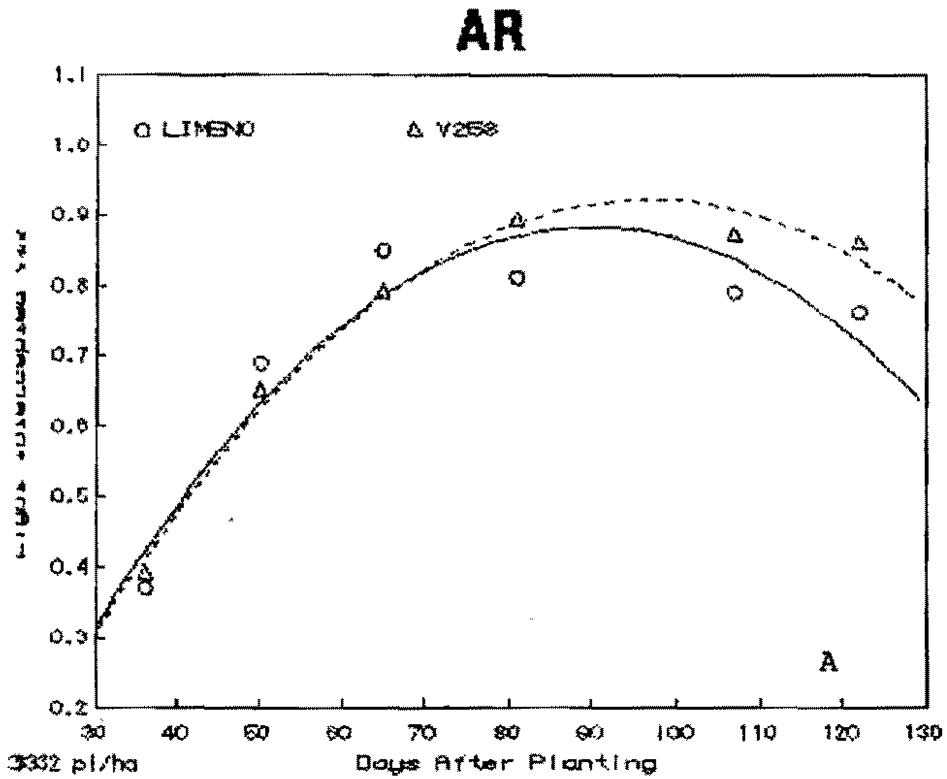


FIGURE 9. LIGHT INTERCEPTION OF A TRADITIONAL (LIMENO) AND AN IMPROVED (V-258) MAIZE VARIETY AT A PLANTING DENSITY OF 2.49 PLANTS/M2. A) INTERCR ON ALTERNATE ROWS B) INTERCROP ON THE ROW.



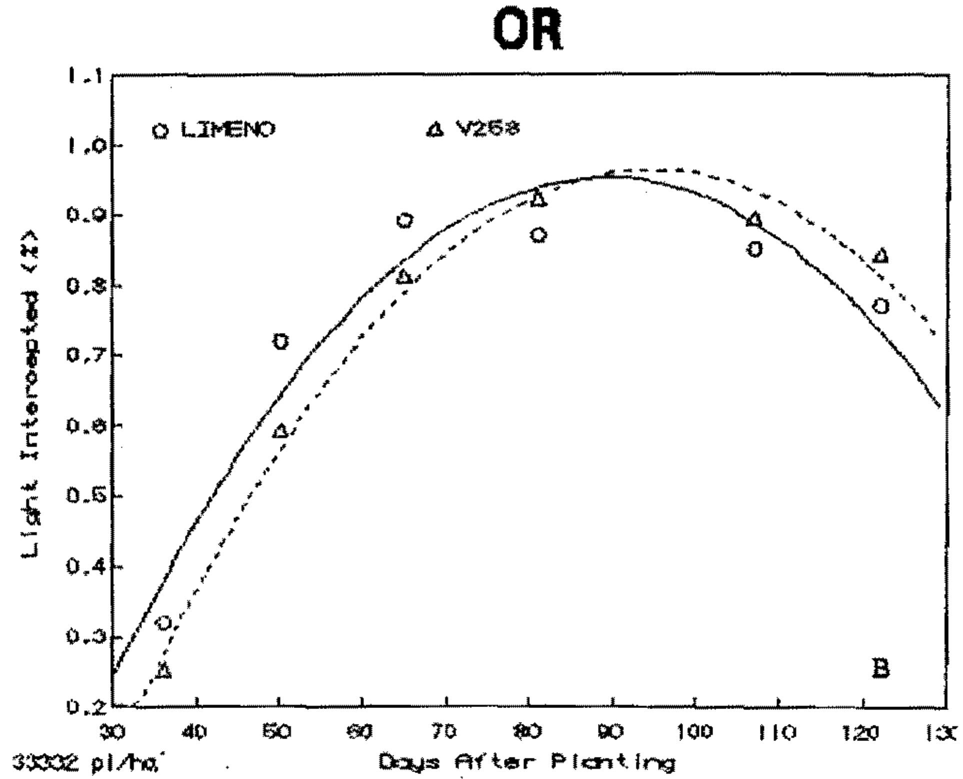


FIGURE 10. LIGHT INTERCEPTION OF A TRADITIONAL (LIMENO) AND AN IMPROVED (V-258) MAIZE VARIETY AT A PLANTING DENSITY OF 3.33 PLANTS/M2. A)INTERCR ON ALTERNATE ROWS B) INTERCROP ON THE ROW.

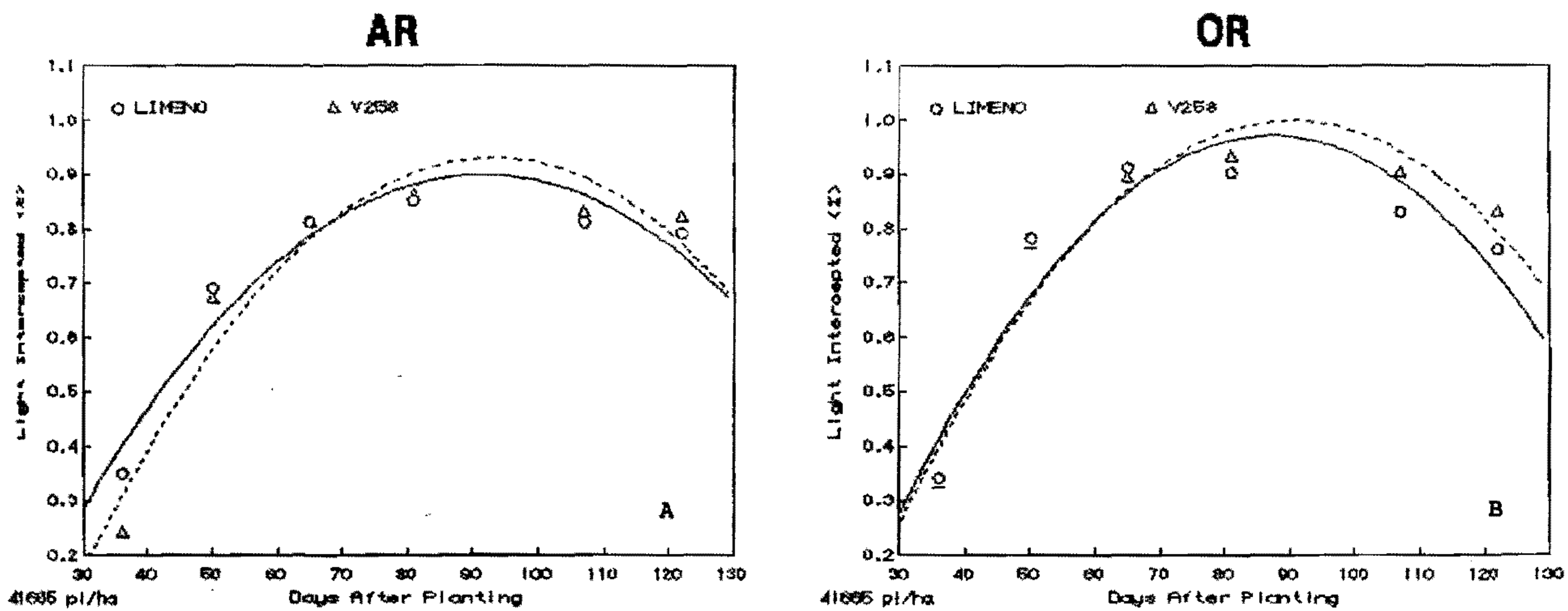


FIGURE 11. LIGHT INTERCEPTION OF A TRADITIONAL (LIMENO) AND AN IMPROVED (V-258) MAIZE VARIETY AT A PLANTING DENSITY OF 4.16 PLANTS/M2. A)INTERCROP ON ALTERNATE ROWS. B) INTERCROP ON THE ROW.

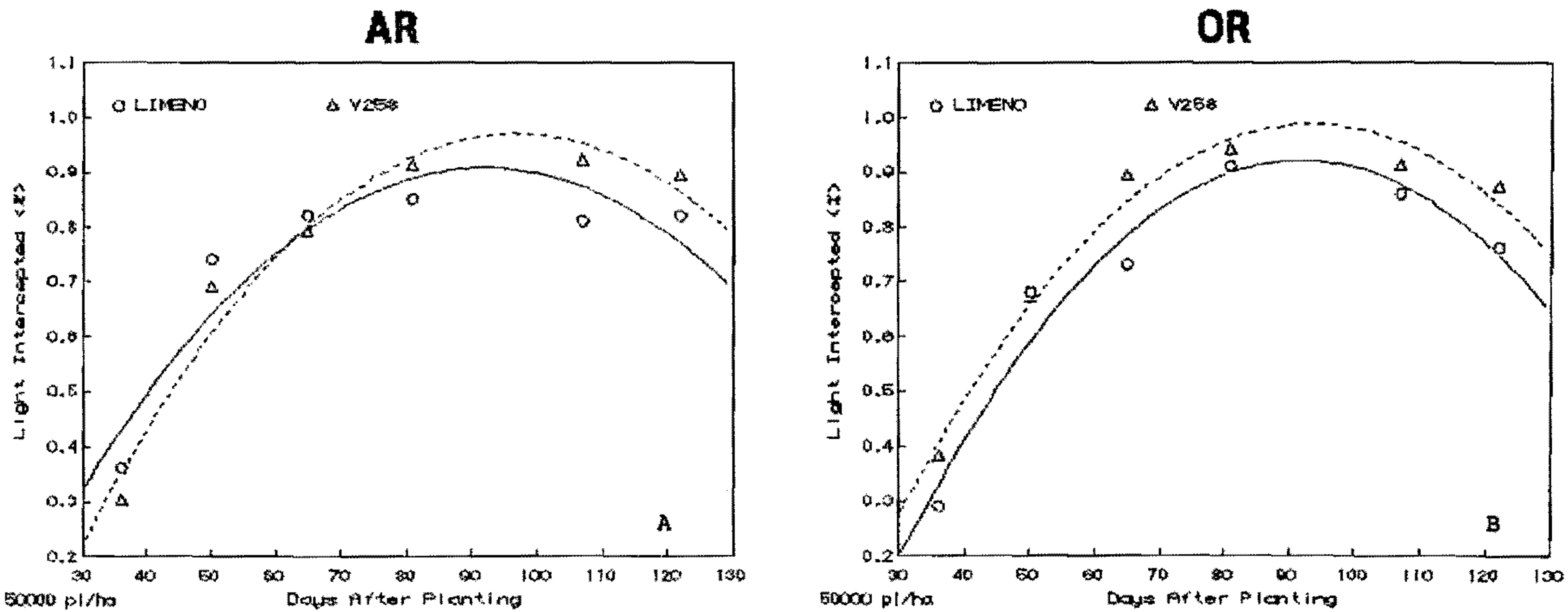


FIGURE 12. LIGHT INTERCEPTION OF A TRADITIONAL (LIMENO) AND AN IMPROVED (V-258) MAIZE VARIETY AT A PLANTING DENSITY OF 4.99 PLANTS/M2. A)INTERCROP ON ALTERNATE ROWS B) INTERCROP ON THE ROW.

ANNUAL REPORT 1989

CASSAVA ENTOMOLOGY

The cassava crop is confronted with a large complex of insect and mite pests throughout the cassava growing ecosystems of the world. The cassava entomology program is involved with collaborative research projects on all three continents where cassava is being grown, in the Americas, Africa and Asia. The program has been an active participant in the Africa Wide Biological Control of Cassava Pests through a collaborative project with IITA. Numerous natural enemies of mites and mealybugs have been collected, identified, researched, reared, and shipped to IITA via quarantine institutions in Europe. Monthly shipment of mite predators were made during 1989 and a newly identified predator of mealaybugs, Hyperaspis sp. found in the Llanos of Colombia, was shipped to IITA and released in African cassava fields. This project continues to excite and challenge entomologists and other scientists on both continents.

Continued studies with other major pests of cassava such as burrowing bugs (Cyrtomenus bergi), whiteflies and the cassava hornworm, have contributed additional information about these pests. Emphasis was also given to the implementation of control strategies at national program levels as well as collaborative research projects in Colombia, Cuba, Panamà, Paraguay and Brazil.

Cassava Mealybugs

Although numerous species of mealybugs have been identified attacking cassava, two species, Phenacoccus herreni and P. maninhoti, can cause considerable reduction in cassava yields. P. manihoti, native to the neotropics, is a pest in Africa where it has spread to about 30 countries. A major biological control program by IITA with CIAT's collaboration is bringing this insect pest under control. The CIAT Cassava Entomology Program is continuing to evaluate mealybug natural enemies in the neotropics for shipment to IITA, Benin for eventual release in Africa for P. manihoti control. CIAT maintains colonies of two mealybug species (P. herreni and P. madeirensis), 6 mealybug predator species and two parasites. At present a weekly production of 20,000 P. herreni females with ovisacs and 1000 P. madeirensis females allows the maintainance of predator and parasite colonies as well as providing mealybug populations for artificial infestations in field screening of cassava germplasm for resistance.

Explorations during 1989 confirmed the presence of P. herreni in Venezuela for the first time. P. herreni populations were found in several sites in Venezuela, including San Juan de Macarapana, Chirigua, and Nurucual in the department of Sucre; Los Barrancos de Fajardo, Maturin and Boquerón de Amanà in Monagas; Cantaura in Anzoategui; Marin in Yaracuy; Maracay (in the germplasm bank at U.C. Venezuelan experimental fields of the Faculty of Agronomy) in Aragua. Farmers in these areas confirm that mealybug populations have been with them for many years although they do not appear to be causing major demage. The widespread distribution of this species in Venezuela leads one to speculate that its origin may be the northern South America. When severe _P. herreni_ attacks occurred in N.E. Brazil in the early 1980's it was speculated that the mealybug may have been introduced into the area. _P. herreni_ was first repórted in Brazil, in Belem, Para, in 1975, thereafter spreading rapidly throughout the Northeast. Few natual enemies, especially parasites were found associated with these outbreaks, again leading to speculation that the species was not indigenous.

In contrast, _P. herrerni_ populations in Northeatern S.A., especially Colombia and Venezuela, have a large complex of natural enemies including numerous parasites. During explorations in Venezuela two parasite species, _Aenasius vexans_ (Encyrtidae) and an unidentified encyrtid were collected as well as several predator species. _A. vexans_ was the predominant parasite, found in 82% of parasitized females vs. 18% for the unidentified encyrtid. The most frequently observed predators were _Nephus_ sp. (Coccinellidae), Chamaemydae (Diptera), and _Ocyptamus_ sp. (Diptera). The parasite species will be collected and reared at CIAT for future study and possible introduction into Colombia and Brazil where they have not been reported.

Future explorations are planned for the countries of Guyana, Surinam and Fr. Guiana where _P. herreni_ poplulations should also exist. _P. herreni_ populations may have spread along the coastal area of S.A. on infested planting material, and eventually arriving in N.E. Brazil, where the absence of natural enemies, and the presence of favorable environmental conditions and the considerable area planted to cassava, contributed to the development of major outbreaks.

During 1989 six predator species were evaluated as potential candidates for control of cassava mealybugs (Table 1) (_Cleothera notata_, _Cleothera onerata_ [both collected at CIAT], _Cleothera_ sp. (Peru), _Hyperaspis_ sp. No. 1 (Carimagua), _Hyperaspis_ sp. No. 2 (Carimagua), and _Hyperaspis_ No. 3 [Huila, Col.]). The tribe Hyperaspini includes about 500 species in 14 Genera and the Americas are its center of distribution. They prey primarily upon scale insects and mealybugs (75%) and could therefore be important in biological control programs.

Rearing methods for coccinellid predators have been developed at CIAT. Mealybug infested, potted cassava plants are placed into an organdy-covered rearing cage (80 x 90 x 200 cm). Male and female coccinellids are released into these cages and allowed to feed and oviposit for 48 hours before plants are removed to a similar rearing cage, after making sure that no coccinellids

remain on the plants. Care is taken to assure tha species remain separate. After ecolosion, coccinellid larvae feed on mealybug eggs and immatures, pupate and complete their life cycle to adults.

The experimental arena for life table and predation/ consumption studies consists of a large petri dish (15 x 3 cm) with a circular hole (9 cm diameter) cut into the lid and covered with organdy for aireation. Mealybug ovisacs with some adult females, removed from the colony are placed on a square piece of paper towel, in the center of the petri dish. Two ends of the paper towel square are folded downward so that mealybug eggs remain on the underside, in order to simulating leaf conditions. Predator larvae usually prefer feeding on the leaf undersurface. Small drops of honey are placed in each petri dish, providing additional food. Three males and five females of coccinellid species being studied are removed from the colony and placed in the petri dish which is sealed with parafilm. Petri dishes are maintained at 28°C, 55± 4% RH and 12L:12D. The adults are allowed to oviposit for 24 hrs. before removal, thereby assuring offspring of uniform age. The petri dishes are maintained, under the aforementioned conditions and monitor daily during the entire life cycle.

Developmental times for the six species varied from 18.4 to 20.9 days (Table 2). Hyperaspis sp. No. 1 had a significantly longer developmental period from oviposition to pupation than any of the other species. The duration of pupal stage averaged from 6.9 (Hiperaspis sp. No. 2) to 10.4

(Cleothera sp.) days. The pupal development time of Hyperaspis sp, No. 2 is significantly shorter than that of the other species (Table 3).

The total development time (egg to adult) was significantly shorter for Hyperaspis sp, No. 2 (mean of 26 days) than the other species which ranged from nearly 28 days for Hyperaspis sp. No. 3 to a high of 3.2 days for Hyperaspis sp. No. 1 Table 4). The sex ratio of Hyperaspis sp. No. 2 was (2 females: 1 male compared to the other species in which the sex ratio was 1:1 (Table 5).

A short developmental period from oviposition to adult emergence may be a favorable attribute for biological control. Shorter development time permits more generations per generation of prey. Hyperaspis sp. No. 2 is distinguished from the other species by its short pupation period (6.8 days) while its feeding period, most important in biological control, remains as long as that of the other species.

Comparative consumption studies of mealybug eggs by larvae of Hyperaspis sp. No. 2 and Cleothera notata were carried out in the laboratory. There was no significant difference between the two species: C. notata consummed 36.65 mg of mealybug eggs and Hyperaspis sp. No. 2, 37.95 mg, during their respective larval development (Table 6). Hyperaspis sp. No. 2 tends to move quickly and searches actively for prey. Its searching ability appears to be superior to that of the other species. Successful establishment of C. notata in La Libertad (Colombia) where it was released during the past year suggests that it has potential as a biological control agent. I was sent to IITA Nigeria during 1988 where it has been reared and released.

Hyperaspis sp. No. 2, also has excellent potential as a biological control agent. This species has also been sent to IITA/Benin where it is being mass reared. Some releases of this species have already been made.

Cassava Green Mite Biological Control Project.

The objective of the research reported here was to provide a scientific basis for the selection of phytoseiids for introduction to Africa for control of the cassava green mite (CGM)(CGM. A series of laboratory and field studies provided comparative data for characteristics such as prey specificity, capacity for population increase with CGM as prey, and density-dependent response to CGM under field conditions. Data from exploration trips were used to characterize the ecological zone of adaptation of several phytoseiids, and to identify species with a high likelihood of adapting to African cassava agroecosystems. Biological differences between geographical subpopulations of phytoseiids were identified, and the significance of such strain differences for biological control was evaluated.

Laboratory Studies

Life Tables

Life tables (25 C; 70 + 5% R. H.; 12L:12D) offering *Mononychellus tanajoa* as prey were completed for 20 species/strains of phytoseiids. As a rough measure of the degree of specificity of each phytoseiid, a second life table was constructed for each species offering Tetranychus urticae as prey.The intrinsic rate of increase (r_M) was relatively low (< 0.10)when CGM was offered as prey to A. anonymus, Euseius concordis, A. aerialis, and C. transvaalensis (Fig. 1). Differences in performance on the two prey types were found for A. limonicus, A. tenuiscutus, and C. transvaalensis; these had negative growth rates when T. urticae was the prey. Superior r_M's with T. urticae as prey were observed for A. californicus, Phytoseiulus macropilis, and Cydnodromella pilosa. P. persimilis, whichis not associated with cassava, but known as a successful predator of T. urticae in a number of crops, performed better when CGM rather than T. urticae was offered as prey. This suggests that other data in additon to life tables should be used in assessing specificity of candidate species for CGM.

Thelytoky

To test the hypothesis that thelytokous (female-only) species might be promising biological control agents for CGM, life tables were constructed for Amblyseius mexicanus, A. herbicolus, A. neotunus and Clavidromus transvaalensis and were compared with thoseof non-thelytokous species.

Three of the four thelytokous species were below the global mean for r_M (0.16) and two of these, C. transvaalensis and A. herbicolus were at least 1 standard deviation below the mean (Fig.2); however, the r_M of A. mexicanus was comparable to that of *A. limonicus*. Thelytoky was suggested as a possible positive selection criterion because it was presumed that colonizing ability might be superior to that of species where both sexes are present. Although this may be the case, life table analysis suggests that good colonzing ability may not be associated with the ability to use CGM as prey.

Significance of Gegraphical Subpopulations.

A. limonicus from CIAT has proven more difficult to rear than populations collected from the North Coast of Colombia, implying that differences between geographical subpopulations or strains may exist. If the differences are great enough, the likelihood of successful establishment in Africa could depend on the selection of the right strain. In order to test for strain differences, *A. limonicus* strains from CIAT and the North Coast, from CIAT and Brazil and Colombian and Brazilian strains of *A. anonymus*, *A. idaeus*, and *A. aerialis* were crossed. Progeny were obtained in all crosses, however significant reproductive incompatibility was detected in reciprocal crosses of different Colombian strains of *A. limonicus* (Table 7), of Colombian and Brazilian *A. limonicus* (Table 8), and of Colombian and Brazilian *A. aerialis* (Table 9), compared to test crosses between individuals of the same strain. No significant reduction in the mean number of eggs/female was observed when Brazilian and Colombian *A. idaeus* were crossed, however significantly fewer females oviposited in the reciprocal crosses than in the test crosses suggesting that there may be some behavioral isolation affecting copulation (Table 10). In the Brazilian - Colombian crosses of A. anonymus no significant differences were observed compared to the test crosses (Table 11).

Predator Meal Analysis

Electrophoretic analysis of the gut contents of predatory mites can be used to test the hypothesis that the cassava green mite is an important component of the diet of phytoseiid predators in the field. The first step in the use of this technique is identification of a characteristic electrophoretic "fingerprint" for each predatory mite and for each item in the range of possible acarine and non-acarine foods which may contribute to its diet.

Considerable progress has been made in identification of a suitable electrophoretic system. Different techniques were tested using a range of phytoseiid species available in laboratory colonies. Phytoseiids were fed phytophagous mites of known identity and their gut contents were compared to those of predators which had been starved for 24 hours. The most successful method was polyacrylamide gel electrophoresis (PAGE). Phytophagous mites which have been tested include M. tanajoa, M. progresivus, M. caribbeanae, M. mcgregori, T. urticae, and Oligonychus peruvianus. All these species are distinguishable electrophoretically except for M. progresivus and M. tanajoa, which are considered a single species based on morphological data.

Field Studies

Within-plant Distribution of Phytoseiidae

In 4320 samples collected over 12 sampling dates from a predator exclusion experiment, an average of 1.09 phytoseiids/leaf were found on the first fully developed leaf, whereas an average of 1.98 phytoseiids/leaf were found on mature leaves between the 10th and 15th node. 59% of the A. idaeus collected over 4 sampling dates (n = 95) were found on mature leaves between the 10th and 15th node. The remainder were found on the first fully developed leaf.

Preliminary results from a field study of the within-plant distribution of A. limonicus indicate that consistently more A. limonicus/leaf are found on or below leaf 10 than on the youngest leaves (Fig. 3). The growing points of 20 plants/sampling date were dissected to look for phytoseiids, however recovery from the terminals was negligible. These results indicate that evaluations of establishment after liberation of A. limonicus or A. idaeus in African cassava fields should be based on on data from a mature leaf between the 10th and 20th node.

Predator exclusion

A predator exclusion study was planted in the North Coast of Colombia with the objective of determining whether phytoseiid predators are capable of a density-dependent response to Mononychellus spp. and whether they are effective in reducing yield loss. The treatments were predator exclusion (permethrin, applied every 15 days), mite exclusion (acaricide (every 15 days), a single application of acaricide and permethrin (made after the first sampling date), and an unsprayed control. The treatments were replicated in three blocks and the number of M. caribbeanae, a species closely related to CGM, on 30 leaves each from the 1st and 10th nodes were counted for each plot on each sampling date.

Cumulative mite numbers on both the first and tenth fully expanded leaves were significantly higher (ANOVA; $P < 0.05$) in the permethrin-treated plots than in the other treatments (Fig 4). There was no significant difference in cumulative numbers of mites between the first and tenth leaf; however the pattern of accumulation was different in the two levels. Mite numbers increased on leaf 1 after the rainy period between the 25th and 35th week after planting, reflecting movement onto the new foliage which appeared in response to the rain.

Permethrin treatment was successful in maintaining A. idaeus numbers at barely detectable levels which were not significantly different from those in the acaricide-treated plots in the first fully developed leaf (Fig. 5). A large difference ($P < 0.01$) in cumulative numbers was observed between the two leaf strata with higher numbers on leaf 10 in the unsprayed and acaricide/ permethrin-treated plots. The accumulation patterns of A. idaeus and M. caribbeanae suggest a density-dependent response of the predator to the prey.

Tetranychid species other than CGM are often associated with cassava in the neotropics and represent alternate prey which may be preferred over CGM by some phytoseiid predators. The number of infested webs of O. peruvianus on the central lobe was counted on 30 leaves 1st and 10th leaves in each plot on each sampling date. O. peruvianus numbers on the first leaf were negligible. On the 10th leaf the smallest population occurred on the acaricide-treated plots followed by the permethrin treated plots (Fig. 6). After a small initial growth spurt in the dry season, there was little further population growth until the end of the rainy period and only in the unsprayed plots and where acaricide and permethrin were applied once. The relatively low number of webs which accumulated in the permethrin-treated plots suggests that A. idaeus is not an important predator of O. peruvianus. Comparison of the temporal aspects of the dynamics of A. idaeus and O. peruvianus (Fig. 7) populations also suggests that A. idaeus is not an effective predator of O. peruvianus. The heavy webbing produced by O. peruvianus may serve as a deterrent against A. idaeus.

Statistically significant differences in root yields were not observed; however the highest mean yield was obtained from acaricide treated plots (37 T/Ha) and the lowest from plots where predators were excluded (26 T/Ha).

Exploration/Agroecological Data.

Based on the distribution of CGM in Africa and on the Carter (1986) agroecological criteria for cassava microregions in South America, a priority scheme for natural enemy exploration and selection was constructed (Fig. 8). Highest priority is given to lowland, isothermic, seasonally dry (4-6 months/year with < 60mm precipitation) zones. Second priority is given to lowland, isothermic, semiarid (7-9 dry months/year), and third priority is given to highland, isothermic areas which are either seasonally dry or semiarid. Excluding data from Brazil, of 455 collection records of CGM, 39% are from priority zone 1, 1% are from zone 2 and 4 percent are from zone 3. The humid lowlands and highlands account for 47 and 9% of the records respectively.

The remainder of this report will deal primarily with phytoseiid species with > 20 collection records (excluding Brazil). The most common species were A. limonicus, A. anonymus, G. annectens, G. helveolus, A. rapax, E. concordis, and A. tenuiscutus (Table 12). Species with more than the mean number of records in priority zone 1 (seasonally dry lowlands) are A. aerialis, I. zuluagai, A. idaeus, P. macropilis, A. cannaensis, A. limonicus, A. rapax and A. dentilis (Fig. 9). Species with more than the mean number of records in priority zone 2 (semiarid lowlands) are E. ho, G. annectens, P. macropilis and A. tenuiscutus (Fig. 10) The seasonally dry and semi arid highlands are a relatively unimportant ecological zone for phytoseiids in cassava.

A few species have between 17 and 23 % of total records in the humid highlands (Fig. 11). These are I. zuluagai, A. idaeus, A. aripo and A. peregrinus.

The humid lowlands, on the other hand, appear to be an important ecological zone for a number of phytoseiids (Fig 12). A. chiapensis, E. concordis, G. helveolus, A. anonymus, A. aripo, and A. peregrinus have more than the mean number of records in the humid lowladns.

Most species have a rather broad distribution with respect to rainfall pattern (Fig. 13), however, A. aerialis, A. chiapensis, A. peregrinus, E. concordis, I. zuluagai, A. canaensis, A. dentilis, and A. rapax appear to be more narrowly-adapted than the other species. A. chiapensis, A. peregrinus and E. concordis seem to be humid zones whereas A. aerialis, I. zuluagai, A. idaeus, A. cannaensis and A. rapax and A. dentilis seem to be specifically adapted to seasonally dry zones. E. ho and A. tenuiscutus are the species best adapted to semiarid zones.
The presence of phytoseiids in cassava throughout the growing season, has been proposed as selection criterion because of the importance of rainy season survival to permanent establishment of species introduced to Africa. Records of species with 20 or more collections in cassava were classified according to the age of the cassava field at the time of collection. All species except for A. idaeus and P. macropilis were found in cassava from 0 to 12 months of age. No records of these species were found in cassava from 10-12 months of age. Fourteen of the 17 species tended to predominate in cassava of less than 7 months of age (Table 13) and A. dentilis, A. aerialis and A. rapax tended to predominate in cassava of more than 7 months of age. All species were collected during both the rainy and dry seasons. Phytoseiids classified earlier as predominantly humid zone species were collected in more than 50 % of cases during the wet season, whereas the semiarid and dry zone species, with the exception of A. idaeus, were collected during the dry season in more than 50% of cases.

Species Selection

Species with > 20 records of collection in cassava, or with thelytokous reproduction, or which were available in laboratory colonies for biological studies were considered as possible candidates for introduction to Africa against CGM. In conclusion, it is recommended that species which have any combination of the following characteristics not be considered for introduction to Africa against CGM (Table 14): low fecundity when reared on an all-prey diet of CGM, low specificity for CGM, inappropriate ecological adaptation, very few records of collection on cassava compared to other hosts or very few records of collection on cassava.

Species which remain for consideration for introduction to Africa are A. limonicus, A. rapax, A. tenuiscutus, G. annectens, G. helveolus, P. macropilis, A. dentilis and A. bellottii.

The Cassava Borrowing Bug (Cyrtomenus bergi).

The Cassava burrowing bug, a soil borne hemipteran, continues to cause severe damange to cassava in certain locations in Colombia, as well as other countries, especially Panama. Surveys in Colombia, in collaboration with ICA (Instituto Colombiano Agropecuario) reveal that this insect attacks and damages numerous other crops. These include onion (Allium fistulosum), peanuts (Arachis hypogea), maize (Zea maize) sorghum (Sorghum vulgare), sugar cane, coffee, coriander, pastures and potatoes. Yield losses in some of these, particularly peanuts and onions, are considerable and numerous applications of pesticides are used in control programs. This wide host range hinders control because adults fly from one crop or field to another.

Previous studies have shown that C. bergi can complete its development and oviposit on a cassava only diet; however, it has also been shown that sweet or low HCN varieties are more acceptable than bitter or high HCN varieties.

A comparison is also made between cassava and two other crops, onion and maize. Under laboratory conditions, nymphal development and oviposition was measured. In addition experiments were designed to study feeding preference between cassava, maize and onions.

In preference studies, 20 adult and 30 nymph C. bergi were placed in the center of a 10 x 20 x 30 cms plastic tray containing soil and two of the aforementioned crops, one at each extreme of the tray. Observations on adult and nymph feeding were made after 3 days. After 3 days 92% of the C. bergi individuals were feeding on maize when given onion as an alernative, and 78% when given cassava (Table 15). Cassava was slightly preferred over onion.

Three days after reversal of the plant species in the trays (the C. bergi individuals were left undisturbed) the insects returned to feeding on their preferred hosts (Table 15). These results indicate that the maize-cassava planting system could increase populations of C. bergi.

Oviposition was measured by allowing 20 pairs of C. bergi to feed for 45 days on each of the three plant species. Young adults, less that 30 days old were randomly selected from a laboratory colony that had been maintained feeding on sweet cassava. the number of eggs oviposited by females feeding on maize (157) was more than seven times greater than those oviposited on cassava (21) and nearly nine times greater than those on onion (18) (Table 16). Egg hatch was also greater on maize and least successful on onions. Mortality of nymphs was lowest on maize, 28% and highest on cassava, 55% (Table 17). Female mortality was 10% on maize 45 and 50% respectively on cassava and onion. Nymphal development was shortest on maize (91.5 days), longest on onion (119.3 days), and intermediate on cassava 11 days) (Table 17). Mortality was higher on onion than on maize. Mortality data are not available for cassava.

These data indicate that maize is preferred by C. bergi over both cassava and onions. The low oviposition rate on cassava also helps explain the constant decline of C. bergi colonies when maintained on cassava. The switch from cassava to maize for colony maintenance has resulted in greater availability of C. bergi for experimentation.

High populations of C. bergi on cassava may be the result of migration of C. bergi into cassava fields from other crops or from weeds. C. bergi is not reported to be a serious pest on maize, which may be tolerant because of its extensive root system; however, a cassava-maize-cassava rotation could lead to severe losses in the second cassava planting.

Onion does not appear to be a preferred host; however, crop damage is severe in several areas of Colombia. Migration of adults of C. bergi into onion fields could account for this observation.

Control of *C. bergi*.

Previous studies have shown that *Crotalaria juncea* is effective for *C. bergi* control when it is intercropped with cassava; however,cassava yield is low due to competition from Crotalaria. The use of a systemic pesticide, although costly, also gives acceptable control of *C. bergi*. The combination of pesticide use with crotalaria was evaluated and compared to treatments of crotalaria only.

Intercropping with crotalaria throughout a 12 month crop cycle resulted in the most effective control with only 7.5% of the roots showing damage symptoms (Table 18) compared to nearly 69% root damage in the control plots. The application of systemin every 45 days during a 12 month cycle or the combination of systemin every 45 days for six month and crotalaria for 6 monts also gave acceptable results. Intercropping with crotalaria reduced cassava yields by nearly 32% whereas the combination of sytemin applications for 6 months (every 45 days) followed by 6 month intercropping with crotalaria did not reduce yield significantly (Table 19).

Cassava Whiteflies.

Several species of whiteflies attack cassava. The three predominant species in Colombia are *Aleurothrixus socialis*, *Trialeurodes variabilis* and *Bemisia tuberculata*. The predominant species in Brazil, *Aleurothrixus aipin*, is causing considerable damage in many areas of Northeast and Central Brazil. This species was reported for the first time in Colombia during 1989, along with Paraleyrodes sp., also previously unreported. Both species were found in the Amazon region of Colombia. Progress inthe identification and characterization of genetic strains of whiteflies of the genus Bemisia, in collaboration with the Univ. of Tel Aviv, Israel is reported in detail in the Virology Section of the CIAT Cassava Program, Annual Report.

In recent years, high whitefly populations have been reported from Paraguay, Brazil, and Colombia. The reason for these outbreaks is unknown. Different species are involved in each country; B. tuberculata in Paraguay, Aleurothrixus aipen in Brazil, and A. socialis and T. variabilis in Colombia.

Predators and parasites of whiteflies, especially in Colombia are common. The predator Delphastus pusillus and the parasites Amitus aleurodinus and Eretmocerus aleyrodiphaqus have been studied in Tolima, Colombia. D. pusillus attacks a range of whitefly species, and field data suggessts it is capable o a functional response to whitefly density; however,this predator does not appear to control whitefly populations and predators probably play only a minor role in whitefly population dynamics.

Parasitism, especially on A. socialis, the predominant species in Colombia on cassava, appears to be a more important mortality factor than predation. A. socialis parasitism by A. aleurodinus and E. aleyrodiphaqus ranged from 49.1% to 54.3% in experimental plots in ICA, Nataima-Tolima. Parasitism of T. variabilis was negligible.

The cropping system employed (maize or cowpea) did not have a significant effort on either parasitism or predation levels.

Over a period of several years, evaluations of whitefly resistance have been carried out at ICA-Nataima, Tolima. The cassava varieties M Ecu 72, M Col 336, M Pan 70, M BRA 12, and M Col 339 were selected as resistant or tolerant to whitefly attack. The predominant whitefly species was A. socialis. Crosses were made between resistant x resistant and resistant x susceptible clones and the progeny were evaluated under heavy whitefly preassure. No immunity to whitefly attack was expressed; all varieties and progeny supported whitefly populations; however, damage symptoms were more severe on some clones than others. For example, M Bra 12 often presented high whitefly populations but negliable damage symptoms.

Four hybrids were selected for replicated yield trials at ICA-Nataima: CG 489-4; CG 189-23, CG 489-31 and CG489-34. These were evaluated along with P 11 (CMC 40); P 12 (CMC 76) and the regional variety Quindiana. Due to problems of robbery of roots and stakes during the 1988-89 growing cycle the data presented is incomplete, and an additional cycle is being evaluated.

All four hybrids ware high yielding with excellent culinary characteristics (Table 19). Although P 11 (CMC 40) had the highest yield, despite heavy whitefly attacks and damage, dry matter content was unacceptably low (26%). Yield of the four hybrids ranged from 37.4 t/ha for CG 489-4 to 55.9 t/ha for CG 489-34. The regional cultivar Quindiana yielded well (40.5 t/ha) with excellent dry matter content (34.2) in spite of high whitefly populations and moderate damage symptoms. All four hybrids had a low level of damage despite of moderate to high adult whitefly populations. All four hybrids are pubescent and therefore resistant to thrips.

During April 1990 a field day will be held at ICA-Nataima for the pre-release of these hybrids. Planting material will be distributed to participating farmers to evaluate at the farm level. It is expected that sometime during 1991, one or more of these hybrids will be released by ICA.

The Cassava Hornworm, Erinyis ello.

The cassava hornworm is a major pest of cassava throughout the neotropics. Numerous natural enemies of this sphingid moth have been reported in previous Annual Reports. Due to the migratory behavior of the adults (see Cassava Annual Report, 1988), stable biological control is difficult to achieve. Trichogramma marandobai Brun, Moraes & Soares, was found parasiting hornworm eggs in the Department of Cauca, Colombia. This is the first report of this parasite. In addition a predator, Podisus obscurus (Pentatomidae) was identified and studied. At present more than 40 natural enemies (parasites, predators, and pathogens) of E. ello have been recorded.

An important aspect of the ongoing research in biological control has been the establishment of a system for mass rearing of hornworms under controlled conditions. Oviposition is negligible under laboratory conditions, so large field cages (2.5 x 25 x 25 mts) are used. These permit flight which appears necessary for oviposition. Eggs obtained in these cages are brought to the laboratory for hatching; all five larval instars are reared in plastic boxes (desinfected with 1% sodium hyperclorite for 24 hours). Prepupae and pupae are housed in mesh cages (1 x 1 x 1 meter) and emerging adults are rotated back to field cages for oviposition. Adults are offered a 5% sugar solution and eggs are collected daily. At present about 27,000 eggs are produced monthy with an average of 1,400 eggs per female and a sex ratio of 1.2 females per male. One thousand horworm eggs weigh 1.2 grams.

The possibility of storing hornworm eggs under low temperatures to delay hatching was studied. Eggs placed in paper bags were stored at 40°C and hatching was evaluated every 24 hours by removing them from cold storage and placing them at 25°C. Hatchability after 24 hours at 4°C was 40% while a control group stored at 25°C resulted in a 90% eclosion. Hatchability was reduced to 30% after 48 hours and 1% after 72 hours of storage at 4°C.

The pentatomid P. obscurus was studied in the laboratory (25° ± 5°C and 60% ± 5% RH). This larval predator has been observed feeding primarily on the 1st. instar of E. ello. The egg stage of P. obscurus lasts 6.8 days; there are five nymphal instars with an average total development time of 21.2 days (range of 17 to 27 days). Adult survived up to 91 days with an average of 63% days. All nymphal and adult stages will feed on E. ello larvae. The first instar of P. obscurus, feeds on E. ello, it does not cause mortality. Although the second through fifth instars cause some larval mortality of and the adults cause the greatest mortality (Table 20). Under laboratory conditions, an average of

75 hornworm larvae are consumed during the nymphal stage and an average of 627 larvae are consumed by one P., obscurus adult.

The hornworm virus disease (see Annual Report, 1988) offers an effective natural enemy for control of E. ello because it is easy to obtain and to store and can be applied when hornworm outbreaks occur without affecting other natural enemies of E. ello or of other cassava pests such as mealybugs and mites. During 1989 emphasis was placed transferring this technology to national programs, especially in Colombia but also in Cuba, Mexico and Brazil.

ICA (Instituto Colombiano Agropecuario) in collaboration with CIAT has initiated a project for integrated control of E. ello on the Atlantic Coast of Colombia in the Departments of Atlantico (Palmar de Varela), Sucre (Betulia), Cordoba (Monteria and Sahagun), and Santander del Sur (San Gil). In recent years there have been frequent hornworm attacks of increasing intensity in these areas. A training course for ICA technicians from each of the aforementioned zones was held at CIAT. Emphasis was given to the detection and monitoring of hornworm attacks and to the acquisition, storage, and application of the hornworm virus. An audiotutorial unit on the biological control of E. ello and a video on the use of the hornworm baculovirus were developed as teaching aids.

The Pilot Project Center has been installed at ICA-Turipana (Monteria) where numerous meetings to coordinate the selection of participating campesinos have taken place. At this Center two light traps have been installed as well as a freezer for baculovirus storage, a micronizer for virus application together with the equipment and supplies needed to rear _E. ello_ and to increase the supply of the baculovirus. Light traps have also been installed on cassava farms in all of the aforementioned areas.

The project is now functioning and data on _E. ello_ populations is being catalogued. At present hornworm populations have not reached levels requiring virus applications. Meanwhile several training courses run by ICA with small groups of farmers have taken place from May to November 1989 throughout the project zone.

TABLE 1. Comparison of 6 species of coccinellids.

Species	Elytra	Spots	Oviposition (Ovisacs)	Larval Max production	Pupation
Cleothera notata	Yellow	8 Black	Within	Yes	Soil
Cleothera onerata	Yellow	4 Black	Outside	Yes	Leaf
Cleothera sp.	Black	10 Yellow	Within	Yes	Soil
Hyperaspis sp. No 1	Black	4 Yellow	Outside	Yes	Leaf
Hyperaspis sp. No 2	Black	2 Stripes	Outside	Yes	Leaf
Hyperaspis sp. No 3	Yellow	6 Brown	Within	Yes	Soil

TABLE 2. Comparison developmental time in days from oviposition to population for 6 species of coccinellids beetles 1.

Species	No.	Mean	Range	S. D.	T-Grouping
Hyperaspis sp. No 1	40	20.90	19-24	1.17	A
Cleothera onerata	40	19.98	17-25	2.01	B
Hyperaspis sp. No 2	39	19.15	16-21	1.39	B C
Cleothera notata	40	19.13	17-22	1.14	C
Hyperaspis sp. No 3	40	18.95	16-21	1.24	C
Cleothera sp.	41	18.37	16-21	1.65	C

1 Same letters in T-Grouping indicate no significant difference from each other at P = 0.0001 (Anova multiple t-test. fisher's lsd)

TABLE 3. Comparative pupal developmental time in days from pupation to adult emergence for species of coccinellid beetles[1].

Species	No.	Mean	Range	S. D.	T-Grouping
Cleothera sp.	41	10.37	7-14	1.99	A
Hyperaspis sp. No. 1	40	10.30	8-12	0.88	A
Hyperaspis sp. No. 3	40	8.95	7-11	0.81	B
Cleothera notata	40	8.80	7.11	0.91	B
Cleothera onerata	40	8.80	6-12	1.49	B
Hyperaspis sp. No. 2	39	6.85	5-9	1.01	C

1 Different letters in T-Grouping indicate a highly significant difference from each other at P = 0.0001 (anova multiple T-Test. fisher's lsd)

TABLE 4. Comparative total developmental time in days from oviposition to adult emergence for 6 species of coccinellid beetles 1.

Species	No.	Mean	Range	S. D.	T-Grouping
Hyperaspis sp. No. 1	40	31.20	28-34	1.32	A
Cleothera onerata	40	28.83	25-32	1.62	B
Cleothera sp.	41	28.73	26-32	1.34	B C
Cleothera notata	40	27.93	26-31	1.43	C
Hyperaspis sp. No. 3	40	27.90	26-30	1.15	C
Hyperaspis sp. No. 2	39	26.00	23-30	1.81	D

1 Different letters in T-Grouping indicate a highly significant difference from each other at P = 0.0001 (anova multiple T-Test. fisher's lsd)

TABLE 5. Comparative sex ratios of 6 species of coccinellids.

Species	Females	No.	% Males	No.	% Total
Cleothera notata	A	18	45.0	22	55.0 40
Cleothera onerata	A	20	50.0	20	50.0 40
Cleothera sp.	A	21	51.2	20	48.8 41
Hyperaspis sp. No. 3	A	19	47.5	21	52.5 40
Hyperaspis sp. No. 1	A	20	50.0	20	50.0 40
Hyperaspis sp. No. 2	D	26	66.7	13	33.3 39
TOTALS		124	51.7	116	48.3 240

1 Different letter indicates a highly significant difference from others at P = ?????????

TABLE 6. Comparative consumption of mealybug eggs (in millegrams) by larvae of two species of Coccinellid beetles 1.

Larval species	No. Larvae	Mean (MG.)	Range (MG.)	S. D.	T-Grouping
Cleothera notata	20	36.65	30-43	3.57	A
Hyperaspis sp.	20	37.95	26-52	6.17	A

1 Same letters in T-Grouping indicate no significant difference from each other at Alpha = 0.01 (Anova multiple T-Test. fisher's lsd)

TABLE 7. Hybridization between A. limonicus strains from Colombia.

CROSS Female		male	n	Mean no. eggs/female	% females ovipositing
VAL	X	VAL	10	5.1 AB	90
COR	X	VAL	15	3.2 BC	67 **
VAL	X	COR	15	2.5 C	67
COR	X	COR	10	7.7 A	100

VAL = Valle, Colombia; COR = Cordoba, Colombia Means followed by different letters are significantly different (DMRT; P = 0.05).
** Significantly lower in hybrid than in self crosses (Binomial test; P = 0.05).

TABLE 8. Hybridization between *A. Limonicus* strains from Colombia and Brazil.

CROSS Female male			n	Mean no. eggs/female	% females ovipositing
BR	X	BR	10	11.7 A	90
CO	X	BR	18	0.7 D	22 **
BR	X	CO	18	5.0 C	67
CO	X	CO	10	5.7 AB	100

BR = Brazil; CO = Colombia.
Means followed by different letters are significantly different (DMRT; P = 0.05).
** Significantly lower in hybrid than in self crosses (Binomial test; P = 0.05).

TABLE 9. Hybridization between _A. aerialis_ strains from Colombia and Brazil.

CROSS Female		male	n	Mean no. eggs/female	% females ovipositing
BR	X	BR	10	4.2 B	80
CO	X	BR	25	1.8 C	57 **
BR	X	CO	21	0.5 C	28
CO	X	CO	10	13.6 A	100

BR = Brazil; CO = Colombia.
Means followed by different letters are significantly different (DMRT; P = 0.05).
** Significantly lower in hybrid than in self crosses (Binomial test; P = 0.05).

TABLE 10. Hybridization between *A. idaeus* strains from Colombia and Brazil.

CROSS Female male			n	Mean no. eggs/female	% females ovipositing
BR	X	BR	12	7.9 NS*	92
CO	X	BR	20	3.6	75 **
BR	X	CO	20	5.5	70
CO	X	CO	13	5.9	92

BR = Brazil; CO = Colombia.
* Anova.
** Significantly lower in hybrid than in self crosses (Binomial test; P = 0.05).

TABLE 11. Hybridization between *A. anonymus* strains from Colombia and Brazil.

CROSS Female male			n	Mean no. eggs/female	% females ovipositing
BR	X	BR	10	10.0 NS*	100
CO	X	BR	12	12.7	73 NS**
BR	X	CP	15	13.3	100
CO	X	CO	10	11.9	100

BR = Brazil; CO = Colombia.
* Anova
** Binomial test.

TABLE 12. Phytoseiid species with at least 20 records of collection in the neotropics excluding Brazil.

Species	No. Records
A. limonicus	636
A. anonymus	157
G. annectens	107
G. helveolus	94
A. rapax	83
E. concordis	77
A. tenuiscutus	75
A. aerialis	74
E. ho	73
A. aripo	73
A. dentilis	68
A. idaeus	44
A. cannaensis	38
A. peregrinus	38
P. macropilis	31
I. zuluagai	23
A. chiapensis	22

TABLE 13. Phytoseiids occurring predominantly in young cassava plantations (<7mo.).

Species	n	% Total records
A. idaeus	44	94
E. concordis	77	72
A. peregrinus	38	69
G. annectens	107	68
A. chiapensis	22	68
A. cannaensis	38	66
A. anonymus	157	63
I. zuluagai	23	61
_E. ho_	73	61
A. limonicus	636	60
A. tenuiscutus	75	60
A. aripo	73	60
G. helveolus	94	58
P. macropilis	31	58

TABLE 14. Non-selected species of phytoseiids for introduction to Africa against cassava green mite.

	JUSTIFICATION				
SPECIES	FECUNDITY	SPECIFICITY	ECOLOGICAL ADAPTATION	HOST PLANT RANGE**	FREQ. OF OCCURRENCE
A. aerialis	X	X			
A. anonymus	X				
A. cannaensis		X			
A. chiapensis		X	X	X	
A. herbicolus	X	X			X
A. idaeus		X			
A. largoensis		X			X
A. neotunus	X				X
*A. peregrinus**			X		
C. transvaalensis	X	X			X
E. concordis	X	X	X		
E. ho		X		X	
I. zuluagai				X	

* *A. peregrinus* and *A. aripo* may be the same species.
** ≤ 50% of collection records were on cassava.

TABLE 15. Feeding preference of C. bergi for onion (Allium fistolusum) maize (Zea maize), and cassava (Manihot esculenta).

Crop species mixture	Crop prefered	% prefered
Experiment I		
Maize * Onion	Maize	92 %
Maize * Cassava	Maize	78 %
Cassava * Onion	Cassava	58 %
Experiment II *		
Onion * Maize	Maize	88 %
Cassava * Maize	Maize	76 %
Onion * Cassava	Cassava	54 %

* In experiment II the crops were reversed in the plastic trays but the insects were not disturbed.

TABLE 16. Oviposition of 20 female C. bergi feeding on maize, onion and cassava for 45 days.

Crop.	Number of eggs	% eggs hatched	% Mortality of nymphs total	males	females
Maize	157	89	28	45	10
Cassava	21	81	55	65	45
Onion	18	61	42	35	50

TABLE 17 The development of nymphal stages of C. bergi feeding on maize, cassava* and onion.

		M A I Z			O N I O N		
Life Stage	Duration in days	S. D.	Mortality %	Duration in days	S. D.	Mortality %	Duration in days
1 st instar	14.6	2.1	25 %	15.4	3.8	34 %	13.8
2 nd instar	15.6	2.4	5	19.2	3.9	11	17.8
3 nd instar	16.6	2.6	5	23.6	3.8	6	21.1
4 th instar	18.2	2.8	1	24.5	4.8	2	25.0
5 th instar	26.5	3.0	2	36.6	4.9	3	33.6
TOTALS		91.5	5.14	38 %	119.3	10.49	56 % 111.3

*. Cassava C. bergi feeding data taken from thesis by C. Garcia, 1982.

TABLE 18. Control integrado de C. bergi (Froeschner) en el cultivo de la yuca.

Treatment	Yield* t/ha	% Root Damage	Damage* Grade
Crotalaria 1-12 months	17.3 B	7.5 C	1.0 B
Sistemín 1-6 - Crot. 7-12 months	23.6 A	12.5 C	1.4 B
Sistemín 1-12 months	25.5 A	20.0 C	1.1 B
Crotal. 1-6 - Sist. 7-12 months	20.1 B	46.3 B	1.2 B
Control	25.4 A	68.8 A	3.5 A

* Means followed by the same letters are not significantly different (P > 0.05; Dunccun's multiple range test).

TABLE 19. The evaluation of four cassava hybrids and tree cultivars for whitefly (*Aleurotrachellus socialis*) resistance and yield at ICA-Nataima, Tolima Col.

Clone	yield	% dry matter	Adult popul. grade	Pupa popul. grade	Damage grade
CG 489-4	37.4	32.2	3.7	3.7	0.3
CG 489-23	42.8	33.5	5.0	3.7	0.0
CG 489-31	39.8	30.3	4.3	3.3	0.0
CG 489-34	55.9	29.8	4.7	3.7	0.0
P-11 (CMC-40)	69.1	26.3	5.0	5.0	4.0
P-12 (CMC-76)	32.4	33.5	5.0	4.7	2.7
REGIONAL (Quind.)	40.5	31.2	5.0	5.0	3.0

TABLE 20. The consumption of 1st instar *Erinnys ello* larvae by nymphal and adult stages of *Podisus obscurus* (Dallas)

Development* Stage (instar)	No. Observation	Number of *E. ello* larvae consumed Maximun	Minimun	Average
N1	25	0	0	0
N2	20	11	2	7.6
N3	20	17	3	9.2
N4	20	62	3	18.6
N5	20	74	16	47.0
Adult	14	960	448	627.0
Totals		1,124	472	709.4

* (Laboratory condition; 25° ± 5°C and 60% ± 5% RH).

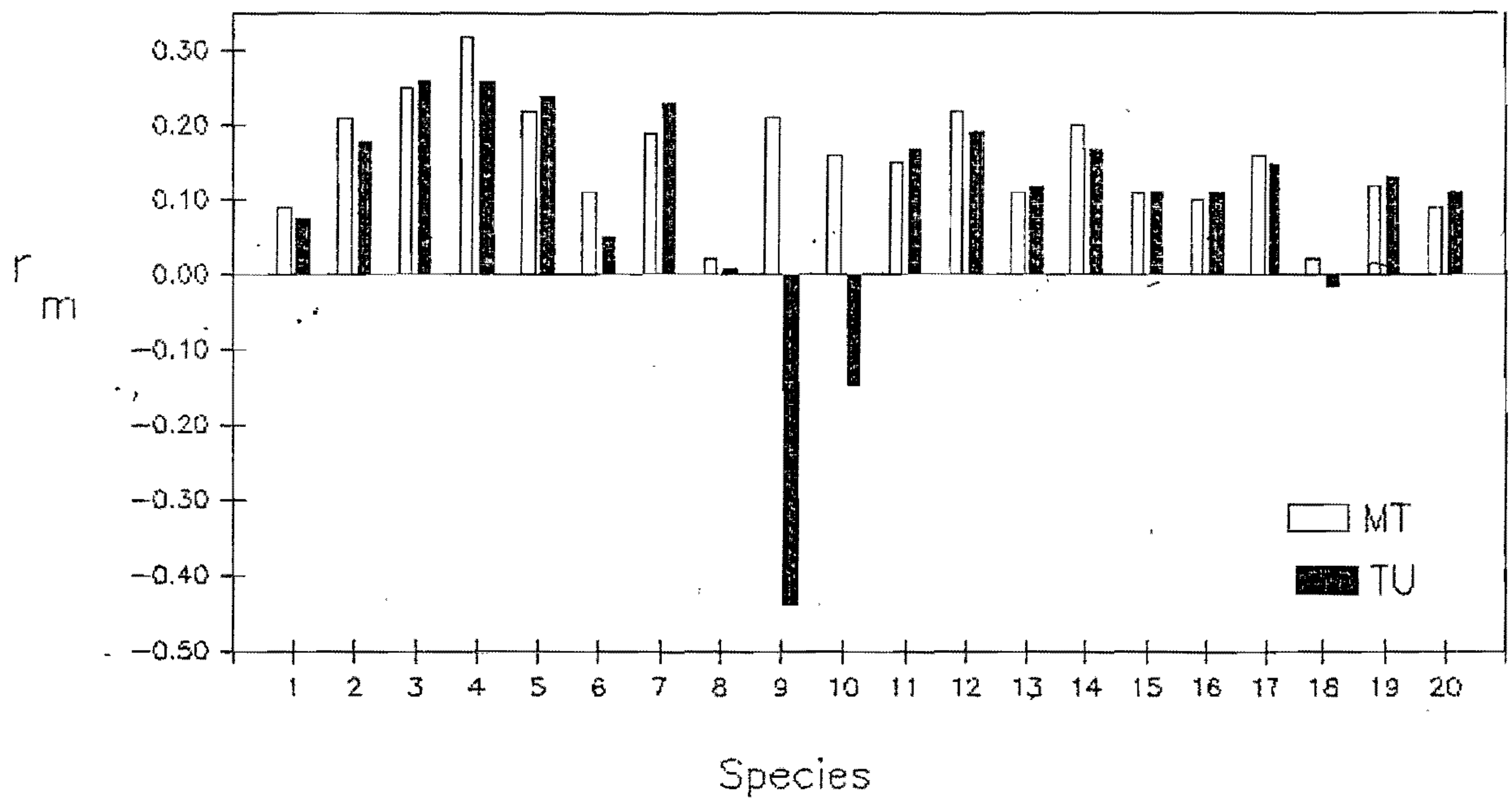


FIGURE 1. Intrinsic rate of increase (r_m) for 20 Phytoseiidae comparing *M. tanajoa* (MT) and *T. urticae* (TU) as prey. X-axis numbers correspond to the following species: 1 *A. anonymus*, 2 *G. annectens*, 3 *A. idaeus*, 4 *P. persimilis*, 5 *A. californicus*, 6 *E. concordis*, 7 *P. macropilis*, 8 *A. aerialis*, 9 *A. limonicus*, 10 *A. tenuiscutus*, 11 *C. pilosa*, 12 *P. mexicanus*, 13 *A. chiapensis*, 14 *A. largoensis*, 15 *A. cannaensis*, 16 *A.* 16 *A. kazimiae*, 17 *G. helveolus*, 18 *C. transvaalensis*, 19 *A. neotunus*, 20 *A., herbicolus*.

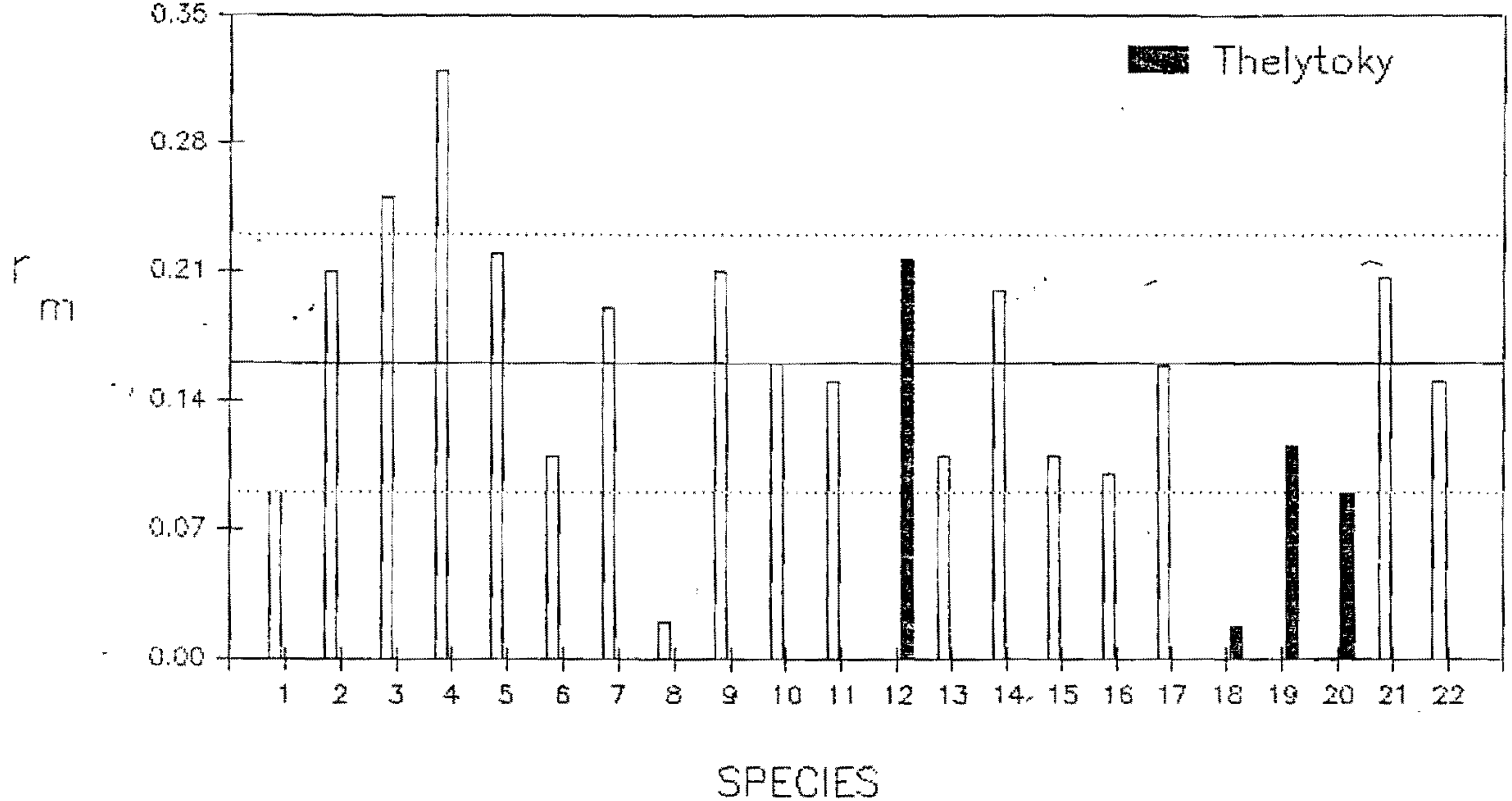


FIGURE 2. Intrinsic rate of increase (r_m) with CGM as prey for 22 species/strains of Phytoseiidae including 4 species with thelytokous reproduction. The solid line represents the mean of r_m and dotted lines represent one standard deviation from the mean. The x-axis numbers correspond to the following species: 1 A. anonymus, 2 G. annectens, 3 A. idaeus, 4 P. persimilis, 5 A. californicus, 6 E. concordis, 7 P. macropilis, 8 A. aerialis, 9 A. limonicus, 10 A. tenuiscutus, 11 C. pilosa, 12 P. kazimiae, 17 G. helveolus, 18 C. transvaalensis, 19 A. neotunus, 20 A. herbicolus, 21 A. limonicus-UCR, 22 A. limonicus-Biotactics.

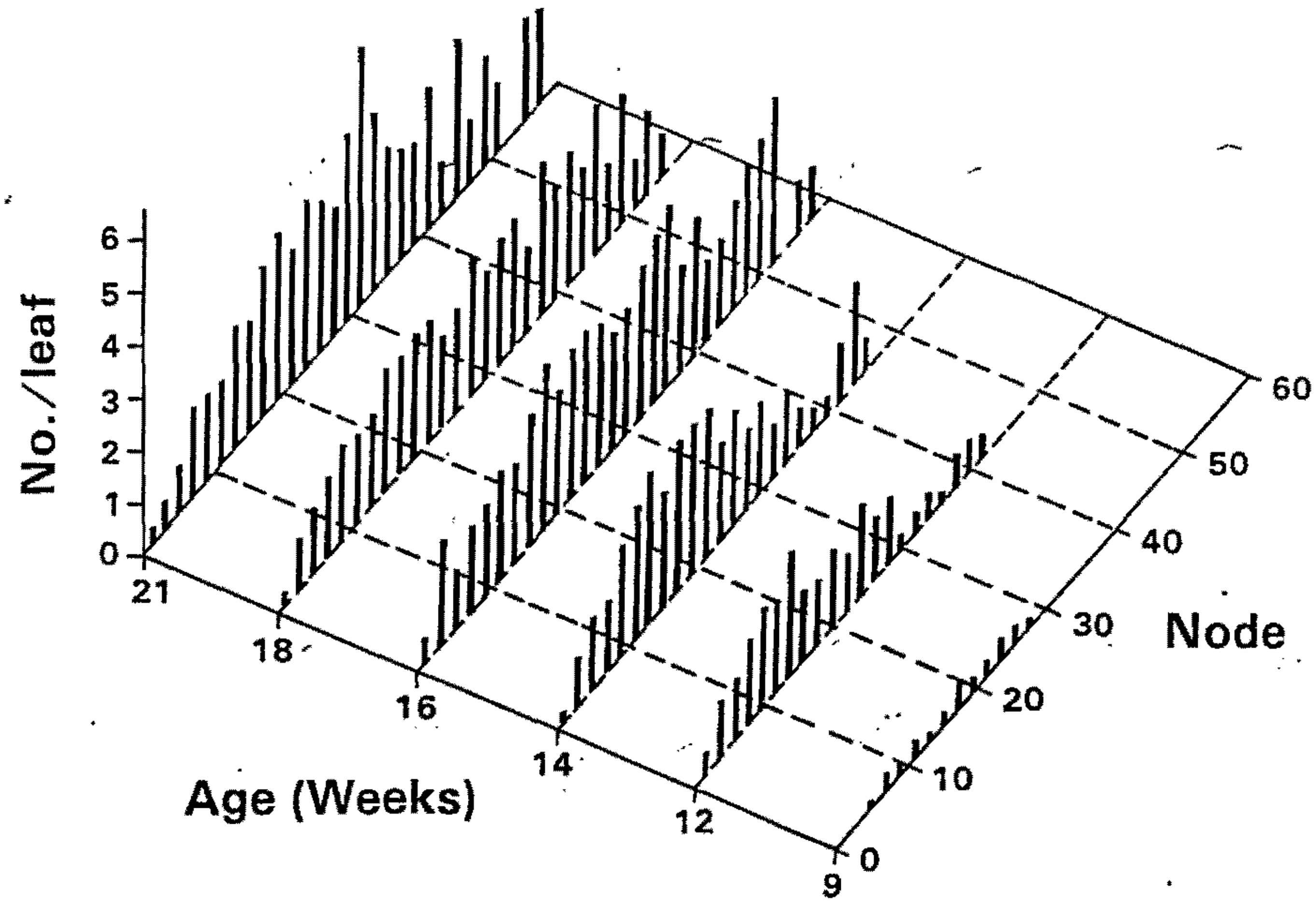


FIGURE 3. Within-plant distribution of *A. limonicus* in cassava. Means/leaf are computed over 20 leaves at each node location.

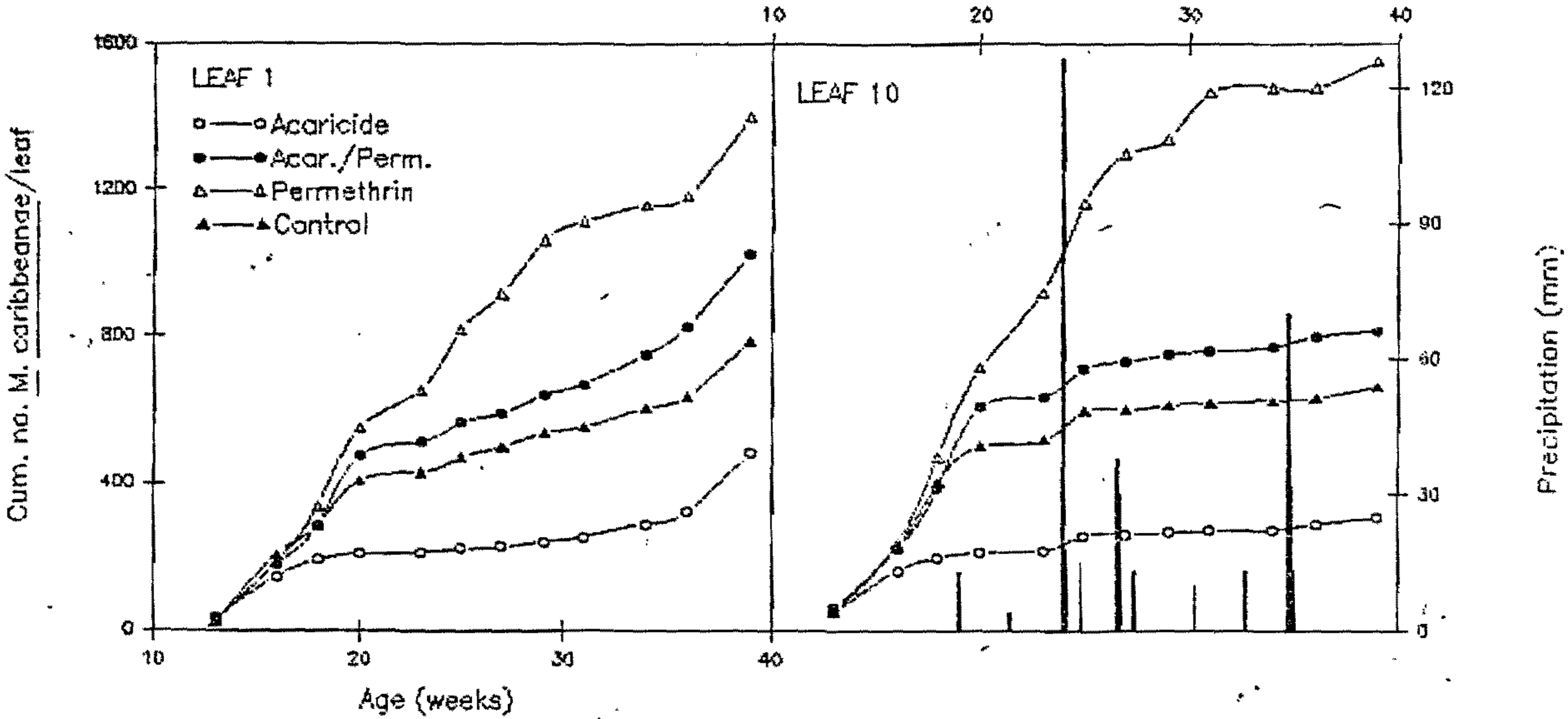


FIGURE 4. Effect of chemical predator exclusion and acaricide treatment on cumulative numbers of *M. caribbeanae* on the first and tenth leaf of cassava. Each point represents the mean of 90 leaves. Individual rain events (mm) are superimposed on the right panel.

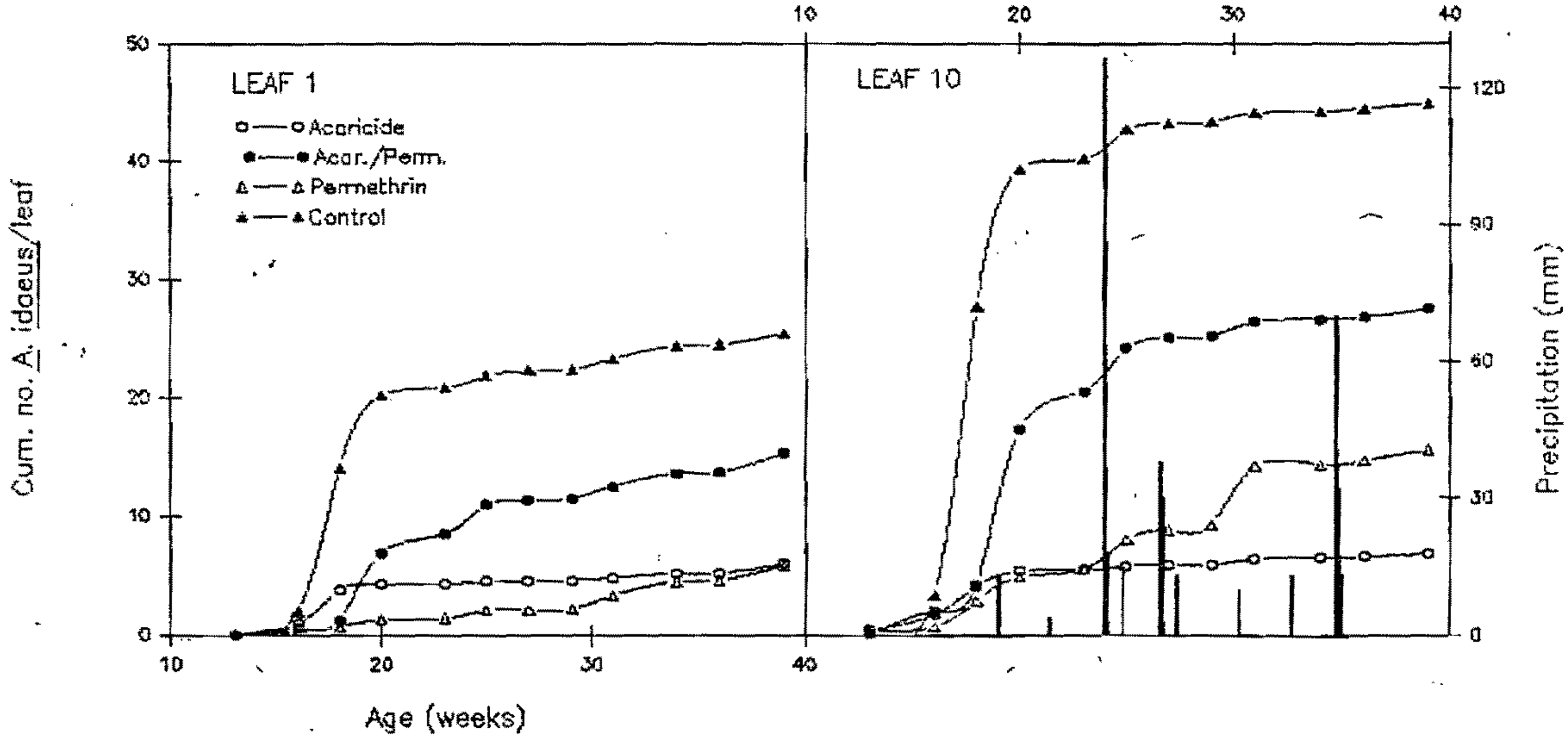


FIGURE 5. Effect of chemical predator exclusion and acaricide treatment on cumulative numbers of *A. idaeus* on the first and tenth leaf of cassava. Each point represents the mean of 90 leaves. Individual rain events (mm) are superimposed on the right panel.

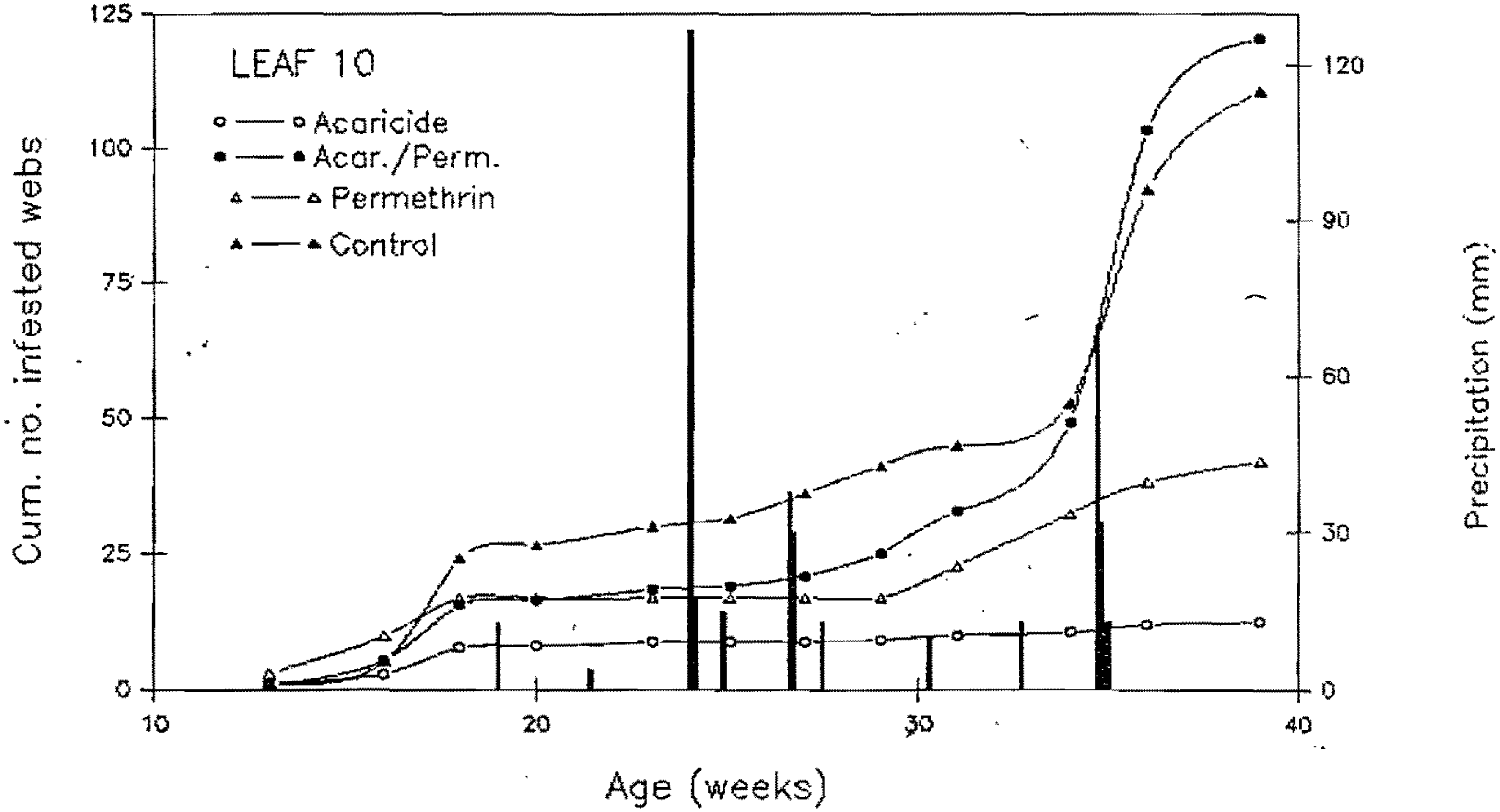


FIGURE 6. Effect of chemical predator exclusion and acaricide treatment on cumulative numbers of webs infested with O. peruvianus on the tenth leaf of cassava. Each point represents the mean number of infested webs on the central lobe of 90 leaves. Individual rain events (mm) are superimposed.

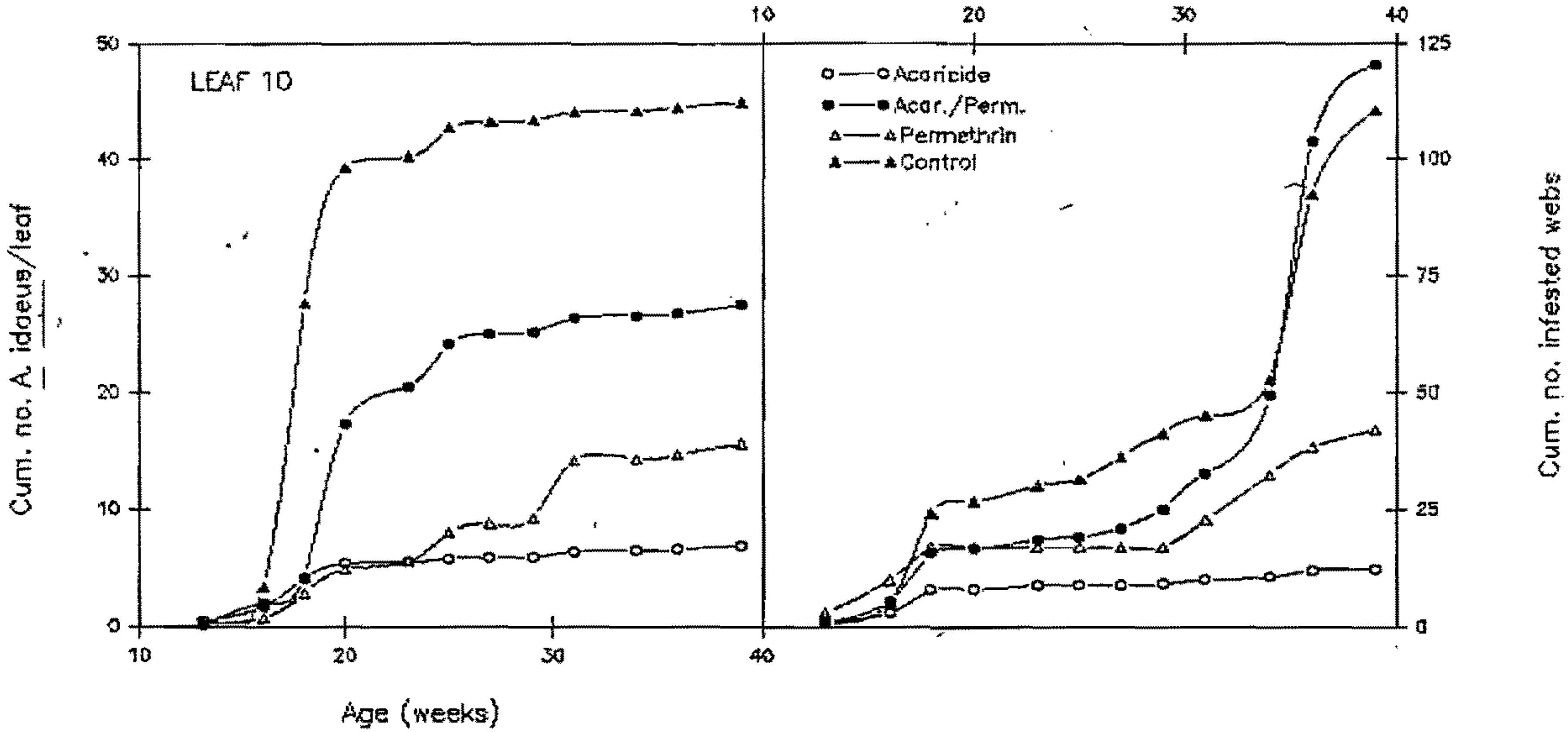


FIGURE 7. Effect of chemical predator exclusion and acaricide treatment on cumulative numbers of A. idaeus and O. peruvianus on the tenth leaf of cassava. Each point respresents the mean of 90 leaves for A. idaeus and the mean number of infested webs on the central lobe of 90 leaves for O. peruvianus.

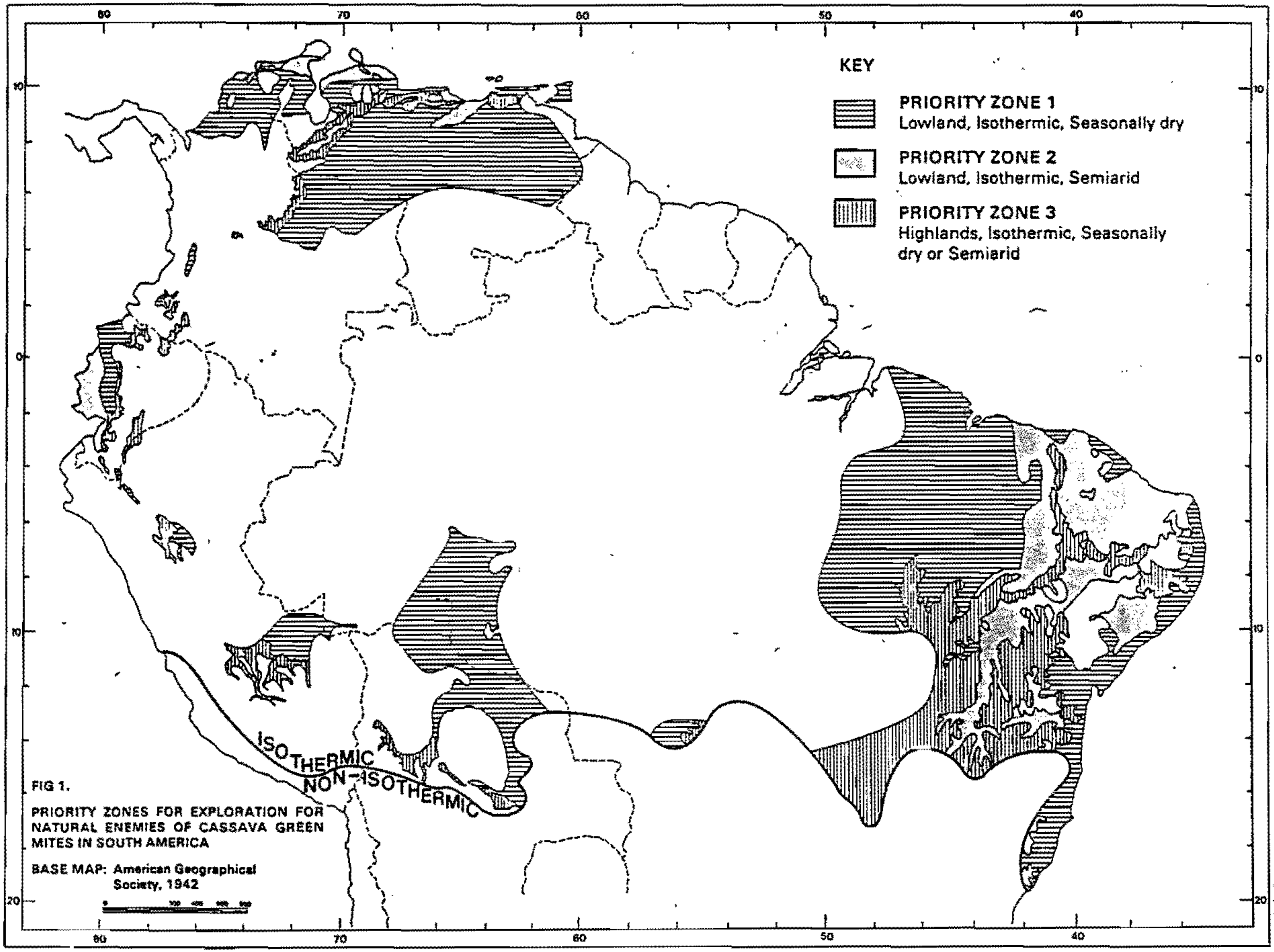


FIGURE 8. Priority zones for exploration for natural enemies of cassava green mite in South America (map based on agroecological microregions defined by Carter [1986]).

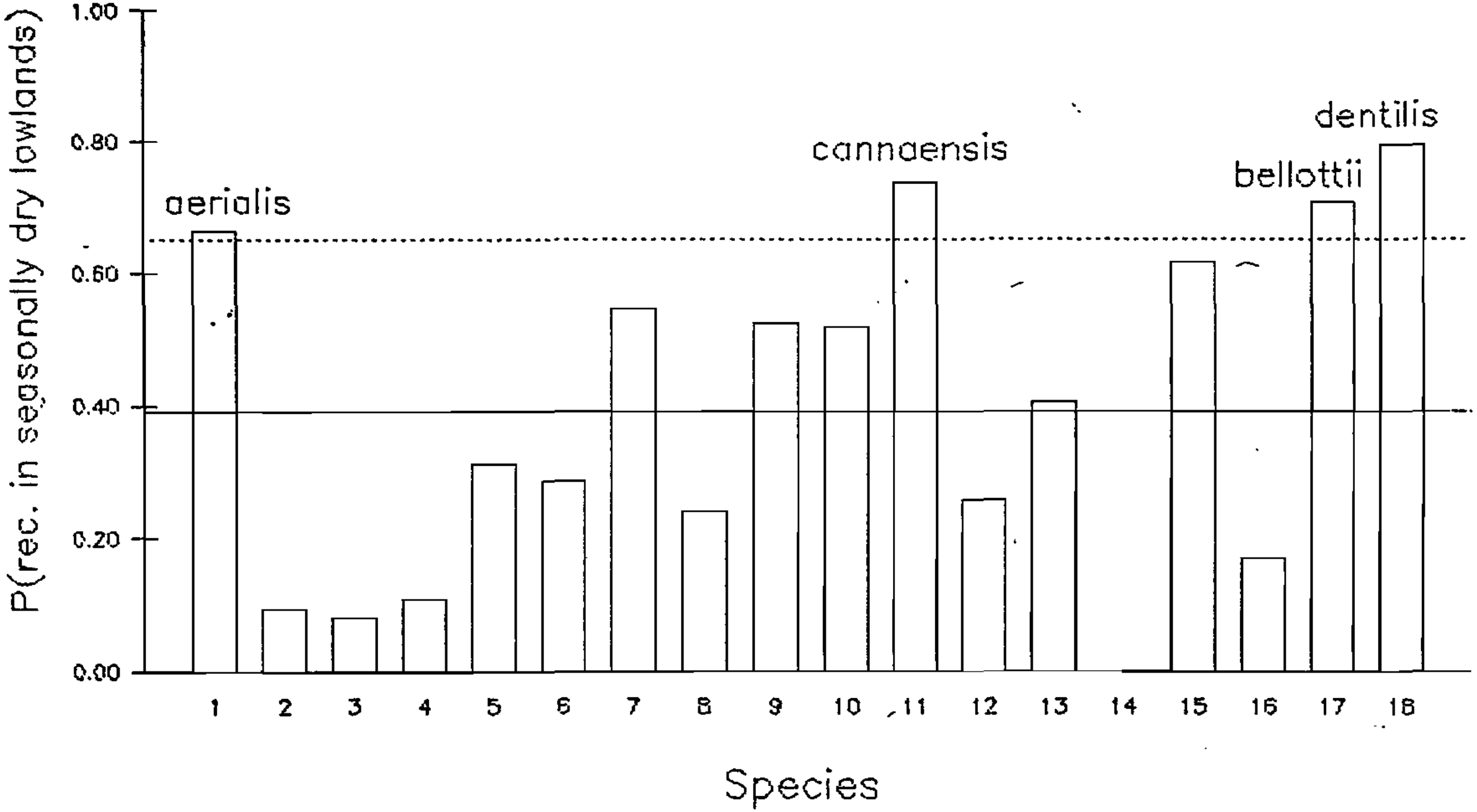


FIGURE 9. Frequency distribution of phytoseiids associated with cassava green mite in Priority Zone 1 in the Neotropics: Seasonally dry lowlands. The solid line represents the mean frequency and the dotted line is one standard deviation above the mean x-axis numbers correspond to the following species: 1 A. aerialis, 2 A. chiapensis, 3 E. concordis, 4 E. ho, 5 G. annectens, 6 G. helveolus, 7 I. zuluagai, 8 A. anonymus, 9 A. idaeus, 10 P. macropilis, 11 A. cannaensis, 12 A. aripo, 13 A. limonicus, 14 A. peregrinus, 15 A. rapax, 16 A. tenuiscutus, 17 A. bellottii, 18 A. dentilis.

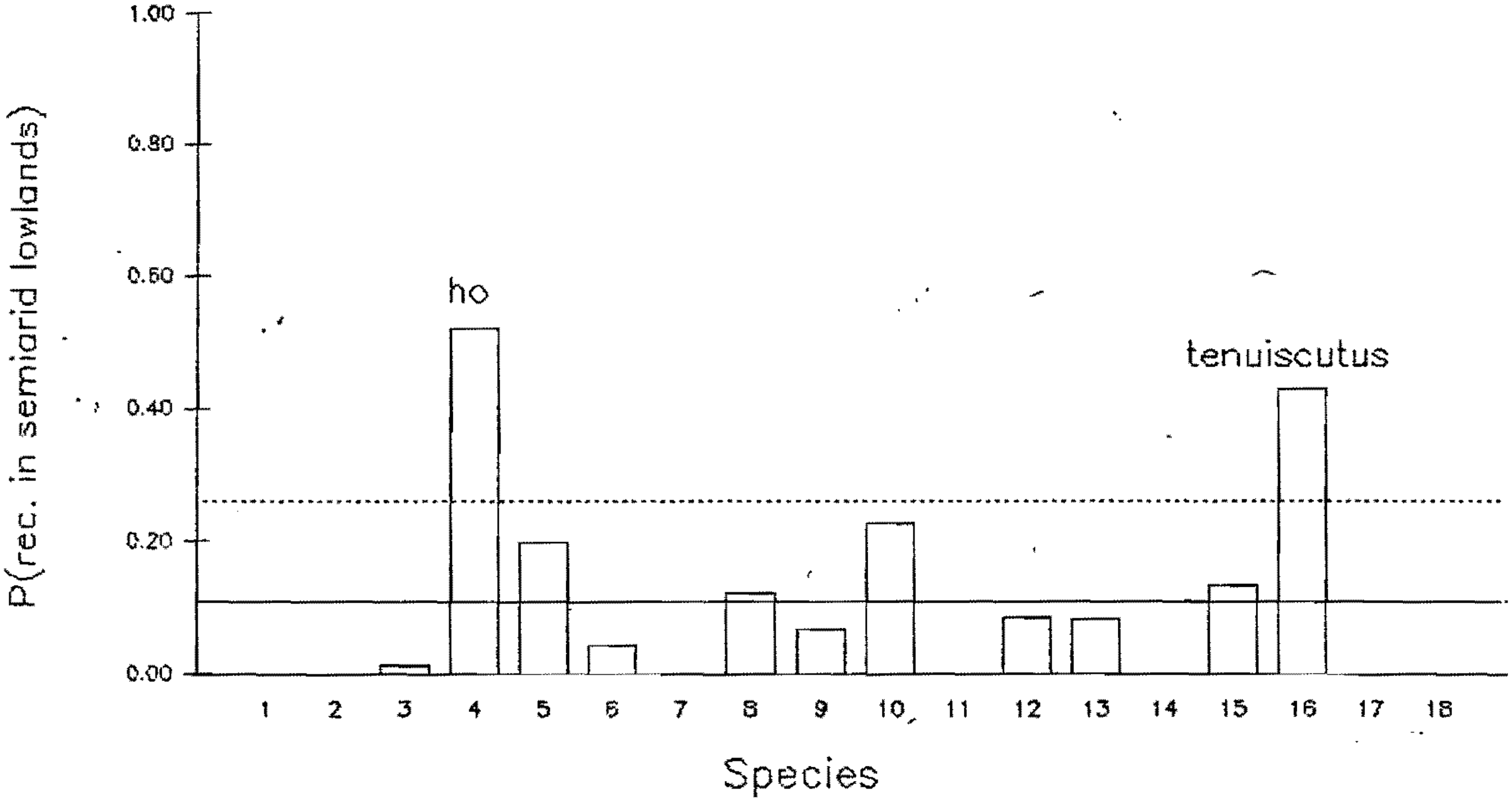


FIGURE 10. Frequency distribution of phytosseiids associated with Cassava Green Mite in Priority Zone 2 in the Neotropics: Semiarid lowlands. The solid line represents the mean frequency and the dotted line is one standard deviation above the mean. X-axis numbers correspond to the following species: 1 A. aerialis, 2 A. chiapensis, 3 E. concordis, 4 E. ho, 5 G. annectens, 6 G. helveolus, 7 I. zuluagai, 8 A. anonymus, 9 A. idaeus, 10 P. macropilis, 11 A. cannaensis, 12 A. aripo, 13 A. limonicus, 14 A. peregrinus, 15 A. rapax, 16 A. tenuiscutus, 17 A. bellottii, 18 A. dentilis.

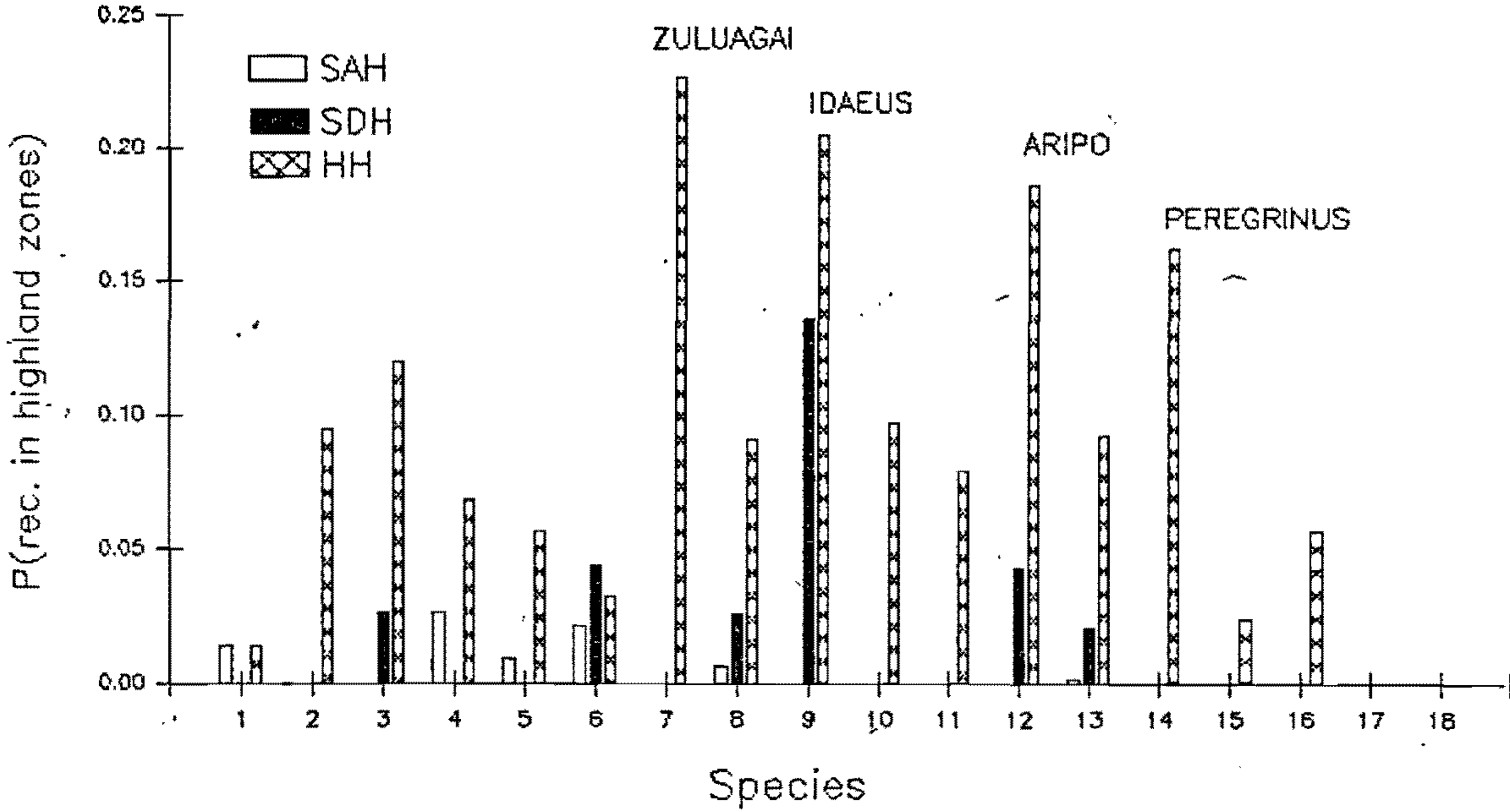


FIGURE 11. Frequency distribution of phytoseiids associated with Cassava Green Mite in seasonally dry highlands (SDH), semiarid highlands (SAL) and humid highlands (HH) of the neotropics. X-axis numbers correspond to the following species: 1 A. aerialis, 2 A. chiapensis, 3 E. concordis, 4 E. ho, 5 G. annectens, 6 G. helveolus, 7 I. zuluagai, 8 A. anonymus, 9 A. idaeus, 10 P. macropilis, 11 A. cannaensis, 12 A. aripo, 13 A. limonicus, 14 A. peregrinus, 15 A. rapax, 16 A. tenuiscutus, 17 A. bellottii, 18 A. dentilis.

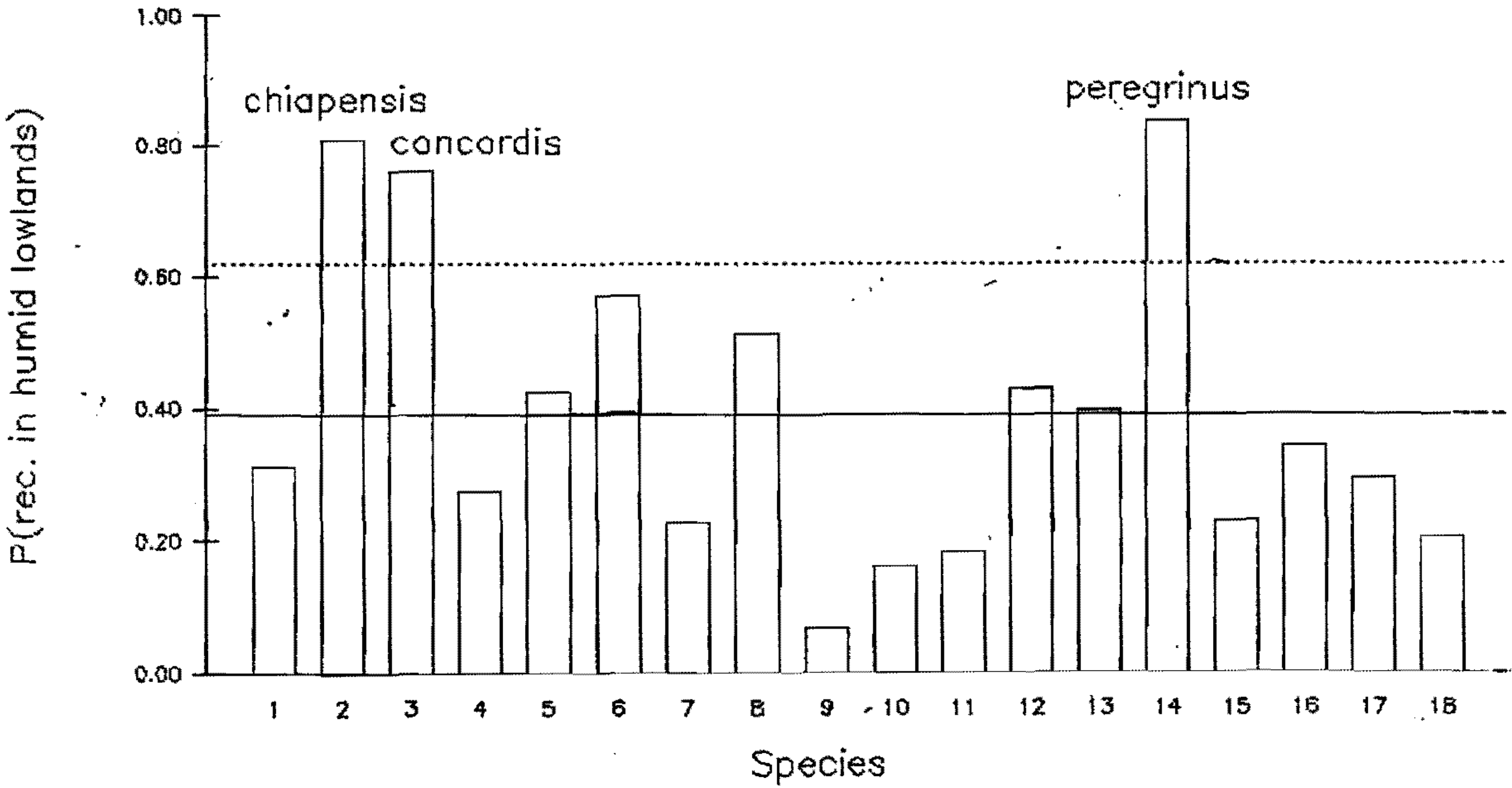


FIGURE 12. Frequency distribution of phytoseiids associated with Cassava Green Mite in humid lowlands of the neotropics. The solid line represents the mean frequency and the dotted line is one standard deviation above the mean. X-axis numbers correspond to the following species: 1 A. aerialis, 2 A. chiapensis, 3 E. concordis, 4 E. ho, 5 G. annectens, 6 G. helveolus, 7 I. zuluagai, 8 A. anonymus, 9 A. idaeus, 10 P. macropilis, 11 A. cannaensis, 12 A. aripo, 13 A. limonicus, 14 A. peregrinus, 15 A. rapax, 16 A. tenuiscutus, 17 A. bellotti, 18 A. dentilis.

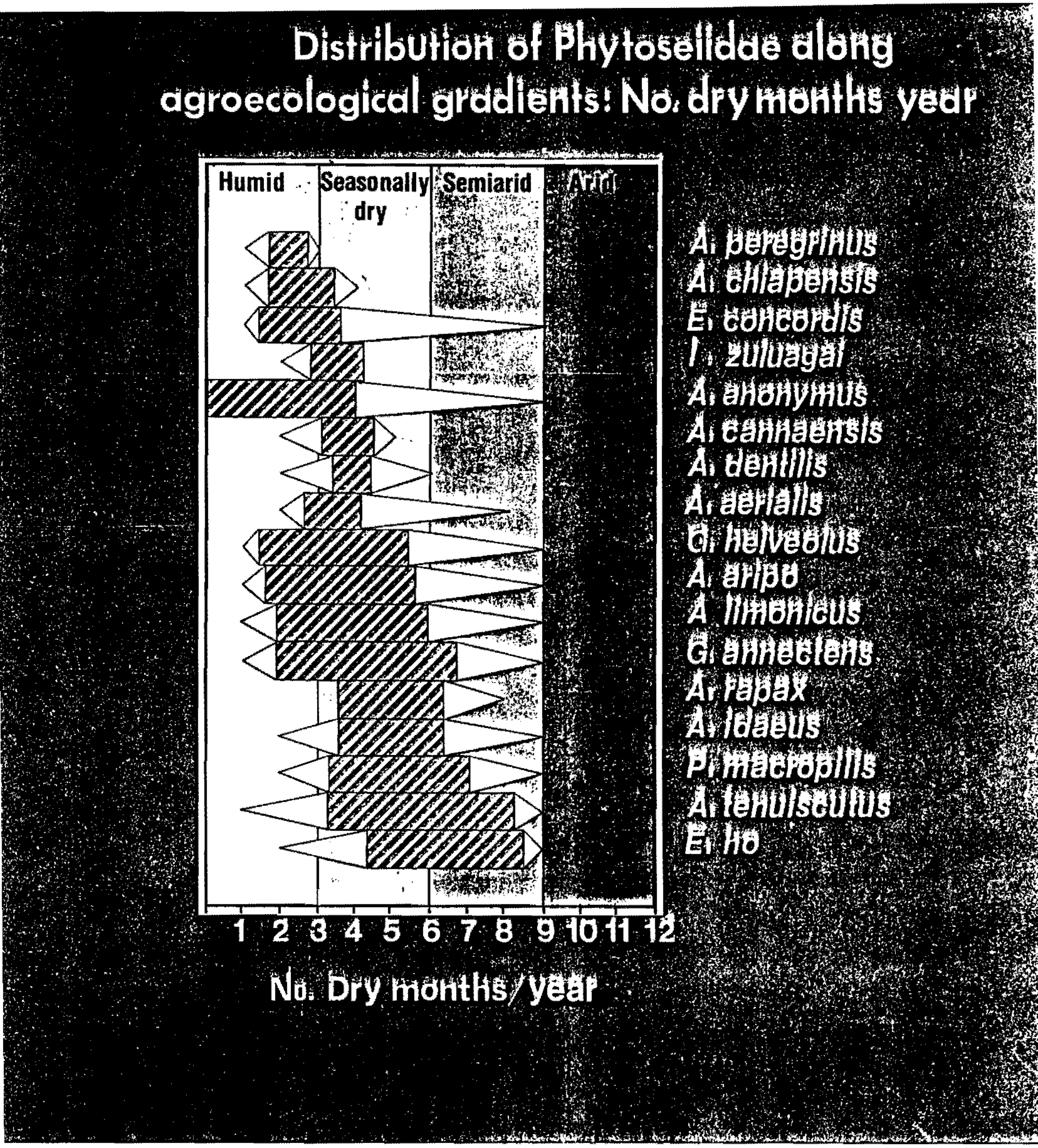


FIGURE 13. Distribution of phytoseiids associated with Cassava Green Mite in the neotropics along agroecological gradients: Number of dry months per year. The hatched bars represent the mean ± one standard deviation, the arrows represent the range.

CASSAVA PATHOLOGY - 1989

Special emphasis was given in 1989 to research on fungal root rots and on defining production systems for different ecological regions where pathological problems of cassava were endemic. Research on cassava endophytes was initiated this year in order to determine their etiology and effect on different cassava genotypes.

A. Root rot problems of cassava

Root rots are the most important pathological problems of cassava, especially in those areas where the crop is being planted during successive cycles. Considering that the most important root rot problems thus far are induced by species of *Phytophthora*, *Fusarium* and *Diplodia*, research priorities have been focused on the causal agents of these genera and the diseases they induce.

1. Phytophthora root rot

a. Taxonomy

Root rots induced by *Phytophthora* spp. are most severe in flooded areas, badly drained soils and/or during abnormally heavy rainy seasons. Three species of *Phytophthora* have been reported inducing root rots: *P. erythroseptica*, *P. cryptogea* and *P. drechsleri*. Based on last year's etiological studies, it was concluded that the species of *Phytophthora* inducing root rots in several plantations in Colombia do not belong to the above-reported species; rather they belong to *P. nicotianae* var. *nicotianae*. This species can be differentiated from *P. drechsleri* (the most common *Phytophthora* species affecting cassava) by symptomatology, structural differences, optimum growth temperatures and fungicide sensitivity (Table 1). These differential characters facilitate species identification for further studies regarding their epidemiology and control.

b. Mycorrhiza-Phytophthora relationships

Reports on interaction between vesicular arbuscular mycorrhizal (VAM) fungi and soil-borne pathogens affecting a given host are controversial. While some researchers have reported a significant increase in root rots, others have observed a reduction of root rot damage. This interaction was investigated in cassava with the following results:

1. The VA-mycorrhizal species *Glomus manihotis* has a beneficial effect on: Root/shoot ratio (dry weight), fine root, tubers and initials and leaf weights, compared to the non-mycorrhizal controls (Table 2 and 3). This confirms earlier reports (CIAT, 1983). The increased weight and high leaf retention

rates suggest a more efficient use of the plant's resources.

The lack of a positive effect of Entrophospora colombiana on some of the growth factors (Table 2 and 3) contradicts earlier reports. Other microorganisms may have a negative effect on the VAM inoculum, since it was produced on cassava.

2. Mycorrhizal infection appears to have a protective effect against the Phytophthora agent. P. n. var. nicotianae-inoculated plants showed more damage than controls, but when inoculated plants were also inoculated with the mycorrhiza species damage levels did not increase as much as in non-mycorrhiza inoculated plants. Whether different mycorrhizal species give different levels of protection against Phytophthora is not clear from this investigation.

   The mycorrhizal plants might be more resistant to disease attack because of a better phosphorus balance or because of mechanical effects: more lignin is produced in VA-mycorrhizal roots which could help to restrict pathogen infection and their advance in the roots.

c. Flooding-Phytophthora relationships

Hydroponic plantings of 5 cassava clones with different levels of tolerance to flooding and to P. n. var. nicotianae showed that: (1) the tolerance of cassava to flooding is due to a quick formation of a secondary root system on the upper unflooded base of the stem (Fig. 1 and Table 4); (2) the tolerance of cassava to P. n. var. nicotianae is, on the other hand, due to inhibitory biochemical effects on the pathogen in the root tissues. No production of secondary root system was observed on infected, susceptible or resistant clones; (3) the tolerance of cassava to flooding appears not to be correlated with its resistance to P. n. var. nicotianae. After evaluating more than 35 clones for tolerance to both these stresses, none of the clones evaluated showed simultaneous tolerance to both flooding and P. n. var. nicotianae; and (4) the effect of P. n. var. nicotianae infection was additive to the effect of flooding (Table 4 and 5). Plantings on P. n. var. nicotianae-infested soils will possibly show more severe root rots after flooding.

As any damage induced by flooding terminates with a complete deterioration of the primary root system of affected plants, programs aimed to overcome these two problems should be better directed towards (1) the improvement of genetic resistance to Phytophthora spp.; and (2) the prevention of flooding, either by using improved cultural practices (such as by planting on ridges; improving drainage; timing the plantings to escape heavy rainy periods; etc.) or by selecting for early-maturing genotypes to be harvested before flooding, such as those normally used in the varzea zone of the Amazon.

d) Screening for resistance

(i). **At CIAT:**

Twenty-three clones were evaluated for resistance to both P. dreschsleri and P. n. var. nicotianae by the root-bored inoculation method (CIAT Annual Report 1988). Results showed that: (a) resistance to the above pathogens appears not to be linked. However, cassava clones resistant to both pathogens exist; (b) even though no immune resistance was identified, highly resistant clones to each of these two pathogens were found; (c) resistance to P. drechsleri appears to be more frequent than to P. n. var. nicotianae (Table 6).

The above results and the fact that high populations of all of these pathogens appears to be ecosystem related (P. drechsleri has been found affecting cassava only in the varzea region of Brasil and P. n. var. nicotianae in areas located at intermediate altitudes of more than 900 m.a.s.l.) suggest that growers should be careful to select appropriate resistant genotypes for planting in different areas if Phytophthora-broad resistant genotypes are not available.

(ii).At Manaos (varzea zone of the Amazon):

The evaluation for resistance to P. drechsleri is a cooperative effort with CPAA (Centro de Pesquisa Agroforestal da Amazonía) and the CNPMF. Thus far, of 197 clones evaluated under field conditions, only three (1.5%) have been rated as resistant. These clones are also highly resistant to F. solani, another pathogen commonly found in the varzea region. In addition, the resistant clones (IB-188, IB-175 and IB-158) showed very good precocity (yielded more than 22 ton/ha in a 6-month growing cycle) and produced a yellowish colored root cortex, which is highly valued for farinha production in the area. These clones are being massively propagated for release to growers next year.

With regard to the origin of the evaluated material, resistant clones originated in the Amazon none of the clones introduced from the CNPMF has shown resistance to either *P. drechsleri* or *F. solani* thus far. Similarly, a high percentage of the introduced clones have shown early and abnormal germination of the buds during the growing cycle; these buds commonly become highly affected by anthracnose pathogens, which reduces the quality of the planting material produced by affected plants. Trials on the establishment of introduced clones after a second cycle in Manaos have shown losses of up to 45% in bud germination.

2. Fusarium root rots

a. Etiological studies

In order to define cultural characteristics for the *in vitro* production of spores of *F. solani* and *F. oxysporum* (the species of *Fusarium* which have most effect on cassava) the effect of culture medium, light and pH were investigated. This will help further screening work directed to identifying resistance to these two pathogens. Results have shown that:

- Growth of these two *Fusarium* spp. was slightly affected (but not at significant levels) by both glucose-cassimine acid and Park media; but the growth of *F. solani* was faster under continuous light exposure than in the dark; the growth of *F. oxysporum* was in contrast faster under continuously dark conditions (Table 7).

The above four media can be used effectively for growing these two pathogens *in vitro*.

- Spore production decreased at significant levels when the two pathogens were grown on the Park medium (Table 8). PDA appears to be the best medium for a high spore yield; but *F. solani* cultures must be incubated under continuous light exposure and *F. oxysporum* cultures in darkness.
- Use of an acidified medium increases spore production by *F. solani*. In contrast, *F. oxysporum* produces more spores on alkaline medium (Table 9). However, the mycelia growth of both species was favored by raising the pH of the medium; this effect was much more significant for *F. oxysporum* (Table 9).

These results suggest that optimal pathogen growth is obtained on PDA medium for *F. solani* under light and for *F. oxysporum* in darkness; but for better spore production, the former should be grown on acid media (pH = 3.0 to 4.0) and the latter on alkaline media (around 8.0).

b. Screening for resistance

In 1989, 220 clones were evaluated for resistance to F. oxysporum and 114 to F. solani, using the cutting inoculation system (Annual Report, 1986). Results indicated that independent-type resistance to each pathogen exists. Only two of the evaluated clones showed combined resistance to the above pathogens.

3. Diplodia root rot

In order to elucidate resistance mechanisms for Diplodia manihotis on cassava, cuttings were taken from basal, intermediate and upper portions of stems from 10-month-old plants of 10 susceptible and resistant clones. These were analyzed for dry matter, cellulose, hemicellulose, lignin, total and reducing sugars, starch and HCN contents. Results differed significantly only between the dry matter contents of the intermediate portion of stems of susceptible and resistant clones (Table 10). However, values obtained for some of the resistant and susceptible clones in groups C and D overlapped. It seems that other biochemical factors not yet investigated are responsible for resistance to D. manihotis in cassava.

The evaluation of 220 clones for resistance to this pathogen has established 4 groups based on cluster analysis, which makes it possible to differentiate genetic from acquired (i.e. a protective effect due to benefical microbial growth on stem epidermis) resistance of evaluated genotypes (Table 11).

Genotypes with acquired resistance showed around 80% bud germination and an intermediate rate (around 50%) of fungal infection, 20 days after inoculating cuttings from plants grown under field conditions. When cuttings from similar sources were disinfested by Na-hypochlorite, germination dropped to around 15% and fungal invasion increased to more than 90% (Table 11). This was probably due to the eradication of the beneficial microorganisms growing on the stem epidermis. Bud germination of cuttings from plants of susceptible clones growing under field conditions was low (7-13%) and fungal infection was high (more than 90%). In contrast, the percentage of bud germination of cuttings of resistant clones was high, and the fungal invasion was relatively low. However, values for bud germination decreased, and there was increased fungal invasion when cuttings were sterilized before inoculation. Clones with intermediate genetic resistance showed similar values for bud germination or fungal invasion after the inoculation of sterile or unsterile cuttings (Table 11).

4. Effect of weed control methods on root rots

The effect of weed control by both herbicides and/or mechanical means, on root rots was evaluated at Media Luna (sandy soils with low organic matter content) and CIAT (clayed soils with high organic matter content).

a. At Media Luna. The highest yield of the susceptible clone Venezolana "Coñito" (M Col 2215) was obtained when weeds were controlled by herbicide treatments, and the highest yield of the resistant clone "Verdecita" (M Col 1505) was obtained on plots in which weeds were controlled by hoeing (Table 12). The resistant clone Verdecita showed the lowest percentage of root rots, which correlates with evaluations under controlled conditions for root rot resistance.

The control of weeds by machete allows competition with weeds due to a quick plant recovery; this is reflected in the low yields obtained with both the resistant and susceptible clones (Table 12). General results suggest that the method used to control weeds in cassava areas characterized by sandy soils infested with root rot pathogens (such as D. manihotis and/or F. oxysporum) should be related to the susceptibility of the clone being grown to soil-borne pathogens infesting the area: to control weeds on plots planted with a susceptible clone, root damage should be avoided (eg. by using herbicides); to control weeds on plots planted with a resistant clone, mechanical tools (such as hoes) can be used wihout increasing root rot losses.

b. At CIAT. The use of machete to control weeds also decreased root rot damage as well as yields because of the competition of cassava with weeds. The control of weeds by hoes increased root rot damage due to the injuries caused during weeding operations (Table 13). On this location, (with high organic matter content and clayed soils) microbial population and activity are particularly high during the rainy seasons. Consequently, root rot problems can be very severe if roots are injured during these periods. Herbicide treatments to control weeds during the first two months of planting followed by mechanical weed control (hoes) appears to be the best method for controlling weeds at CIAT and similar locations.

B. Cassava endophytes

Endophytes are microorganisms (mostly fungi) able to grow inside their host tissues without inducing visible necrotic symptoms. They have been reported as affecting several grass species and various commercial crops inducing growth promotion (beneficial effects) or deleterious effects. Their existence on cassava was suspected for the following reasons: a) yield of low-yielding-virus-free plants of traditional clones can be increased by passing through meristem cultures (CIAT's Annual Reports 1985, 1986, 1987); b) the performance (i.e. yield) of meristem-culture derived plants decreases sharply and uniformly under field conditions (CIAT's Annual Reports 1987, 1988); c) generally, a wide range variation of root yield (kg/plant) is frequent among disease symptomless plants growing on the same plot; and d) the long growing cycle of cassava and its vegetative propagation allow infection and dissemination of these parasites.

Research undertaken to demonstrate the existence of endophytes on cassava have given the following results so far:

1. More than 10 fungal species were isolated from internal tissues of the epidermis, colenchyma and parenchyma of stems of symptomless low yielding plants of various clones (Table 14). Most of the isolated fungal species have been reported as endophytes on wheat and barley: i.e. Septoria nodorum is the endophyte most commonly found on wheat and isolated at the highest frequency (52%) on cassava (Table 14).
2. Inoculations on plantlets and callus tissue by spraying, puncturing or immersion in a fungal suspension of some of the above isolated fungi did not induce visible symptoms, but inoculated species were reisolated from inoculated tissues 30 days after each inoculation.
3. The weight of symptomless-free plants treated with

systemic fungicides was higher than untreated controls two months after treatments (Table 15). These differences were much more significant among plants derived from cuttings than from shoots. It may be due to the higher probability of endophyte infections of cuttings than of shoots.

The above results strongly suggest the existence of infections by endophytes on cassava. They appear to belong to the deleterious group, capable of reducing yields. Further research will include histological studies to observe fungal invasion into the host tissues and related research to determine their importance for cassava production. Similarly, attempts will be made to isolate beneficial endophytes and evaluate their effect on yield and other traits.

C. Cassava production systems

As a result of several years of research on cassava pathology in different cassava-growing areas with various contrasting edapho-climatic characteristics and with the cooperation of various sections of the Cassava Program, the following cassava production systems have been defined:

1. <u>varzea region of the Amazon</u>

Cassava is being planted in two different regions of the Amazon: (a) coastal or unflooded area (terra firme) with extremely acid (pH 4.0) and infertile soils; and (b) varzea, or the flooded basin edges of rivers with alluvial, fertile and with near neutral pH soils. Cassava yields on terra firme are of around 6.0 ton/ha/year while on the varzea region are above 20 ton/ha/ after six months. In 1983 a severe root rot outbreak was reported in the varzea area of the Amazon causing around 60% losses on almost 84,000 ha of cassava. A collaborative research project with UEPAE-Manaos (Unidade de Execucao de Pesquisa Agropecuaria de Ambito Estadual), the CNPFM and CIAT, included research on control of the cassava root rot problem (induced by P. drechsleri and F. solani) through varietal resistance, cultural practices (crop rotation, mixed cropping, planting on ridges, and selection of planting material), and chemical treatment of cuttings. This led to the definition of the following cassava production system for the regions of the Amazon:

a. Infested land (showing more than 5% root rot on previous cassava harvesting) should be rotated with maize or rice during the dry semester season of the region.

b. Before planting cassava, soils must be ploughed once, disked twice; and then ridges about 0.30m high must be constructed.

Drainage canals should be constructed or improved.

c. Twenty-cm cuttings from lignified stems of 10 to 12-month-old plants of tolerant clones should be selected visually (absence of rotting signs or mechanical injuries). This planting material should be produced in the coastal area.

d. Selected cuttings must be treated by dipping for 10 min in a suspension of fosetyl-Al 80% at a concentration of 2g/liter.

Results following the above system are compared with these obtained by the traditional system in Table 16; the accumulative effect on yield induced by each of the components of this system is also shown. The resistant clone used in this experiment was the most resistant clone found after screening more than 130 clones during a four-year evaluation period (4 consecutive plantings). Although it yielded only 6.5 t/ha without technology, the application of cultural control practices and treatments to cuttings increased yield of this clone 4.5 times (Table 16). This system of production for the varzea region of the Amazon is being validated in 10 different municipalities of the region and will be officially released during a field day that

EMBRAPA and UEPAE are planning to organize for next August-September, 1990.

2. Media Luna region.

The Media Luna region is characterized by sandy soils with low organic matter content (0.3%) and nearly neutral pH (6.8). These characteristics are common in Edaphoclimatic Zone I (ECZ I) where a high percentage of cassava is grown (Thailand, Northeast Brasil, etc). Land in Media Luna has been used intensively for several decades (mostly for cassava production) under a traditional system characterized by very limited inputs. As a result, soils have been depleted of nutrients and have a high accumulation of inoculum potential of soil-borne pathogens (mostly *Diplodia manihotis* and *Fusarium oxysporum*) that reduce crop establishment and plant vigor, and cause severe root rots.

Initial yields in Media Luna were relatively high (higher than 20 tons/ha, according to farmer's information), but have sharply decreased during the last decade, until reaching an average of only 3-4 ton/ha last year. Research developed during the last 14 years by different sections of the Cassava Program led to the definition of the following cassava production systems for Media Luna:

a. Land should be fallowed or rotated with corn or sorghum if cassava has been cultivated for more than 4 consecutive cycles. Debris from weeds or rotated crops must be incorporated into the soil before planting cassava by plowing once and disking twice.

b. Cuttings should be taken from 10 to 12-month-old plants of high yielding, root rot-tolerant clones. Cuttings must be 15-20 cm long (containing at least 5 nodes/cutting), selected visually and, treated for 20 min in a suspension of sistemin (2cc/l), benomyl and captan (3g/l each) before planting.

c. Plots should be sprayed after planting with karmex (1 kg/ha) and lazo (1.5 l/ha) as a preemergent weed control practice. Two to three months later weeds can be controlled manually during the growing cycle (11 months) as required.

d) Plots should be fertilized (best results have been obtained with 15-15-15 NPK at 300kg/ha) at a rate of 100kg/ha at the 1st, 2nd and 3rd months of planting.

This year's results applying the above system to plots of 300 plants with 4 replicates each of three clones (one susceptible and two tolerant to the abiotic and biotic problems of this region) are shown in Table 17. Root yield of even the susceptible clone was increased several times. Similarly, the number of selected cuttings/ha also increased considerably, which will reflect positively on yields during the next plantings (Table 17). This system is being validated by 12 growers and in two demonstration trials planted in the area.

3. Ibiapaba Sierra - Ceara, Brasil

The savanna region in the Ibiapaba Sierra runs through the states of Piaui and Ceara; its elevation is around 900 m.a.s.l., temperature averages 20°C; soils are semiacid (pH around 5.1) and sandy, but with intermediate levels of organic matter (1-3%). In 1985, a severe outbreak of the witches'-broom mycoplasm was reported to be affecting 4,000 ha in 4 municipalities of the region. Losses were up to 95%, with an average of 40% of the total root production of cassava in the affected area.

Research was initiated in 1987 with the cooperation of the Department of Agriculture of Ceara and the CNPFM of EMBRAPA. Results of this investigation led to the following conclusions in relation to the dissemination and control of this mycoplasma:

a. No motile vector (i.e. insects) has been found in the area thus far.

b. Dissemination through the use of infected cuttings, taken from diseased plants, was 100% (Table 18).

c. Disease transmission 8 months after grafting was 100% when diseased scions were grafted on healthy cuttings, and 60%, viceversa (Table 18).

d. Disease incidence was lowered by using cuttings from symptomless plants taken from plots affected at different disease levels (Table 19). This system gave very good results even when it was performed by technicians or producers (Table 19). It is expected that extension programs directed to the eradication of the disease by using diseased-free cuttings for planting be successful.

Based on the above results, the following production system was defined for areas where the witche's-broom mycoplasma is endemic:

a. Planting material (cuttings) must be selected from symptomless 12-14 months old plants (due to moderate temperatures the growing cycle of cassava in this area is around 14 months). Cuttings should be 15-20cm long and treated with manzate (3g/l) by dipping for 10 min before planting.

b. Machetes and tools used during cutting preparation and shipping should be disinfested with Na-hypochloride (2%) by cleaning them with wet rags.

c. Cassava debris from previous plantings should be burned before planting new selected cuttings.

d. Suspected diseased plants as well as voluntary plants from previous plantings, should be rougued. To facilitate their identification, weekly inspections of the plantations are recommended.

Some 8,000 copies of a pamphlet describing disease symptons and the above production system have been distributed by extension agents working in the area, as well as by community leaders. Similarly, several demonstration plots were planted this year for field days that extension agents and researchers from the cooperating institutions are planning. It is expected that through this action the actual severity of this disease can be reduced significantly.

Table 1. Differential characteristics between *Phytophthora drechsleri*, *P. nicotianae* var. *nicotianae* and Colombian isolates.

Characteristic Features	*P. drechsleri*	*P. n.* var *nicotianae*	Colombian Isolates
Symptoms	Yellow maceration of infected tissues	Brown maceration of infected tissues	Brown maceration of infected tissues
Clamydospore production *in vitro*	Absent	Abundant	Abundant
Zoosporangia	Various shapes unpapillated	Oval and papillated	Oval and papillated
Zoospore production *in vitro*	At 5°C	At 20°C	At 24°C
Optimum growth temperature	28-31°C	25-30°C	24-28°C
Fungicide sensitivity:			
.fosetyl-Al 80%	+*	-	-
.captan 50%	-	+	+
.Cu oxychloride 60.5%	-	+	+

*+= High sensitivity; -= No or slight sensitivity.

Table 2. Leaf retention and root/shoot ratio for the mycorrhizal treatments.

Mycorrhizal treatment*	Root/shoot Ratio	Leaf retention Week 14-19 (%)
Non-mycorrhizal	0.26c**	67c
Entrophospora colombiana	0.32b	77b
Glomus manihotis	0.42a	89a

* The data for plants with and without Phytophthora are pooled for clarity. The pathogen had no significant influence on these parameters.

** Averages in the same column followecd by the same letter are not significantly different according to Duncan's multiple range test (_ = 0.05).

Table 3. CM 523-7 stakes planted in a screenhouse in pasteurized, fertilized Santander de Quilichao soil. They were inoculated at planting with VA-mycorrhizal spores and at 14 weeks with Phytophthora nicotianae var. nicotianae and were harvested at 19 weeks. The plants were etiolated because of low light intensity in the screenhouse.

Treatments			Dry weight (g)			
VA-mycorrhiza	Pathogen	Damage level*	Fine root	Tubers+ initials	Leaf	Height (cm)
Non-mycorrhizal	-	4.4**c***	4.8c	2.7b	5.0c	150ab
	+	6.0a	4.4c	2.4b	4.1d	143b
Entrophospora colombiana	-	4.4c	6.3b	2.9b	6.3b	156a
	+	5.3b	5.7bc	3.2b	6.7b	154ab
Glomus manihotis	-	3.6d	8.6a	6.2a	8.5a	127c
	+	4.4c	8.4a	5.1a	9.0a	132c

* Damage level: 1 = 0-10% of rootlets showing damge; 10 = 90-100% rootlets showing damage.

** Data shown are averages of 20-24 plants in each treatment.

*** Averages in the same column followed by the same letter are not significantly different according to Duncan's multiple range test (α = 0.05).

Table 4. Cumulative average of dry weight (g) of the root system of 5 cassava cultivars after flooding and inoculated with *Phytophthora nicotianae* var.. *nicotianae*.

Cultivar	Controls	Flooding	Flooding and inoculated with *P. n.* var. *nicotianae*
CG 165-2	32.2*	11.6**	7.3
M Ven 156	17.4	11.8	7.4
CM 507-37	34.6	27.6	16.1
CM 2766-5	19.7	12.5	11.8
M Ind-4	8.4	16.3	6.3

* Averaged data taken from 3 plants/treatment.

** These data refer to total dry weight including the secondary root system produced after flooding.

Table 5. Cumulative damage (% of rotting) induced on 5 cassava cultivars after flooding and inoculated with Phytophthora nicotianae var. nicotianae 12 days after treatments.

Cultivar	Controls	Flooding	Flooding and inoculated with P. n. var nicotianae
CG 165-2	3*	33	93
M Ven 156	5	73	100
CM 507-37	7	73	100
CM 2766-5	5	60	98
M Ind-4	8	85	96

* Averaged data taken from 20 plants/treatment. The percentage of rotting was calculated on the basis of visual observation of brownish discoloration of roots/plant.

Table 6. Disease reaction (percentage of invaded root tissues from point of infection) of 23 clones to *Phytophthora drechsleri* and *P. nicotianae* var. *nicotianae* 7 days after their inoculation by the root-bored inoculation method (see Annual Report, 1988).

Cultivar	*P. drechsleri*	*P. n.* var. *nicotianae*
CM 3967-8	5	55
SM 829-2	2	55
SM 827-5	2	48
CM 5290-4	5	45
CMC 76	5	45
SM 826-2	2	40
SM 825-5	4	35
M COL 1684	4	35
CM 5259-3	15	30
SM 827-2	0.5	25
M VEN 218	2	25
CM 3320-9	5	15
CM 3967-5	0.5	10
CM 3322-15	20	0.5
CMC-91	10	5
SM 827-3	5	6
SM 831-1	8	5
SM 826-1	5	2
SM 823-10	5	2
CM 3967-6	0.5	8
M CUB 74	10	15
CM 523-7	2	5
CM 5473-7	5	10

Table 7. Growth (cm) of *Fusarium solani* and *F. oxysporum* on four media incubated under continuous light or darkness, 8 days after incubation at 24°C.

	Growth of *F. solani* under		Growth of *F. oxysporum* under	
Medium	Light	Darkness	Light	Darkness
PDA	9.0*	8.8	8.6	9.0
Tochinai	8.8	9.0	8.7	7.8
Glucose-Cassimino	7.3	8.9	7.7	7.5
Park	7.6	8.0	7.6	7.8

* Averaged data from 20 Petri dishes/treatment.

Table 8. Spore production (No. of spores/cm^2) of *F. solani* and *F. oxysporum* on four media incubated under continuous light or darkness, 8 days after incubation at 24°C.

	Spore production of *F. solani* under		Spore production of *F. oxysporum* under	
Medium	Light	Darkness	Light	Darkness
PDA	$8.0x10^6$*	$9.3x10^4$	$2.3x10^4$	$3.5x10^6$
Tochinai	$2.0x10^4$	$3.5x10^3$	$1.8x10^4$	$2.3x10^4$
Glucose/Cassimino	$2.5x10^4$	$3.2x10^4$	$3.5x10^3$	$1.0x10^3$
Park	$5.0x10^3$	$1.4x10^2$	$3.0x10^2$	$8.0x10^2$

*Averaged data from 20 counts/treatment.

Table 9. Sporulation (No. of spores/cm^2) and growth (cm) of F. solani and F. oxysporum on PDA at five different pHs, 8 days after incubation at 24°C.

	Spore production		Growth (cm)	
pH values	F. solani	F. oxysporum	F. solani	F. oxysporum
3.0	$3.3x10^6$	$0.0x10^1$	5.3	3.5
4.0	$1.2x10^5$	$0.0x10^1$	6.7	4.3
6.0	$8.3x10^4$	$2.1x10^4$	7.6	7.4
8.0	$7.1x10^4$	$7.0x10^3$	8.1	8.1
9.0	$2.9x10^3$	$8.0x10^3$	7.9	7.8

Table 10. Tukey's standardized range test for dry matter content in medium portion of stems of 10-month-old plants of 10 clones susceptible and resistant to *Diplodia manihotis*.

Clone	Mean	Grouping
CM 344-71 (S)	37.150**	A
M Col 1684 (S)	34.599	A
M Col 2063 (S)	33.864	AB
M Col 72 (S)	33.422	B
SG 106-59 (S)	32.773	B
M Col 2065 (S)	32.023	BC
M Col 2032 (S)	29.670	CD
M Ecu 82 (S)	29.497	CD
M Bra 12 (S)	29.356	CD
M Col 1522 (S)	29.331	CD
M Col 2057 (R)	29.321	CD
SG 107-35 (R)	29.173	CD
CM 1834-19 (R)	29.129	CDE
M Col 1505 (R)	27.093	DE
CG 501-1 (R)	27.085	DE
CM 1223-1 (R)	26.933	DE
M Bra 174 (R)	26.617	DE
M Col 1964 (R)	25.981	E
M Col 1823 (R)	25.930	E
M Mal 2 (R)	24.093	E

* (S) = Susceptible; (R) = Resistant clones.
** Means of 10 cuttings.

Table 11. Groups of genotypes according to percentage of bud germination and fungal invasion on unsterile and sterile cuttings of 10-month old plants 20 days after dip inoculation in a spore suspension (10^4 spores/ml) of *Diplodia manihotis*.

Group	No. of clones/ Group	Unsterile cuttings: Average % Bud Germination	Unsterile cuttings: Average % Fungal Invasion	Sterile cuttings*: Average % Bud Germination	Sterile cuttings*: Average % Fungal Invasion
I (SS)**	139	10.13	94.5	-	-
II (AR)	20	78.94	50.54	14.00	94.47
III (IR)	35	51.89	62.93	50.11	65.05
IV (R)	26	91.12	34.35	71.58	50.31

* Cuttings were sterilized for 10 min in Na-hypochloride (3%) and washed twice with sterile water before inoculation.

** (S) = clones showing susceptibility; (AR) = susceptible clones showing acquired resistance on unsterile cuttings and susceptibility on sterile cuttings; (IR) = intermediate resistant reaction; (R) = resistant clones.

Table 12. Effect of weed control methods on root rots induced by *Diplodia manihotis* and *Fusarium oxysporum* at Media Luna, a sandy area with low organic matter content.

Weed control method*	Fresh root yield Coñito** (M Col 2215)	Fresh root yield Verdecita** (M Col 1505)
Herbicide	14.8	10.6
Herbicide+hoe	11.6	10.9
Hoes	9.4	13.3
Herbicide+machete	6.4	9.8
Machete	3.7	5.2

* Weed control method: Herbicide = Karmex (2 kg/ha) and Lazo (1 l/ha) applied as preemergent and at the 3rd. and 6th. months of planting; herbicide+hoe: preemergent herbicide treatment followed by a hoe weed control for 3 consecutive times during a 10-month growing cycle; hoe weed control: 5 consecutive times during the growing cycle; herbicide and machete control: preemergent herbicide treatment followed by machete weed control for 3 consecutive times during growing cycle; machete weed control: 5 consecutive times during the growing cycle.

** Coñito = a susceptible clone; Verdecita = a resistant clone.

Table 13. Effect of weed control methods on root rots induced by several root pathogens at CIAT, a clayed soil with high organic content.

	Fresh root yield		Root rot percentage	
Weed control method*	M Col 1684**	CMC 40**	M Col 1684	CMC 40
Herbicide and hoes	20.4	14.8	2.3	2.0
Herbicide	15.5	11.6	2.2	2.0
Hoes	15.0	10.9	4.0	3.9
Herbicide and machete	13.4	8.1	2.0	1.7
Machete	10.6	3.2	1.2	1.4

* Weed control method: Herbicice = Karmex (2 kg/ha) and Lazo (1 l/ha) applied as preemergent and at the 3rd. and 6th. months of planting; herbicide+shovel: preemergent herbicide treatment followed by shovel weed control for 3 consecutive times for a 10-month growing cycle; shovel weed control: 5 consecutive times during the growing cycle; herbicide and machete control: preemergent herbicide treatment followed by machete weed control for 3 consecutive times during the growing cycle; machete weed control: 5 consecutive times.

** M Col 1684 = an intermediate resistant clone; M Col = a susceptible clone.

Table 14. Fungal species isolated from symptomless cassava stem tissues of low yielding plants of various native clones.

Fungal species isolated	Frequency of isolation (%)*
Septoria nodorum	52.1
Fusarium oxysporum	7.2
Colletotrichum gloeosporioides	5.8
Colletotrichum graminicola	4.3
Alternaria tenuissima	2.9
Trichoderma sp.	2.9
Botrytis sp.	1.4
Torula sp.	1.4
Nigrospora sp.	1.4
Others	20.4

* Percentage based on a total of 54 fungal isolates.

Table 15. Average dry weight (gr) per plant of 20 plants derived from shoots or cuttings of clones M Col 2216 and M Col 1505 treated with 4 systemic fungicides and grown during a 60 days period in 11.5cm-diameter pots with sterile CIAT's sandy soils.

	Source of MCol 2216 plants		Source of MCol 1505 plants	
Fungicide name	Shoots	Cuttings	Shoots	Cuttings
Propiconazole*	26b**	18ab	22ab	19b
Fosetyl-Al	27ab	22a	25a	18b
Benomyl	27ab	23a	26a	21ab
Chlorothalonil	28a	21b	22ab	24a
Controls	25b	15c	21b	15c

* Plants were treated every 15 days with a suspension of 800ppm (a.i.) for each fungicide.

** Weight taken 60 days after the first treatment; plants were grown on plastic pots filled with the same pasteurized soil. Values followed by the same letter were not significant at 0.01 level.

Table 16. Cumulative effect on yield of various cultural practices on tolerant and 15 susceptible clones for the control of root rots induced by *Phytophthora drechsleri* and *Fusarium* spp in the varzea region of the Amazon.

Cultural practices used	Tolerant Clone	Susceptible Clone
Traditional planting	6.5*	0.1
Rotation with maize or rice	16.0	5.0
Drainage and planting on ridges	22.5	8.0
Selection of cuttings	24.5	5.5
Fosetyl-Al 80% (2g/l) treatment to cuttings	29.3	6.5
Integrated system	29.3	7.3

* Averaged production on plots of 20 plants per plot replicated 4 times per treatment.

Table 17. Yield (ton/ha of fresh roots) of three cassava clones with and without a cassava production system* for the Media Luna region (ECZ 1) of Colombia.

Clone	Yield of Fresh roots (ton/ha)	Selected cuttings (No. of cuttings/ha)	Establishment (%)
With technology:			
.M Col 1505 (t)**	19	77.600	97
.M Col 2216 (t)	12	58.800	84
.M Col 2215 (s)	10	42.000	84
Without technology:			
(multivarietal system)***	4	7.300	73

* For details on cassava production system see on the text.

** (t)= tolerant clone; (s)= susceptible clone.

*** Multivarietal system refers to the traditional system used in the area, which includes the above three clones.

Table 18. Transmission of the mycoplasmal witches'-broom disease of cassava by grafting. Results after 6 months of planting.

Cutting position per graft group	No. of plants per graft group	% of disease transmission
Healthy/healthy	20	-
Diseased/healthy	19	100
Healthy/diseased	16	60
Healthy controls	20	-
Diseased controls	18	-

Table 19. Control of the witches'-broom-mycoplasmal disease of cassava by planting selected cuttings from symptomless plants taken from plots with different percentages of infection. Cuttings were selected by researchers, extensionists, technicians and growers after training in disease symptomatology.

% of Infection of source plots	Cuttings Selected By	Total number of evaluated plants	No. of diseased plants	Disease reduction (%)
95.3 (Baixa Fria)*	Researchers	52	25	51.9
50.3 (San Benedicto)	Extensionists	400	15	96.4
	Technicians	396	25	94.1
25.8 (Baixa Fria)*	Researchers	660	14	97.9
	Extensionists	136	9	94.8
	Growers	170	7	94.8
20.3 (Alto Lindo)*	Extensionists	504	10	98.0
	Technicians	568	17	97.1
	Growers	622	25	96.1

* Name of locations where plots where planted. All these locations are located in the Ibiapaba plateau of the State of Ceara, Brasil.

CASSAVA VIROLOGY

It has been a year of some fresh new looks at several of the major problems of cassava virology. Areas of intensive research include the viral-like diseases of cassava, continued characterization of the potexviruses of cassava, and a detailed study of the ds-RNAs found in cassava infected with viruses. The scanning electron microscope was used to differentiate between species of potential whitefly vectors and has proven a useful addition in the studies to look at whiteflies that colonize cassava. The most intensive area of research has been the work with the viral-like diseases of cassava. Cytological studies using the transmission electron microscope of healthy versus diseased cassava plants were made. Interesting results include the finding of virus-like particles, proteins, and nucleic acids associated with cassava plants affected by the Caribbean mosaic disease (CMD).

Potexviruses in Cassava

Additional characterization of both cassava common mosaic virus (CCMV) and cassava X virus (CsXV) were made. The coat proteins of these two viruses are shown in Figure 1. The relative mass (M_r) of the coat protein of CCMV is 28,000 and the coat protein of CsXV has a M_r 26,000. The nucleic acid of CCMV was analyzed in a formaldehyde agarose gel and the ss-RNA species is approximately 6,500 bases in length (Figure 2). Complementary DNA clones were prepared to the type strain of CCMV. These clones represent approximate 75% of the size of the genome, and most of the characterization has been on the cDNA clone, designated pCCMV28 (Figure 3), which is 3400 bases in length and represents over 50% of the CCMV genome. This cDNA clone contains a poly A tail of a least 60 bases in length which corresponds to the 3' end of the viral genome. Approximately 1500 bases of this clone has been sequenced, including the area of the clone which contains the coat protein of CCMV. The molecular characterization of CCMV is proceeding as part of the collaborative Cassava Trans Project whose ultimate goal is to produce transgenic cassava clones that are resistant to CCMV and African cassava mosaic virus (ACMV).

The cDNA clone of pCCMV28 was used as a hybridization probe to detect plants infected with CCMV. The virus was readily detected from plants grown in the greenhouse for both the Type and Colombia strains (Figure 4). Additional experiments are needed to test the efficacy of using dot blot hybridization on field materials. The advantage of this type of test is that the membranes can be prepared very rapidly with very simple equipment and the results analyzed in a central facility. The membranes can be sent through the mail, and there are no problems with quarantine regulations.

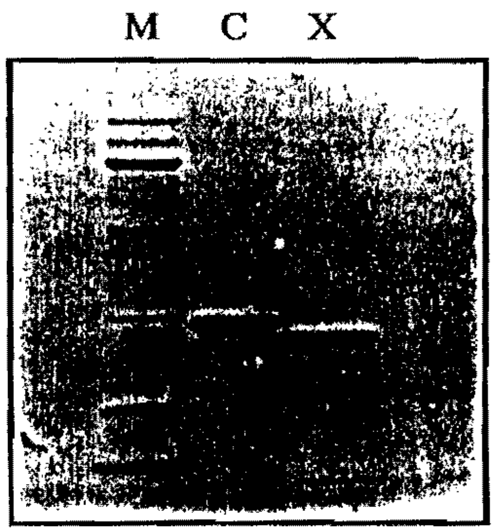


Figure 1. Lane M contains protein markers of 98, 68, 43, 29, 18, and 14 kilodaltons. Lane C contains the coat protein of cassava common mosaic virus and lane X contains the coat protein of cassava X virus.

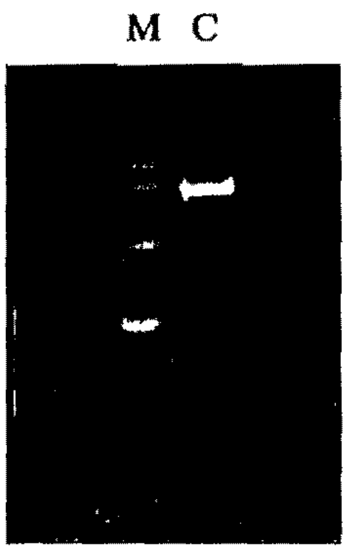


Figure 2. Lane M contains ss-RNA markers of 9.5, 7.5, 4.4, 2.4, and 1.4 kb. Lane C contains CCMV RNA.

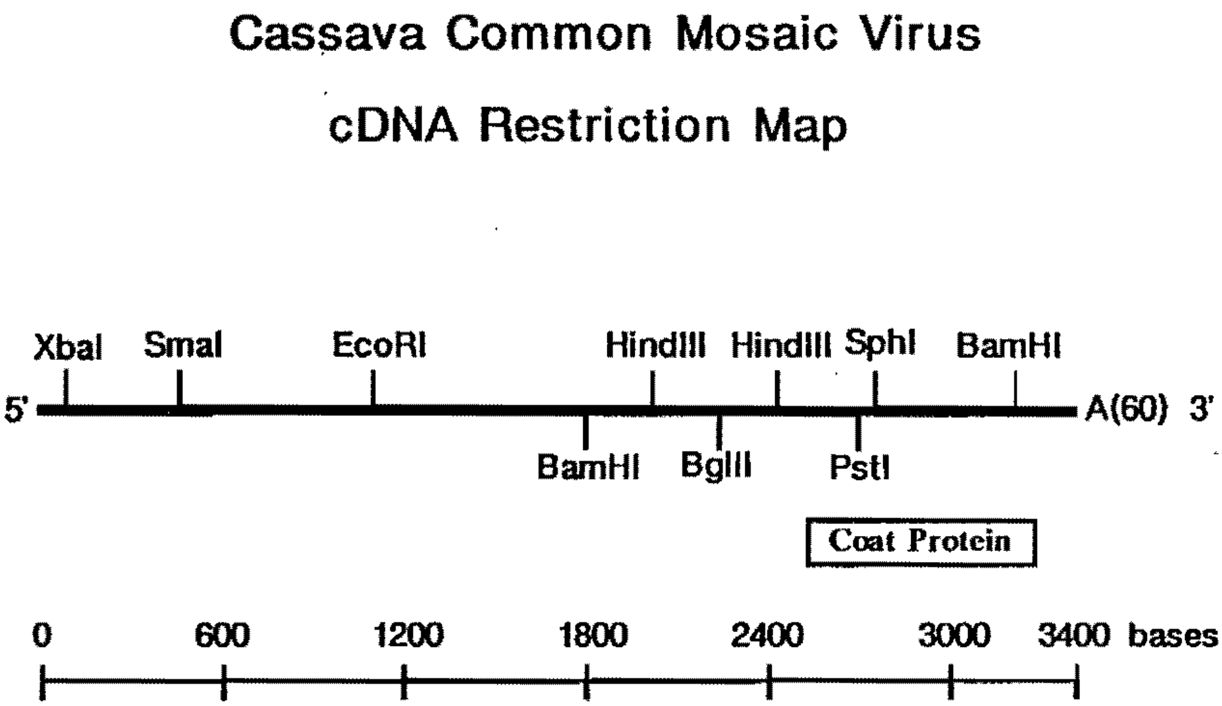


Figure 3. This cDNA clone is approximately 3,400 bases in length and represents 60% of the genome of CCMV. The 3' end of this clone contains a polyA tail and the 3' terminal gene is the capsid protein.

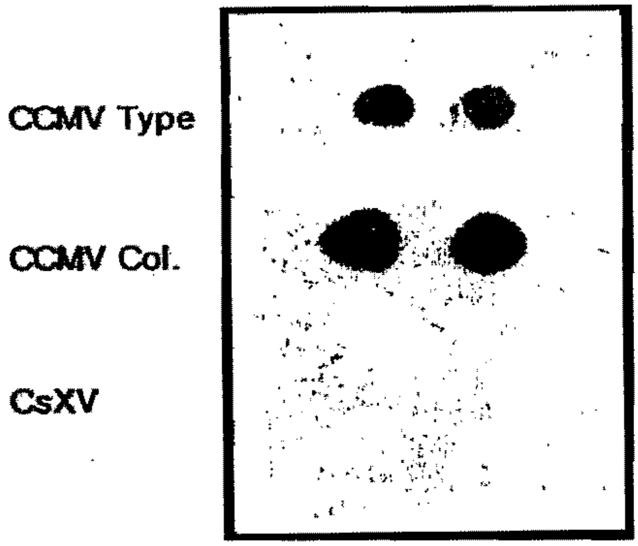


Figure 4. An autoradiogram of a dot blot of cassava common mosaic virus strains, cassava X virus, and healthy plant material. The probe was a cDNA clone representing the type strain of CCMV which was radiolabelled in a nick translation reaction.

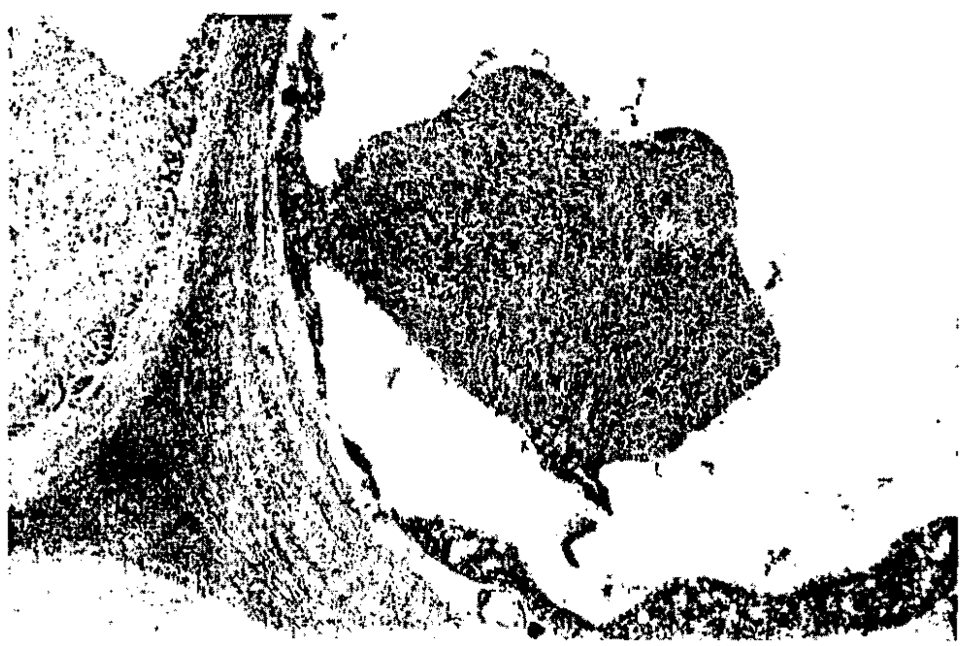


Figure 5. A transmission electron micrograph of an inclusion body found in cassava plants infected with cassava common mosaic virus. The inclusion body consists primarily of CCMV viral particles.

A cytological study, using the transmission electron microscope (TEM), of plants infected with CCMV or CsXV was made, and inclusion bodies were found in the parenchyma cells of infected leaves and consisted of viral particles (Figure 5). These inclusions are typical of inclusion bodies reported for other potexviruses. Inclusion bodies have not been found in cassava infected with CsXV, which probably reflects the low titer of CsXV in cassava.

Serologically specific electron microscopy (SSEM) was used to detect CCMV and CsXV. Both viruses could be detected by their homologous antisera, and this may be an alternate test to ELISA when only small sample volumes are available (Figure 6).

Characterization of Nucleic Acid Bands Found in ds-RNA Extractions

Double stranded RNA (ds-RNA) analysis as a means to detect cassava viruses has been used for several years in the indexing program to assure that cassava is virus-free. This technique, however, like serology works best when one has positive and negative controls and knows the origin and size of the bands of the virus being detected. When setting up the procedure, there are several positive controls which are needed, including plants singly inoculated with each virus

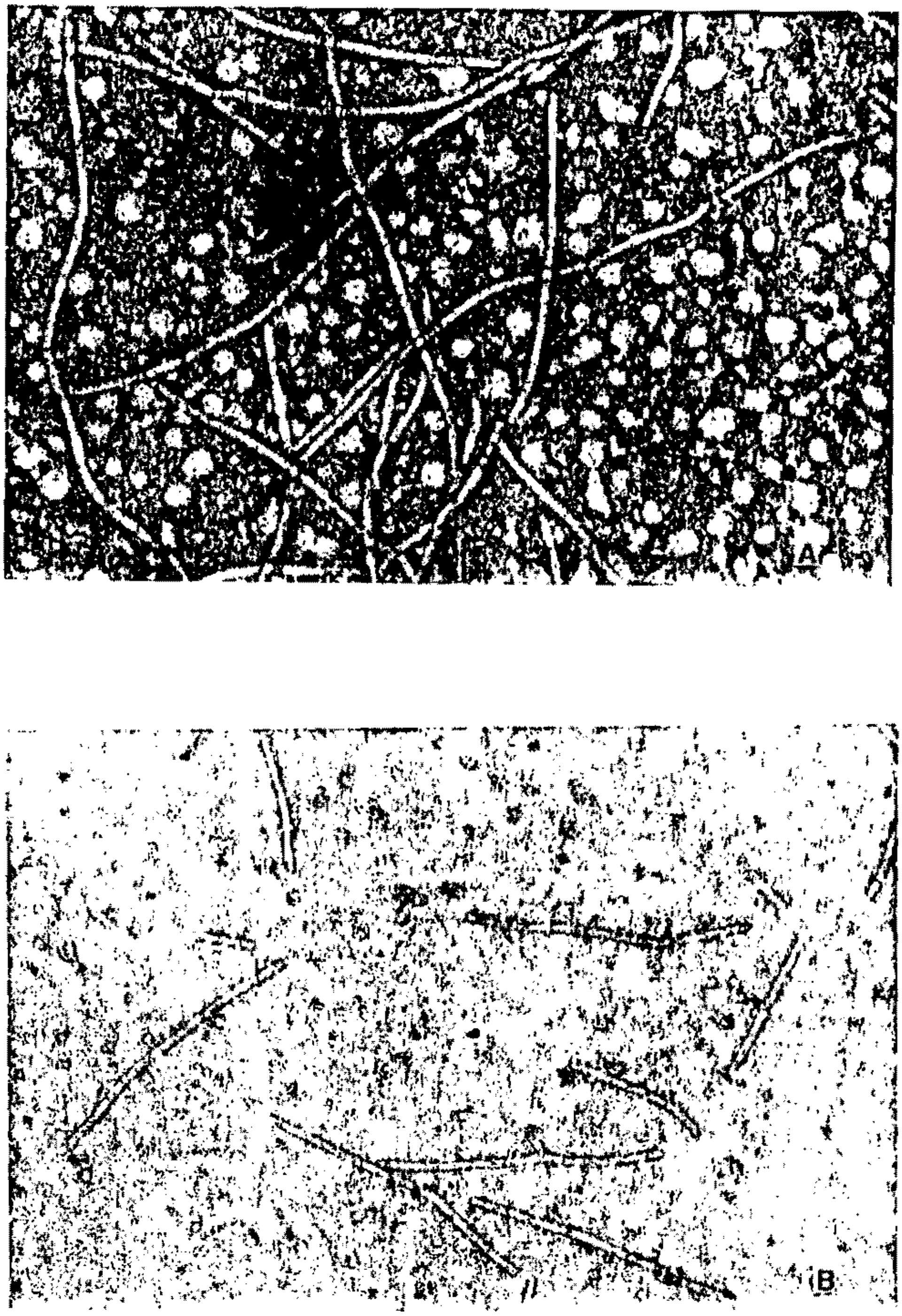


Figure 6. Serologically specific electron mircrographs of cassava common mosaic virus (A) and cassava X virus (B) The viruses were reacted with antisera specific to their respective coat proteins.

being tested, a sample of DNA to test the DNase I treatment, and ss-RNAs and ds-RNAs to test the treatment of RNase A in presence of high and low salt. The necessity of the enzyme treatments is illustrated in Figure 7. This is a picture of an agarose gel of the nucleic acids present after the ds-RNA extraction procedure of N. benthamiana infected with CCMV, and there are two bands of high molecular weight. The top band (T) is DNA, since it is digested with RQ1 DNase but is not digested with RNase A treatments. This band is found in healthy N. benthamiana (data not shown) and is probably genomic DNA. The band labelled M is approximately 7000 bases in size and was only digested by the RNase A treatment in low salt proving that it is ds-RNA. This band is not found in healthy N. benthamiana and corresponds to the expected size of the replicative form of CCMV.

One band of ds-RNA, approximately 10,000 bases in length, was found in some apparently healthy cassava plants. This band was shown to be graft-transmissible (Figure 8), and is larger than the size expected for the replicative form of a potexvirus. While there are no symptoms in Secundina or other cassava clones containing this ds-RNA band, it is considered to be of probable viral origin because it is graft-transmissible.

Although the ds-RNA technique is useful in identifying plants that are infected with viruses that have RNA genomes,

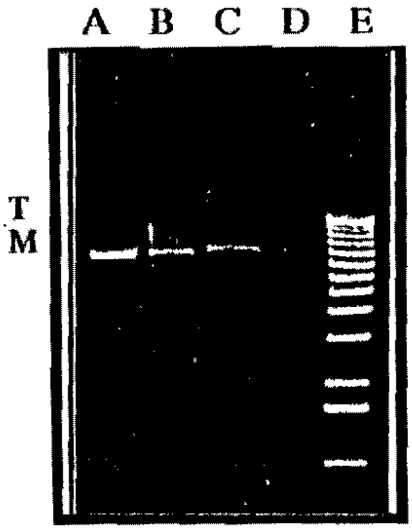


Figure 7. The nucleic acid pattern using the ds-RNA extraction procedure of plants infected with cassava common mosaic virus. Lane A is untreated; lane B is treated with DNase; lane C is treated with RNase in high salt; lane D is treated with RNase in low salt; lane E are DNA size markers

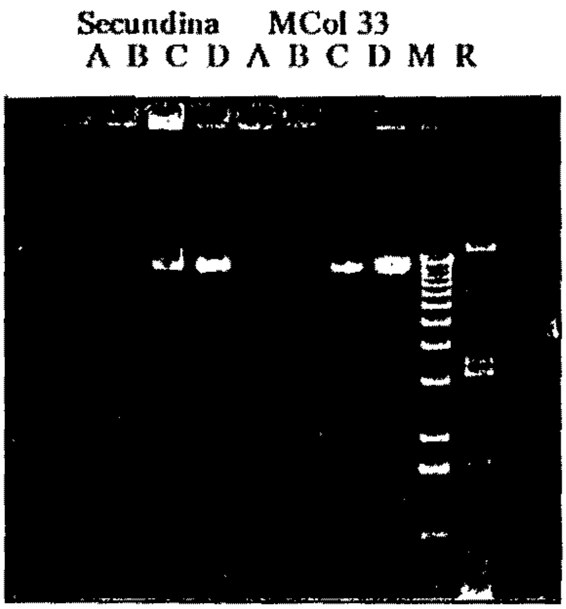


Figure 8. Double-stranded-RNA bands of approximately 10,000 base were found in appearently healthy plants of Secundina and MCol 33. Lane A is a healthy plant without bands; lane B is a healthy plant grafted onto a healtly plant; lane C is the mother plant with the ds-RNA band; lane D is a healthy plant that was grafted onto the mother plant containing the ds-RNA band. The scion was remove from the rootstock to prove that the ds-RNA band was not being translocated to the scion. Lane M contains ds-DNA markers and lane R contains ds-RNA markers.

this assay is only partly reliable, as demonstrated by the negative results obtained with some plants known to be infected with CCMV or CsXV. One gram is currently the minimum leaf tissue that is used in the ds-RNA assays. The most consistent results, using the ds-RNA extraction procedure, were the identification of plants containing a 10 kb ds-RNA band, therefore the VRU continues to assay plants for ds-RNAs in order to screen for latent viruses.

Screening Elite Germplasm for Viruses

The VRU is continuing to maintain designated virus-free elite cassava clones for international shipment. These cassava clones are indexed for the presence of viruses twice a year, and before shipment to national and international collaborating institutions or programs. The following tests are performed:

1. Enzyme-linked immuno-sorbent assays (ELISA) for CCMV and CsXV.

2. The indicator cassava clone Secundina is grafted onto the plants to be assayed, and the plants are placed in an area where temperature does not exceed 28-30C. This is the only reliable test for the Caribbean mosaic and frogskin diseases. This test should also detect ACMV.

3. The cassava plants are screened for the presence of ds-RNAs.

The VRU is in the process of testing an antiserum to a latent potexvirus tentatively designated as cassava Colombian symptomless virus by Dr. Brian Harrison (SCRI, Scottland). Since this virus is latent, a study is needed to determine the geographical distribution of the virus. There is also the need to set up a cooperative project in Brazil for the production of an antiserum to cassava vein mosaic virus, which is a caulimovirus that occurs in Brazil, in order to facilitate the exchange of germplasm between countries.

Virus-Like Diseases of Cassava

Considerable work has been done on the detection of the virus-like agents affecting cassava. Areas of investigation have included cytological studies of the diseased plants, immunological and hybridization assays with antisera and cDNAs of known viruses, and purification protocols with each step monitored by transmission electron microscopy, protein and nucleic acid analyses.

Cytological studies of both healthy and diseased cassava plants were made using the transmission electron microscope. Multiple dark staining areas were found in the nuclei of phloem companion cells of plants affected with CMD (Figure 9). These inclusion-like bodies are similar but not identical to the fibrilar rings of the inclusion bodies found in the phloem companion cells of plants infected with geminiviruses. Similar inclusion-like bodies were found in the nuclei of cassava plants affected with FSD (Figure 10), but they were found not only in the nuclei of phloem companion cells but also in nuclei of epidermal and parenchyma cells.

Since there are several lines of evidence that suggest that CMD and FSD might be caused by geminiviruses, both cDNA hybridization and SSEM analyses of plants affected with CMD or FSD were performed. Since most whitefly-transmitted geminiviruses cross react serologically, the antisera to bean golden mosaic (BGMV), bean dwarf mosaic (BDMV), and ACMV were used in SSEM analyses in an attempt to detect a geminivirus in cassava. Geminivirus particles were easily found in bean plants infected with BGMV, which were used as controls, but not in CMD or FSD affected cassava. The second type of test consisted of total genomic DNA extractions from both healthy and diseased plants which were run on gels and transferred to nitrocellulose membranes. BGMV-infected plants were used as positive controls, and the probe was cDNA clones of BGMV, but the results were again negative. A cDNA clone for ACMV has been obtained and will be used to confirm these results, but at this time there is

Figure 9. Inclusion-like bodies found in the nuclei of phloem companion cells of in cassava plants affected by Caribbean Mosaic Disease. These nuclear inclusion-like bodies are similar but not identical to the fibrilar rings found in the phloem companion cells of plants infected with geminiviruses.

Figure 10. Inclusion-like bodies found in the nuclei of several tissue types including phloem companion, epidermal, and parenchyma cells in plants affected with Frogskin Disease.

still no firm evidence of a geminivirus infecting cassava in tropical America.

Most of the experiments to isolate the causal agents of the cassava diseases of unknown etiology have concentrated on CMD. This reflects the success in finding differences between healthy and CMD-affected plants with the virus purification protocols so far attempted. The growth conditions appear to be very important, and to obtain consistent results the CMD affected plants are transferred to a growth room with 14 hours of light and temperatures below 26 C for two weeks before harvesting the leaf tissue.

The purification procedure for CMD consists of grinding the tissue, a chloroform clarification, a PEG precipitation, followed by centrifugation to concentrate the preparation. The resuspended preparations are analyzed for proteins and nucleic acids by electrophoretic methods, and samples are taken for analysis with the TEM. To further purify the virus-like agent, preparations have been run on cesium chloride or cesium sulphate gradients. Similar results have been obtained using three different isolates of CMD.

The most consistent result has been the presence of a protein band of M_r 60,000 (Figure 11). Protein bands of similar size are sometimes found in healthy plants but always in very low concentrations. This band is larger than

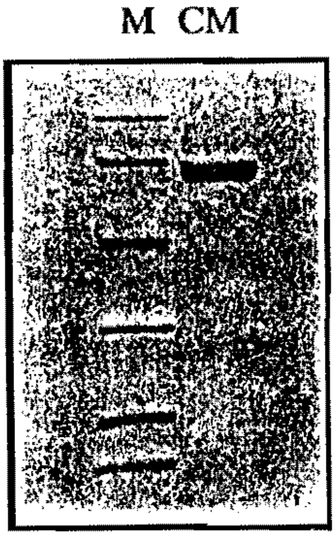


Figure 11. Lane M contains protein markers of 98, 68, 43, 29, 18, 14 kilodaltons. Lane CM contains a protein purified from plants affected with Caribbean Mosaic Disease.

Figure 12. A transmission electron micrograph of virus-like particles that are purified from plants affected with Caribbean Mosaic Disease.

expected for a capsid protein of a virus, but the protein is highly purified after collecting the virus-like band from a cesium gradient. The presence of viral-like particles have also been found both before and after the cesium gradient. These are rod shaped particles that appear to have a central core (Figure 12). They are of many different lengths and are very labile. Additional experiments are needed to find more stable conditions for these particles.

Nucleic acids have been associated with the preparations before the cesium gradients. When liquid nitrogen is used to grind the tissue, there is a band of DNA in the preparation, which is probably genomic DNA that is precipitated by the PEG along with the virus-like particles. There also appear two species of RNA, but these are easily degraded. These results would be expected of a labile ss-RNA virus.

The M_r 60,000 protein is being used as an antigen to produce an antiserum in rabbits. This antiserum will be tested for its efficacy in detecting plants affected with CMD and should clarify the question of whether this protein is a viral coat protein or a host protein that is in higher concentrations in CMD affected plants.

Whiteflies of Cassava

The VRU and Cassava Entomology have a collaborative project with Drs. David Wool and Dan Gerling of Tel Aviv University titled: **Identification and Characterization of Genetic Strains in Whiteflies of the genus *Bemisia*.** The project is using isozyme analysis to distinguish species of *Bemisia* and possible biotypes. The same tests have been used to distinguish various species of other whiteflies that colonize cassava.

Using samples collected in Ecuador, Colombia, and Venezuela, the race-specific electrophoretic patterns within *B. tabaci* indicate the existence of six races in Colombia, one in Western Ecuador and two in Venezuela (Figure 13). These races were named for the geographical location in which they predominate (Figure 14), and tend to occur in areas that are geologically isolated by mountain ranges. There is little evidence to support race differences that reflect host plant preference.

Five species of whiteflies have been found colonizing cassava in Colombia. Three of these species *Aleurotrachelus socialis*, *Trialeurodes variabilis*, and *Bemisia tuberculata* have been previously reported on cassava, but *Aleurothrirux* sp. and *Paraleyrodes* sp. were found in the Amazon region of

Figure 13. DISTRIBUCION GEOGRAFICA DE RAZAS DE *Bemisia tabaci* EN EL NORESTE DE SURAMERICA

Race specific isozyme patterns of the whitefly Bemisia tabaci

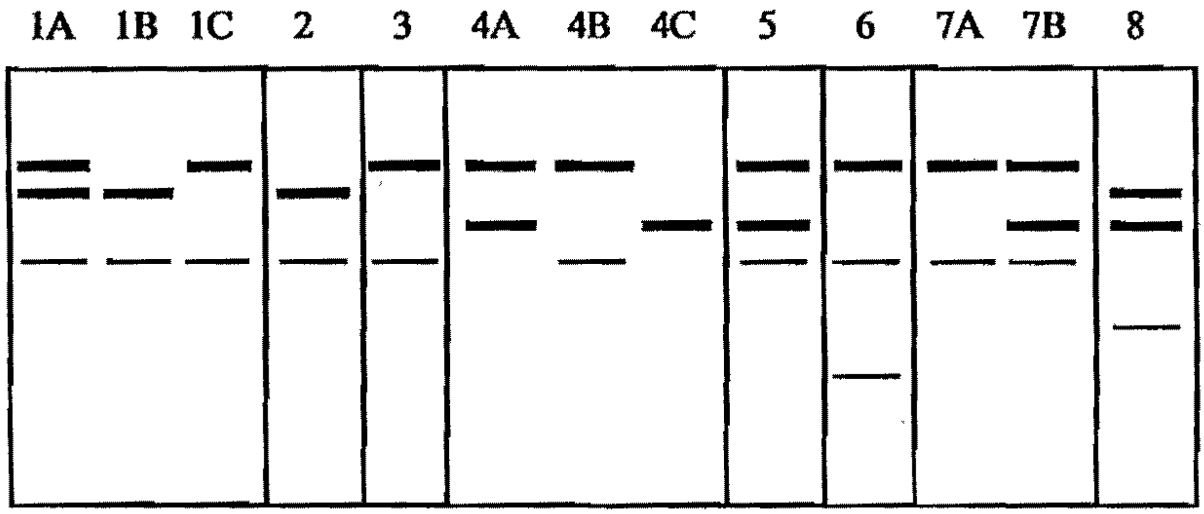


Figure 14. Esterase isozyme banding patterns of eight Bemisia tabaci races from Colombia, Ecuador, and Venezuela. The numbers correspond to the following geographic regions: 1. Valle 2. Cucuta 3. Cauca 4. Tolima 5. Caribe 6. Villavicencio 7. Manabi 8. Maracaibo. Three regions appear to contain heterogenous populations of B. tabaci as marked by the letters. The races tend to occur in areas that are geographically isolated by mountain ranges.

Colombia and this represents the first report of these whiteflies in Colombia.

The scanning electron microscope (SEM) has been used to identify adult whiteflies. The two Bemisia species, tuberculata and tabaci can be distinguished by the number of ommatidia separating their compound eyes (Figure 15). The main advantage of using the SEM to identify species of whiteflies is that specimens are easily preserved in alcohol. This contrasts with the liquid nitrogen treatment that must be used to preserve whiteflies for isozyme analysis.

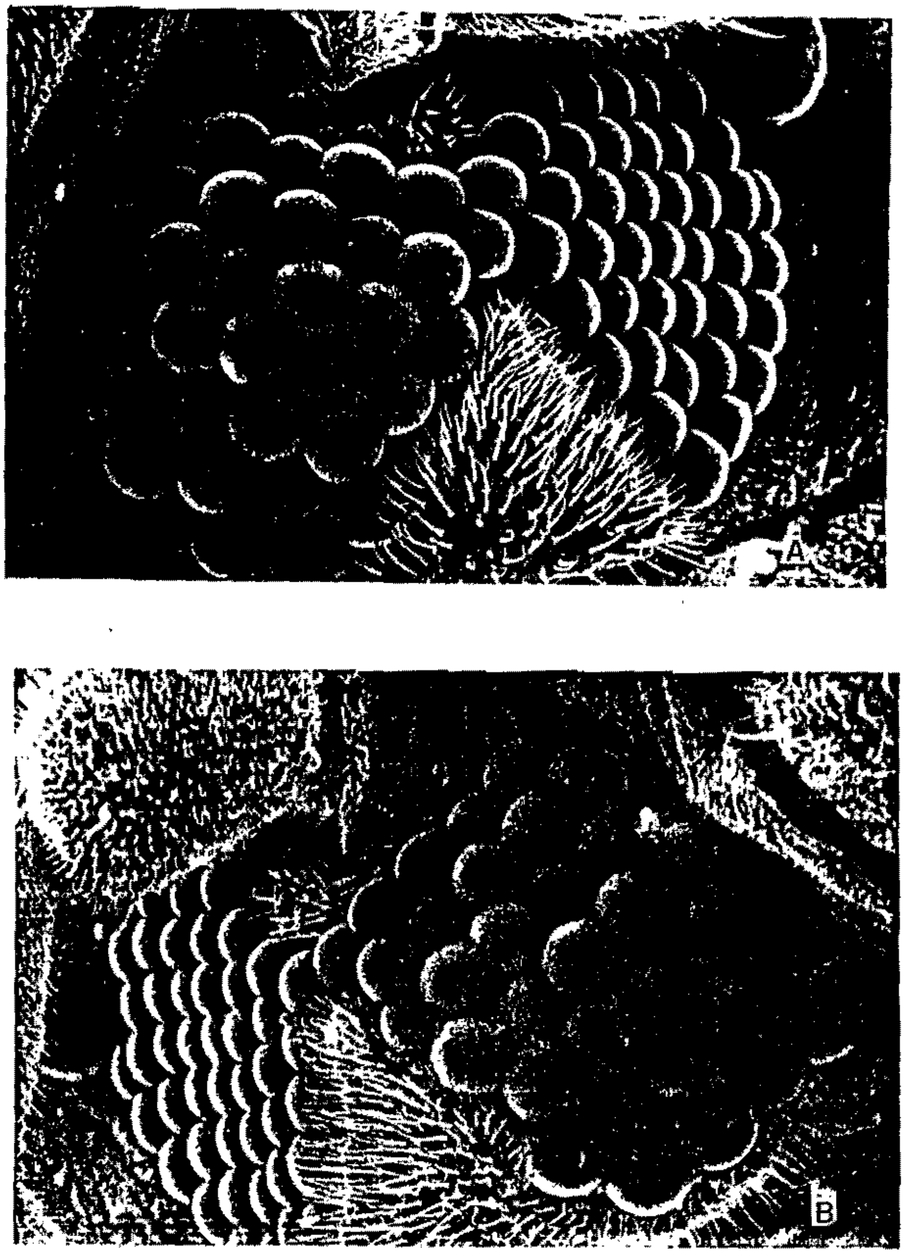


Figure 15. A. Scanning electron micrograph of the eye of the whitefly Bemisia tuberculata. B. Scanning electron micrograph of the eye of the whitefly Bemisia tabaci. The adults of these whiteflies can be distinguished by the number of ommatidia separating the sections of their compound eyes. Bemisia tabaci has only one ommatidium separating the sections while Bemisia tuberculata has two.

CASSAVA UTILIZATION - 1989

The Cassava Utilization Section concentrates its work in five areas: A. Cassava quality, B. Fresh cassava conservation, C. Dry cassava for animal feed, D. Production and marketing of cassava flour for human consumption and E. Production and utilization of cassava starch.

A. CASSAVA QUALITY.

1. Effect of the pre-harvest environment on root quality.

The quality of cassava roots is of vital importance to cassava farmers, since it determines into which markets they can sell their crop. The fresh market for human consumption is normally the highest priced and requires roots of good eating quality. Other industrial markets have less stringent requirements. Experiments over the years have shown that the pre-harvest environment has a large effect on overall root quality, both as regards chemical constituents such as starch and HCN contents and for subjective eating quality. The Utilization Section has been studying the effects of different pre-harvest treatments to obtain a better understanding of which climatic, edaphic and biotic variables are most related to root quality. In this way a crop management strategy for improving root quality could be devised.

Root samples were taken from a wide range of experiments conducted by other sections of the Cassava Program, and analyzed for dry matter, starch, total and reducing sugar and HCN content. A subjective evaluation of eating quality was also included. Table 1 presents the overall results from many such experiments, without going into detail for each one. In general it can be seen that quality does vary with many of the environmental variables tested, but the results are confusing. Especially as regards the application of fertilizer treatments, where some positive and some negative effects were observed. Since the fertility status of the field plot is also important in this respect, and the types of fertilizer treatments are diverse, uniformity of response is, perhaps, not to be expected. As an example, Table 2 presents the results of one experiment carried out with the Physiology Section in Media Luna, on the North Coast of Colombia. The highest level of nitrogen fertilizer produced the worst quality roots (high HCN, low DM and starch), but yielded more than the other treatments. A compromise between yield and quality may have to be sought. More research will be need to identify the critical nutrient components responsible for improving root quality.

In some experiments, there was a strong varietal effect, i.e. a fertilizer treatment which increased starch content in some clones but reduced it in others. The same occurred with HCN content (Table 3). For varietal selection it will be important to identify those hybrids which produce good root quality under conditions of poor fertility: these results suggest that this is possible, although such clones may

Table 1. Summary of quality experiments 1988-89: effects of various pre-harvest factors on root quality [1]

	Increase Quality	Decrease Quality	Varying effect [2]
Dry matter content	fallow drought fertilizer application (2 expts)	virus infection K deficiency	
Starch content	fertilizer application (3 expts)	drought	fertilizer application
Total sugar content	virus infection	fertilizer application (2 expts)	
Reducing sugar content	fertilizer application drought	fallow fertilizer application	
HCN-total	N-fertilizer application		fertilizer application (2 expts) drought
HCN-free	N-fertilizer application		drought
Cooking time		fertilizer application	fertilizer application
Eating quality	fertilizer application (less glassyness)		fertilizer application (taste)

[1] Results of 7 experiments are summarised, including 5 fertilizer application trials which examined such factors as time of application, levels of NPK, fertility status of soil, etc.

[2] Significant increase in some clones tested, decreases in others.

Table 2. Effect of level of N application on root quality factors, from an experiment planted at Media Luna, North Coast of Colombia

Level of Nitrogen applied (kg/ha)	Dry matter (%)	Starch (%)	Total HCN content ppm	Free HCN content (DM basis)	Total HCN content ppm (fresh wt basis)	Yield ton/ha (fresh weight)
0	34.8 ^{a}	78.9 ^{a}	173 ^{ab}	18 ^{a}	60 ^{a}	19.0 ^{a}
50	35.2 ^{a}	82.0 ^{a}	166 ^{a}	27 ^{b}	58 ^{a}	21.3 ^{b}
100	34.2 ^{ab}	81.2 ^{a}	20 ^{bc}	32 ^{b}	67 ^{ab}	25.2 ^{c}
200	32.5 ^{b}	70.4 ^{b}	219 ^{c}	30 ^{b}	71 ^{b}	26.2 ^{c}

Values with different superscript-letter are significantly different (Duncan's multiple range test, $P = 0.05$).

Table 3. Effect of fertilizer application [1] on root parenchyma starch and total HCN contents of 15 clones, 12 months of age at harvest

Clone	Starch content (%) [2]		Total HCN content (ppm) [2]	
	+ fertilizer	- fertilizer	+ fertilizer	- fertilizer
M Bra 12	59.0	74.8*	386	475*
M Bra 174	59.8	78.3*	587	419*
M Bra 191	64.0	80.0*	212	152*
M Col 72	69.0	70.0	334	161*
M Col 1468	64.3	69.8*	187	168
M Col 1684	66.3	61.0*	982	783*
M Col 2057	66.5	76.5*	308	350
CM 507-37	72.8	78.5*	827	825
CM 976-15	77.3	75.8	359	462*
CM 1223-11	74.0	83.0*	696	871*
CM 1533-19	69.0	66.8	575	653*
CM 3320-4	71.0	70.3	217	198
CM 3555-6	76.0	74.3	177	171
CM 3306-9	76.0	72.5*	168	117
CM 455-1	76.5	74.8	709	739

[1] Fertilizer application was 300 kg/ha of 15-15-15.
[2] Starch and HCN contents expressed on dry matter basis.
* Denotes significant difference between means ($P = 0.05$).

not respond well to fertilizer treatment. A period of water stress, followed by 2 months of recuperation, produced significantly lower starch and higher HCN contents than in the control treatment for 4 and 2 of the 8 clones tested respectively (Table 4). However, some clones showed no significant HCN increase or starch content decrease (indeed, roots of CM 1335-4 had lower HCN contents) under stress conditions. The existence of varietal differences with respect to quality variation under environmental stresses is of crucial importance to producing good quality cassava under the low fertility, arid conditions of many small cassava farmers.

Table 4. Effect of water stress on root quality: parenchyma starch and HCN contents

Clone	Starch (%) 1/		Total HCN (ppm) 1/	
	Control	Stress	Control	Stress
M Col 1684	89	76*	723	930*
CM 489-1	73	78	192	354
CM 507-37	82	76	718	805
CM 523-7	86	78*	195	309
CM 922-2	80	77	146	155
CM 1335-4	80	78	123	108
CM 2136-2	87	80*	162	340*
CM 3306-32	87	75*	115	186

* Denotes control and water stress treatment values significantly different (P = 0.05).

1/ Starch and HCN contents are reported on a dry matter basis.

The experiments reported here were conducted at several sites in Colombia in addition to CIAT-Palmira. A further group of experiments are in progress, or already at the stage of sample analysis. This should enable a more complete analysis of the effect of environmental variables on root quality to be made.

2. Starch studies.

As reported in last year's annual report, samples of extracted cassava starch were supplied to ODNRI 1/, London for analysis by Nottingham University for a wide range of starch quality

1/ Overseas Development and Natural Resources Institute.

characteristics. The objectives were twofold: to obtain a comprehensive characterization of cassava starch physico-chemical characteristics, especially as relating to structure and rheological properties and to determine if variation in any of these properties was related to differences in root texture as perceived by consumers. A hard or glassy texture had previously been closely linked to consumer dislike of cassava samples, and is the major quality defect reported by farmers for non acceptance of their crop in the fresh market. Identification of the critical factors responsible for these textural changes would enable germplasm to be screened for eating quality in an objective manner and facilitate research into the effect of pre-harvest variables on eating quality.

Two types of starch samples were sent to the UK from CIAT: (a) samples from 4 cvs selected to show good and poor eating quality, harvested at 10 months of age at CIAT. Such samples were sent from 7 field plots harvested between 1987 and 1989. The samples thus reflected seasonal and environmental effects on root quality, but not plant age effects and (b) samples from plants pruned approximately one month before harvest, and from unpruned plants. Pruning is an effective way of inducing hard or glassy texture in cassava roots. This ODNRI/Nottingham/CIAT project has now finished, and the results are being prepared for publication. Table 5 gives the mean results for 3 of the 15 quality characteristics evaluated by the expert taste panel, for the samples sent to the UK. For all 15 characteristics, harvest date had a significant ($P = 0.001$) effect. The fact that the eating quality of one variety, harvested at different times at the same plant age, is so variable makes selecting clones of good eating quality a long term endeavor (many sites, harvests, etc.) unless the factors controlling eating quality are better understood. Surprisingly, despite the fact that root eating quality varied so greatly between the harvests, the starch samples were all remarkably similar for all characteristics measured. This is excellent for the use of cassava starch in the food industry, for example, because they require a homogeneous product with consistent quality. However, these results do not help to resolve the problem of the cause of hard, glassy texture in fresh cassava roots. Other root components must be responsible for this textural variability, possibly fibre (cell wall/pectins). Changes in membrane permeability can affect texture in potatoes, for example. The pursuit of the causes of fresh root textural problems will continue with an investigation of these characteristics of cassava, and external funding will be required for a collaborative project with an advanced research institute with expertise in this area.

3. HCN and the bitter taste of cassava roots.

Although root HCN imparts a bitter taste to fresh, boiled cassava, it is frequently stated that there is no correlation between bitter taste and HCN content, i.e. that there are other bitter tasting components in the root which confound the overall picture. The expert cassava taste panel was used to test this frequently encountered statement. Fifteen cassava varieties with root parenchyma contents

Table 5. Taste panel evaluations of hardness, glassiness and cassava taste for boiled cassava sample varieties, grown at CIAT and harvested at 10 months of age on 7 occasions between 1987 and 1989

Quality Characteristic	Harvest	Variety			
		HMC 1	CM 681-2	CM 1559-5	CM 489-1
Hardness	1	39^{ef}	53^{d}	55^{cd}	57^{b}
	2	77^{b}	92^{ab}	47^{d}	94^{a}
	3	60^{cd}	82^{bc}	88^{a}	90^{a}
	4	71^{bc}	102^{a}	69^{bc}	53^{b}
	5	52^{de}	56^{d}	73^{b}	98^{a}
	6	108^{a}	74^{c}	70^{bc}	86^{a}
	7	36^{f}	46^{d}	50^{bcd}	57^{b}
Glassiness	1	49^{b}	75^{c}	58^{bc}	51^{de}
	2	50^{b}	109^{b}	57^{bc}	78^{a}
	3	33^{cd}	109^{b}	71^{ab}	75^{ab}
	4	38^{bcd}	130^{a}	49^{cd}	44^{d}
	5	26^{d}	59^{d}	33^{e}	63^{bc}
	6	76^{a}	80^{c}	75^{a}	59^{c}
	7	44^{bc}	32^{e}	36^{de}	26^{e}
Cassava taste	1	85^{de}	76^{cb}	71^{c}	77^{bc}
	2	77^{e}	53^{d}	84^{cb}	72^{c}
	3	109^{ab}	66^{c}	72^{c}	76^{bc}
	4	89^{dc}	49^{d}	92^{ab}	87^{b}
	5	115^{a}	85^{b}	98^{a}	65^{c}
	6	49^{f}	67^{c}	71^{c}	76^{bc}
	7	99^{bc}	97^{a}	102^{a}	102^{a}

Notes: 1. Harvest dates were: 1 = March 25/87, 2 = August 18/87, 3 = January 12/88, 4 = March 15/88, 5 = August 11/88, 6 = November 22/88, 7 = September 5/89.

2. Values with different letter superscripts are significantly different (P = 0.005) using Duncan's multiple range test. The main effect of harvest date was significant at P = 0.001 in all cases.

3. Evaluation scale: 0-150 with 0 = absence of character; 150 = intense expression of character. See Cassava Program Annual Report for 1987 for methodological details of taste panel design and operation.

varying from 40 to 400 ppm (fresh weight) were given to the taste panel of 10 trained experts for an evaluation of the bitter taste. Uncooked and boiled root samples were also analyzed for HCN content using the enzymatic method. This was carried out on three occasions, using roots harvested only 2h previously, then using roots harvested 1 and 2 days before the panel session. This was to allow progressively more time for physiological deterioration to develop after harvest; the phenolic compounds which accumulate after harvest also affect cassava taste and may increase bitterness, and hence as time between harvest and food preparation increases the significance of the correlation between root HCN content and bitterness may decrease.

The results (Table 6) show clearly that root HCN content of both uncooked and boiled cassava root pieces correlates significantly with the bitter taste of the same samples as evaluated by the expert panel. This is true even after two days of storage after harvest, when phenolic accumulation had occurred. The correlation was less significant in the intermediate evaluation after 24h, however. These results mean that the use of the term bitter cassava is acceptable as a synonym for high HCN cassava, since the correlation between the two is high and significant, at least for freshly harvested roots. The taste imparted by the accumulation of phenolic compounds after harvest, although marked, is not bitter (the panel distinguished a deterioration taste specific for this).

Table 6. Correlations between total HCN content of uncooked and cooked cassava root pieces, and the expert taste panel evaluation of bitter taste

	Time between harvest and cooking		
	2 hours	24 hours	48 hours
Correlation coefficient (r) between bitter taste and:			
Total HCN, uncooked root, (DM basis)	0.827 ***	0.619 *	0.843 ***
Total HCN, uncooked root, fresh weight basis	0.784 ***	0.614 *	0.856 ***
Total HCN, cooked root, dry matter basis	0.874 ***	0.333	0.593 ***
Total HCN, cooked root, fresh weight basis	0.894 ***	0.381	0.659 **

Significance of correlation coefficient: ***, P = 0.001; **, P = 0.01; *, P = 0.05.

4. Hydrogen cyanide evaluation.

For many years the Cassava Program has used a rapid HCN evaluation method based on the reaction of picric acid with HCN to produce a colored product. This is scored qualitatively (1-9) according to the intensity of the color reaction. One limitation of this method is that the maximum score is reached at only 150ppm, whereas cassava root parenchyma HCN contents of over 1000ppm are known. It is important to distinguish HCN contents of approximately 250ppm from those even higher because the former can be successfully reduced to acceptable levels (<100ppm) by sun drying, whereas the latter cannot.

Since this rapid HCN method had never been correlated with the quantitative enzymatic method (in routine use by the Utilization Section), advantage was taken of three experiments of the Physiology section to do this. In two of the experiments no significant correlation between the two methods was found. The third experiment did show a significant correlation ($r = 0.570^{***}$) between the picric and enzymatic methods. A closer analysis of the results reveals a very unsatisfactory picture, however. The expected range of response for each score of the picric acid method is shown in Table 7 together with that actually found. It can be seen that the results are very imprecise, with, for example, samples with from 27 to over 300ppm scoring 8 on the color scale.

Table 7. Comparison of the results of the qualitative picrate method and the quantitative enzymatic method for HCN determination in cassava root tissues

Picrate method			HCN: Enzymatic Method						
	Theoretical Range of HCN content (ppm)		HCN content (ppm) Actual range found			Number of samples with HCN content: above	within	below	
Qualitative Score	max.	min.	max.	min.	mean	the theoretical range			N
1		< 10							
2	15	10	55	19	102	6	0	0	6
3	25	15	69	20	100	9	1	0	10
4	40	25	109	23	149	11	4	2	17
5	60	40	92	27	136	5	4	6	15
6	85	60	132	28	176	6	4	11	21
7	115	85	114	42	175	0	2	9	11
8	150	115	392	27	336	3	1	9	13
9		> 150	378	44	455	-	10	9	19

Note: HCN contents are reported on a fresh weight basis.

An experiment was conducted at CIAT to examine some possible causes of the error involved in this qualitative method. The method uses a 1g cube of parenchyma tissue placed in a test tube, with 5 drops of toluene added to release the HCN. The volatile free HCN reacts with the picric acid which is impregnated onto a filter paper strip suspended from the top of the tube, and held in place by a rubber bung. The color reaction takes 24h to develop. It was suspected that release of the HCN from to tissue cube was not total. The effect of homogenizing the tissue to facilitate HCN removal was examined, and the residues of HCN in the tissue cubes after the 24h had passed were determined. The results (Table 8) show that up to 32% of the total cyanide remains in the tissue and thus the results can be a significant underestimate of the total HCN. Maceration of the tissue did not help to improve this, however. The failure to volatilize all the root HCN cannot be the only source of error, however, since overestimations as well as underestimations of root HCN content occurred in the Physiology Section experiment (Table 7). The color reaction itself must be of variable response. Research is required either to improve the accuracy and reproducibility of this method or to develop a totally new rapid qualitative method based on a different color reaction.

B. FRESH CASSAVA CONSERVATION.

1. Barranquilla pilot project.

The objective of this joint DRI [1]-CIAT activity is to achieve the large scale commercial adoption of the fresh cassava conservation technology developed and tested by CIAT/ODNRI.

The initial phase of this project has established the storable product in the marketplace and trained 3 farmer cooperatives in the use of the technology. Cassava in bags in on sale in several supermarkets in Barranquilla, and in some small local shops (see CIAT Cassava Program Annual Report for 1987 and 1988 for details, including breakdown of costs etc.)

An objective of obtaining 20% of the fresh cassava market was fixed. This would mean approximately 8,000 t/y of fresh cassava being marketed with the new technology. For this objective to be met, several new actions were necessary :

a. Training of new farmer cooperatives to supply fresh cassava.

The following cooperatives have received training during 1989:

Department	Cooperatives
Bolivar	El Playón, San Cayetano. Coo San Jose*

[1] Colombian Integrated Rural Development Fund.

Table 8. Determination of residual HCN remaining in root tissues used for the rapid picrate HCN test, and the effect of tissue maceration on HCN residue levels

Variety	Sample preparation	HCN contents (ppm, fresh wt basis):[1] Initial	Residual	% Residual initial
CMC 40	tissue cubes	72 [2]	16	22
	tissue macerated	72	13	18
CMC 40	tissue cubes	57	5	8
	tissue macerated	57	5	8
M Ven 25	tissue cubes	408	87	21
	tissue macerated	408	82	20
M Ven 25	tissue cubes	556	145	26
	tissue macerated	556	178	32
M Col 1684	tissue cubes	161	39	24
	tissue macerated	161	36	22

[1] As determined using the quantitative enzymatic method (Cooke, 1978).

[2] Each residual HCN content is the mean of 5 replications. Each replication consisted of 10 test tubes each containing one gram of root tissue, either macerated or as a tissue cube. The initial HCN contents were taken directly from recently harvested roots at the same time as the same root tissue were used to obtain samples for the rapid picrate test.

Atlántico Villa Rosa, Molinero, Copagro*, Fagrocol*, Coagro Oriente, Copromercar*

Magdalena El Piñón*, Salamina, Coopropivijay, Aproamedialuna

Those marked with an asterisk have supplied cassava to the Barranquilla market during 1989. The rest are waiting for demand to increase (see below).

b. Organization of a distribution enterprise for fresh cassava in Barranquilla.

Since the city has over 5000 small shops, most selling cassava and these are the major site of cassava purchase, a distribution system capable of reaching this retail outlet was required. A centralized wholesale system is also necessary, to coordinate the arrival of cassava from many cooperatives, and its dispatch to supermarkets, markets and shops. If no such enterprise exists, it is likely that individual cooperatives will compete over the supply of supermarkets, for example. A central organization also assists in quality control and in the management of product promotion.

In January 1989 a new second order Federation of cooperatives was formed with its base in Barranquilla. This Federation comprises, in addition to cassava processing cooperatives in Atlantico, Bolivar and Magdalena departments, many other agricultural cooperatives and two small shopkeeper associations based in Barranquilla itself.

The Federation, whose formation has been supported by DRI, had access to an initial credit line and the chief executive has an excellent business background. The Federation was informed of the results and potential of the fresh cassava technology and, as a consequence, proposed to set up a separate cassava distribution enterprise to manage the project.

During February-March 1990 a project was written by the Federation, with technical assistance from CIAT/DRI and CORFAS [1], to enable this to be initiated. The initial requirements for working capital were estimated at 5.1 million pesos (US$12,000). This would enable a central warehouse to be rented and maintained, and provide working capital for cassava purchase and other costs. The rate of return on the capital was estimated at 73% (less inflation of 28%). This project for credit was approved by CORFAS in September 1989, and the Federation acted in October to set up the distribution enterprise.

A new wholesale marketplace in Barranquilla also initiated full operations in October 1989, and the Federation has a warehouse there.

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[1] Corporación Fondo de Apoyo de Empresas Asociativas.

The simultaneous opening of a new wholesale distribution system in Barranquilla together with the arrival of the new cassava product in the marketplace was a very convenient coincidence, and has caused great impact in Barranquilla. Although the distribution enterprise is only starting to operate, firm orders for 117 t/month have been received (Table 9), including some from Bogotá, where the Federation has contracted an agent.

Table 9. Current, confirmed orders for fresh, treated cassava received by the marketing federation based in Barranquilla

Wholesale/Retail outlet	City	Volume (t/month)
Supermarkets	Barranquilla	30
Supermarket	Cartagena	5
Small shops	Barranquilla	30
Wholesalers	Bogotá	40
Distributor	San Andrés (Island)	12

Quality control has also greatly improved: individual cooperatives vary greatly in their capability to select good quality cassava, and this has been a constant source of friction between suppliers and purchasers in the past. Now a central distribution organization exists which can control quality. Table 10 shows the strict quality requirements fixed for the two classes of cassava recognised. In order to enable quality control to be exercised by the Federation, root selection in their warehouse has been included in the operation of the technology. Roots are packed into large (20 kg) bags in the field, and treated. The roots are removed from the bag in Barranquilla, selected and repacked according to quality. A price difference between the two qualities of cassava exists (Table 11).

The future of this business looks promising, given the organizational and business expertise of the Federation and the impact obtained in such a short time since operations began.

c. Promotional activity

Conserved cassava in bags is a new product for the Barranquilla consumer: it does not behave like traditional cassava, and is marketed differently. Promotion is therefore required in order (a) to explain why this cassava is superior to the normally available product and (b) to obtain a wide level of awareness that this product exists, and where it can be purchased.

Table 10. Quality standards for treated cassava fixed by the Federation, October 1989

Physical characteristics	Quality A	Quality B
Root length (cm)	20-40	15-40
Root diameter (cm)	5-8	4-8
	Quality A, B	
Shape:	Whole, normal, not mishapen	
Root rots, diseases	Absent	
Root peduncle	Short	
Peel color	Red, pink or yelow	
Parenchyma color	White or yellow	
Taste	Not bitter or sweet	
Consistency (cooked root)	Firm	
Cooking time (mins), max	30	

Table 11. Costs (Col.$) per kg of treated cassava, quality A and B (Federation, October 1990)

	Quality A	Quality B
Raw Material	50	40
Mertect	2	2
Polyethylene Bag	6.5	6.8
Jute Sack	4	0
String to try bag	2	0.3
Labor	4	3
Transport	7	6
Other	5	3
Total	80.5	61.1
Sale price	90.0	80.0

Col.$410 = US$ 1.00, October 1989.

Such a general promotional campaign requires the use of various media in order to be effective at a city-wide level, and will therefore be relatively expensive (i.e. beyond the capability of the Federation to finance). Maximum impact will be achieved with the use of TV advertising, using the local channel, which is a major expense.

A separate project was prepared for external funding in which finance is sought for the development of promotional material (TV, radio, press adverts, consumer and retailer leaflets etc.), and for their placement over a 2 year period in Barranquilla. Once developed, these materials can be used in other Colombian markets (see next section) as the project expands.

A test market for a new product consists of placing the product on sale using the distribution organization and promotional campaign which would be in place for a full scale commercial launch. This enables the estimation of sales and profits on a truly commercial basis. Without promotion, sales will not reflect the true potential of the product. Thus, only when promotional activity gets underway (mid 1990) will the sales of fresh cassava start to expand and reach the expected levels. At present, funding for the promotional campaign is not assured.

2. Market studies in Cali, Bogotá and Medellin.

In mid 1988 DRI was made responsible by the Colombian Ministry of Agriculture for the drafting of a national plan for cassava, as part of the Government's program of increasing the production and utilization of eight selected crops. One of the major planks of this national plan is the development of the fresh cassava storage technology beyond the confines of the Barranquilla market to the other major Colombian cities. This will help cassava farmers, and consumers in these cities. The first stage of this expansion was the design execution and analysis of market studies undertaken in the three major cities, Bogota, Medellin and Cali. These studies were financed by DRI, and carried out by CORFAS (the NGO responsible for commercialization and credit in the DRI cassava projects) with technical assistance from CIAT. The studies followed the model of the previous ones carried out in Barranquilla and Bucaramanga, but the questionnaire itself was developed jointly by CORFAS and CIAT after reviewing the previous experiences. The interviews with consumers, retailers and wholesalers trading in cassava were carried out between November and December 1988, and a joint CORFAS/CIAT working group analyzed the results in February 1989. The results of this exercise were highly interesting not only from the point of view of the implementation of the fresh cassava technology but also because of information on a range of consumption and quality issues was obtained.

Table 12 shows the main results of the consumer surveys. A surprising result is that the consumption of cassava is highest in Bogota, rather than in Cali. If previous data are reviewed (Table 13) it can be seen that consumption of cassava has increased dramatically in Bogota during the last few years, contrary to our expectations of a continuing decline. Indeed, only in Medellin has consumption declined during the 1980's. This also agrees with the results of 1987 in Barranquilla, where a significant increase in consumption has been found. In Barranquilla this can perhaps be explained by a lower real price of cassava in the consumer market but in Bogota and Cali the increase in consumption has occurred despite the real prices being higher that ever before. A more complete study of the prices of competing starch sources is required. One possible partial explanation is the increasing immigration of populations from cassava consuming regions to Bogota. Indeed, only 48% of the Bogota consumers interviewed were from the city or the surrounding department, whereas 90% of the Medellin consumers interviewed were from the department of Antioquia.

Table 12. Characteristics of cassava purchase and consumption in Bogota, Medellin and Cali

		Bogotá	Medellín	Cali
Purchase frequency (times/wk)		1.7	1.8	2.6
Purchase amount (kg/time)		1.15	0.45	0.65
Last purchase price (Col.$/kg) [1]		272	242	202
Consumption frequency (time/wk)		1.9	2.3	3.1
Consumption per capita (kg/adult equivalent/yr)		17.0	7.0	15.5
Purchase site,%:	marketplace	30	12	44
	supermarket	16	25	21
	local shop	48	62	24
	mobile market	1	1	10
	other	2	0	0

[1] Dec. 1988. US$ 1.00 = Col.$ 334.87.

Table 13. Consumption of fresh cassava in Colombia 1968-1988 kg/adult equivalent/year

	1968	1970	1981	1982	1983	1987	1988
Bogotá	10.4		7.6				17.0
Medellín	13.4		9.8				7.0
Cali	18.2	27.4	7.7	12.8			15.5
Barranquilla	29.4		27.2		30.5	44.8	

Sources
1968 ECIEL Encuesta Latinoamericana
1970 Pinstrup Anderson and de Londoño
1981 DRI
1982 de Londoño
1983 Janssen
1987 van Koersueld
1988 CORFAS/DRI/CIAT market study

The conservation technology was explained to the consumers in a concept testing format, and a purchase intention was obtained (Table 14). The percentage of those consumers who already consume cassava who responded positively (definitely or probably will purchase the product) was highest in Cali at 93% and lowest in Bogota at 63%. In addition, those consumers who do not at present eat cassava cite the high price and poor quality of the product, rather than an inherent dislike of cassava as their reasons for non-consumption. Since these problems can be at least partially overcome by the storage technology, it is interesting that a significant percentage of current non-consumers gave positive purchase intentions (Table 14), especially in Cali. Even though the overall purchase intention is lowest in Bogota, the market is so large that it is worthwhile to try to target those consumers most interested in the technology, i.e. by income strata, site of food purchases etc.. A detailed analysis of the results of this survey will make this possible. The overall conclusions of this study are:

Table 14. Purchase intention of cassava in bags for consumers and non-consumers of cassava

	Purchase intention				
	Definately yes	Probably yes	Don't know	Probably no	Definately no
Consumers					
Bogotá	23	42	21	11	3
Medellín	39	37	9	6	9
Cali	61	32	7	1	0
Non-consumers					
Bogotá	10	16	16	30	28
Medellín	20	28	18	2.	32
Cali	18	45	8	6	22

1) Important problems in the commercialization and quality of fresh cassava exist in the three cities surveyed, and the conservation technology has the potential to provide a solution to these problems, and hence satisfy a consumer need.

2) Consumers in all cities are interested in the new storable product, with most emphasis in Cali and least in Bogota.

3) The distribution system for each city must be designed with regard to the cassava marketing characteristics of each city e.g., purchase site, size of family purchase/week, etc..

4) As a result of the introduction of the technology an increase in cassava consumption could be expected, not only because of increased purchases by consumers, but also because some current non-consumers of cassava will start to purchase the new product.

5) Most consumers cannot identify any cassava variety, or name any visible characteristic associated with quality. Hence it should be relatively easy at the consumer level to introduce new varieties with different characteristics (e.g. peel color) from those currently accepted. Resistance will be concentrated at the wholesaler level.

Following the completion of the market and consumer surveys of the three major Colombian cities, it is the intention of DRI to expand the Barranquilla pilot project to these new markets. First, the operation of the new distribution system and the execution of the promotional campaign must be studied in Barranquilla before expansion occurs. However, it is possible that some marketing of the cassava in bags in Bogota will occur during 1990: the distribution network in Barranquilla has contacts in Bogota and the price differential is sufficient to warrant the dispatch of cassava from the coast. In addition, a cooperative has recently been formed in Socorro, Santander Department for the express purpose of commercializing cassava in bags in Bogota. The results of the market survey will be used to orient this activity during 1990.

3. International cooperation

a. Paraguay

The IDRC financed cassava project with the extension service in Paraguay has been extended for a second phase of three years from 1989, and for the first time includes a utilization component. An important part of this new activity is the testing of the conservation technology under Paraguayan conditions. Initial trials during 1987 and 1988 have shown that the storage technology functions excellently during the months October to May when temperatures are high. However, during the winter months of June to September, the lower temperatures slow the wound healing reactions of the root tissues, and thus make the technology less effective. This can be improved by careful root selection to avoid excessively damaged roots. In addition, the physiological deterioration reaction is also much less rapid in the cold months, mainly because the plants are pruned at the first sign of frost. Pruning induces resistance to physiological deterioration, and thus the reduced effectiveness of the storage technology is not such a problem during this time of the year.

A series of storage trials are currently underway in Paraguay to determine the best combination of treatment variables for the local conditions, including chemical treatment methodology, bag size, root selection criteria, transportation system etc. This work will be carried out jointly with a farmer pre-cooperative group which is interested in pilot commercialization of the technology. A consumer panel evaluation of the quality of storable cassava is also in operation. The results of this work will be known by the end of 1989, and will be used to produce a feasibility study of the use of the conservation technology which will include an economic analyses of costs and potential returns.

b. Brazil

Following a request from the extension service of the State of Paraiba in N.E. Brazil, a trial of the conservation technology was carried out at three locations in that state in mid 1989. These trials were conducted with extension agents and farmers, and bags were distributed to wholesalers, retailers and consumers for evaluation. Although no detailed report has been received, the results have been sufficiently positive for the study to proceed to a more detailed consideration of the commercialization aspects, and CIAT will continue to advise in this area in collaboration with the National Cassava Centre of Brazil. The climatic conditions of N.E. Brazil are similar to those of the Atlantic coast of Colombia, and the technology is expected to function equally well there.

c. Ecuador

A market survey of fresh cassava in Guayaquil has been completed, and a market exists for cassava in bags both in supermarkets and local markets, where cassava is mainly purchased. The Manabi region, where the UAPPY concentrates activities, can only supply good quality cassava from August to October. Market development in Guayaquil will demand a continuous supply of the product, and hence expansion of conservation technology transfer to other cassava production region. INIAP has recently conducted a series of very successful trials of the technology in the Santo Domingo region, where cassava can be produced year-round. CIAT will assist the UAPPY and INIAP in project development for fresh cassava as requested by these national and regional institutions.

d. Africa

Although the conservation technology was designed for specifically Latin American cassava marketing conditions, considerable interest has been expressed by many African visitors to CIAT. Details of the technology have appeared in publications circulating in Africa. This has resulted in many letters to CIAT asking for more details. Greatest interest has been expressed by West African countries and Uganda. In order to assist the transfer of this technology to Africa, an English language version of the audiotutorial on fresh cassava conservation in polyethylene bags has been produced.

C. DRY CASSAVA FOR ANIMAL FEED

1. Establishment of cassava drying industries in Latin America

a. Colombia

The dried cassava industry continues to expand beyond the institutional framework of the DRI-CIAT project (CIAT Cassava Program Annual Reports 1981-88). It is estimated that the total annual production of dry cassava for animal feed is between 12 and 15 thousand tonnes.

Within the DRI-CIAT project, five new farmer drying cooperatives were established and a number of existing cooperatives expanded their drying capacity. Despite the overall increase in drying capacity of the project, the total production of cassava chips was slightly lower than the 1987/88 season at 4800 t. Floods caused by Hurricane Joan in November 1988 resulted in severe crop losses in certain areas and in consequence fresh cassava prices rose substantially limiting the supply of raw material to the drying plants. Direct technical assistance to the dry cassava component of the DRI-CIAT project, through the stationing of a DRI funded agricultural engineer in Barranquilla, ended in May 1989. CIAT, however, continues to provide support for training courses and technical meetings. In this respect CIAT has been actively participating with national institutions in fixing quality standards for dry cassava.

During 1989 CIAT signed an agreement with the Colombian Government's National Rehabilitation Program to provide technical assistance and training for the establishment of further drying plants in other Colombian regions (North and South Santander Departments and Meta Department) and in areas not covered by DRI on the Atlantic Coast Region. The first drying plants are now under construction in these new areas and CIAT is assisting local institutions with the establishment of on-farm variety adaptation trials and seed multiplication lots. In North Santander Department, where individual farmers have been chipping cassava by hand, four CIAT/UNIVALLE redesigned pedal operated chippers (CIAT Cassava Program Annual Report 1988) are being installed.

CIAT has also collaborated with the UNDP financed project on Coca Substitution in Cauca Department in the selection of sites for the establishment of 3 new drying plants; this will bring the total number of plants in this region to 4.

b. Ecuador

The demand for cassava flour as an agglutinant in shrimp feed has stagnated due to price and quality competition from other raw materials. The feed companies are now demanding a higher quality product in terms of ash and fibre content. To this end the Utilization Section has been cooperating with INIAP [1] and FUNDAGRO [2] in the installation and evaluation of root washing machines and flour classifying equipment. The farmer drying associations are also looking to diversify onto the production of starch and flour for human consumption.

c. Panama

The expansion of the dry cassava industry in Panama has been limited by the inability to harmonize costs and prices between producers and consumers of dry cassava. There is a definite interest on the part of the concentrate industry in the use of dry cassava in feed rations but it appears that in the prevailing economic situation it is cheaper to import pellets from Thailand. There are currently 4 natural cassava drying plants in Panama.

d. N.E. Brazil

A Kellogg Foundation financed project based in the State of Ceara, in which CIAT is collaborating with the local agricultural research and extension institutions in the establishment of an integrated cassava development project, was initiated in May 1989. 15 small cassava drying plants have been established with farmer associations, the majority of them in conjunction with "Casas de Farinha" (communal processing equipment used for the production of the traditional cassava flour consumed in Brazil). Approximately 200 t of dry cassava were produced during the 1989 dry season (August-November), all of which has been sold to local livestock farmers specializing in milk production. Finance has been obtained for setting up a further 25 drying plants in 1990.

2. Research on Cassava Drying

CIAT-based research in this area seeks to improve the efficiency of the drying of cassava chips through improving the chip geometry and capacity of the existing chipping machines and the development of appropriate artificial drying systems.

a. Improved cassava chipping machine.

The redesigned cassava chipping machine, described in last year's annual report (CIAT Cassava Program Annual Report 1988), which employs the Colombian-model cutting disc with 8 blades of trapezoidal cross section was extensively field tested in 4 of the natural drying plants located on the Atlantic Coast of Colombia (Table 15). The throughput of the chipping machine varied between 8.2 and 12.3 t/h, averaged over 20 batches per plant with batch sizes ranging from 2 to 30 tonnes. This

[1] Instituto Nacional de Investigaciones Agropecuarias.

[2] Fundación para el Desarrollo Agropecuario.

Table 15. Throughput of the Colombian model cassava chipping machine

Batch	COOPROSANTACLARA			COOPROAPAL			COOPROCINESCA			COOINPRO		
	Date	Fresh cassava (kg)	Time (min)	Date	Fresh cassava (kg)	Time (min)	Date	Fresh cassava (kg)	Time (min)	Date	Fresh cassava (kg)	Time (min)
1	11-02-89	3,608	35	20-01-89	18,787	70	01-02-89	2,461	10	03-02-89	4,473	30
2	14-02-89	6,233	35	22-01-89	24,110	140	02-02-89	1,453	10	04-02-89	8,124	50
3	16-02-89	7,636	53	24-01-89	24,923	131	03-02-89	2,511	13	05-02-89	5,923	36
4	19-02-89	5,422	32	27-01-89	29,933	148	04-02-89	5,136	27	08-02-89	5,058	48
5	21-02-89	2,132	14	30-01-89	24,375	135	05-02-89	2,500	10	09-02-89	8,050	53
6	22-02-89	4,463	22	03-02-89	30,375	160	06-02-89	2,580	10	10-02-89	9,027	57
7	24-02-89	7,097	41	07-02-89	21,883	120	07-02-89	9,000	50	11-02-89	9,015	66
8	25-02-89	4,667	31	09-02-89	23,054	90	08-02-89	3,000	15	12-02-89	9,051	57
9	26-02-89	4,624	30	11-02-89	25,683	165	10-02-89	5,000	20	14-02-89	8,314	57
10	02-03-89	12,596	72	14-02-89	27,451	190	11-02-89	7,784	28	15-02-89	9,029	84
11	06-03-89	11,894	73	16-02-89	25,065	155	13-02-89	3,900	30	16-02-89	9,039	67
12	10-03-89	7,800	45	18-02-89	19,416	150	14-02-89	7,883	24	17-02-89	9,740	68
13	12-03-89	7,843	55	22-02-89	18,631	140	15-02-89	5,000	23	18-02-89	9,006	70
14	17-03-89	8,362	70	24-02-89	11,606	75	16-02-89	6,237	30	19-02-89	9,028	59
15	20-03-89	7,928	60	25-02-89	11,351	75	17-02-89	3,969	20	20-02-89	9,442	90
16	23-03-89	6,909	70	26-02-89	12,947	80	19-02-89	6,960	36	22-02-89	9,039	68
17	29-03-89	8,477	50	01-03-89	17,793	105	21-02-89	6,000	30	23-02-89	8,804	60
18	01-04-89	11,550	72	03-03-89	17,548	90	22-02-89	5,900	30	24-02-89	4,000	30
19	03-04-89	9,625	60	04-03-89	7,743	45	24-02-89	6,000	31	25-02-89	9,100	60
20	07-04-89	12,047	90	07-03-89	26,543	130	25-02-89	4,888	32	26-02-89	5,274	45
Total		152,913	1,010		419,217	2,394		98,162	479		158,586	1,155
Throughput (kg/h)		9,084			10,507			12,300			8,220	

magnitude of throughput represents a 2 to 3 fold increase over that reported in the first years of the Colombian drying project (CIAT Cassava Program Annual Report 1982). These improvements in chipping capacity can be attributed to the redesign of the blade configuration and the feed hopper, changes that have not resulted in appreciably greater costs of construction. A revised construction manual has been prepared and is available for distribution (Vasquez F., Cuero J.L. 1987. Manual Actualizado de la Fabricacion de la Maquina Trozadora de Yuca Tipo Thailandia. Centro Internacional de Agricultura Tropical/ Universidad del Valle, Cali, Colombia. 29pp and 13 plans). The initial reaction of the drying plant managers to the improved cutting disc has been favorable as they recognize the advantage of reduced labor costs. Shorter drying times have also been reported as a result of the more uniform chip geometry. It also appears that the bulk density of the dry chips is significantly increased which should in turn reduce transport costs of the product to the feed mills. These aspects are being investigated more fully.

b. Artificial drying.

A through circulation forced air bin drier for cassava chips has been developed at CIAT (CIAT Cassava Program Annual Report 1985,1986). The suitability of this technology for use by farmers' cooperatives and small scale entrepreneurs has yet to be tested at the pilot plant level in a cassava producing region. In Cordoba Department on the Atlantic Coast of Colombia a large percentage of the cassava is harvested during the rainy season which restricts the possibility of natural drying on concrete floors and it is hoped to obtain finance to construct a pilot artificial drying plant in this area during 1990. Further CIAT-based work on artificial drying will depend on the feedback obtained from the operation of the pilot plant.

3. Cassava-based animal feed

The construction of the pilot plant for the experimental production of a cassava based animal feed was completed early in 1989. The plant, which was set up in cooperation with the Betulia Farmers' Cooperative in Sucre Department, incorporates a hammer mill, a vertical feed mixer and equipment for metering and incorporating molasses into the feed ration. The objective of the project is to produce a cassava based feed which is cost and quality competitive with brand concentrates, thereby providing an additional market for dry cassava and stimulating local livestock production.

Three feeding trials have been conducted with broilers, comparing a feed produced by the farmers' cooperative with a commercially available poultry concentrate. The trials were undertaken in collaboration with three small scale poultry producers who provided the poultry houses and took responsibility for the management of the birds. Each producer was provided with an experimental and control batch of 50 birds each. For the period of the trial (seven weeks) a technician from ICA [1] collected information on feed consumption, live weight gain and mortality.

Table 16 shows the composition of the experimental diets for the three trials. The inclusion of cassava meal varied from 30 to 55% depending on the availability and price of the other raw materials. Table 16 also presents the variable cost of production for the three experimental diets and compares this with the price of the commercial ration. The cost/price margin between the two ranged between 9 and 18% in favor of the experimental diet. The results of the three trials, which are presented in Table 17, show that feed consumption and final live weight were less for birds fed on the experimental diet, however there was only a 5% difference in feed conversion. These differences may in part be attributed to the presentation of the diets: the commercial concentrate was in the form of granules (growing) and pellets (finishing) while the experimental diet was fed as meal. Percentage mortality was similar for both diets. Preliminary analysis suggest that the profit per bird was approximately 15% less for the experimental diet. A more complete economic analysis is being undertaken that will take into account the relative availability and cost of the feed ingredients to the farmers' cooperative.

A survey of poultry producers in the immediate vicinity of the pilot plant is being carried out to ascertain the demand for feed. This information will complete the first stage of the project and a decision will then be taken as to whether further biological trials need to be realized.

Table 16. Composition and variable costs of the experimental diets and price of the commercial feed concentrate

Raw material	Trial 1, April/89		Trial 2, June/89		Trial 3, Aug/89	
	Growing	Finishing	Growing	Finishing	Growing	Finishing
Soya bean meal, %	34.50	33.50	43.00	35.10	37.50	33.00
Cottonseed meal, %	6.90	1.60	-	4.00	-	4.00
Meat meal, %	-	-	-	-	5.00	-
Maize meal, %	16.60	26.50	-	-	-	15.00
Cassava meal, %	33.40	29.80	50.50	55.00	53.20	42.30
Animal fat, %	4.60	4.60	2.60	2.40	1.40	2.10
Vitamins/minerals, %	4.00	4.00	3.90	3.50	2.90	3.60
Variable costs, kg	122.40	122.40	132.90	122.90	131.90	127.10
Price of commercial feed concentrate, Col.$/kg	137.50		147.50		155.00	

[1] Instituto Colombiano Agropecuario.

Table 17. Results of the broiler feed trials. Sucre Department, 1989

Farm	Trial	Feed consumption kg Control	Feed consumption kg Exptl.	Live weight kg Control	Live weight kg Exptl.	Feed conversion kg/kg Control	Feed conversion kg/kg Exptl.	Mortality % Control	Mortality % Exptl.
Piedras Blancas	1	3.76	3.86	1.74	1.52	2.10	2.50	4.0	6.0
(Sampuez)	2	4.05	4.10	1.50	1.47	2.70	2.79	14.0	8.0
	3	3.39	2.83	1.98	1.63	1.71	1.74	2.0	4.0
El Beque	1	4.78	4.56	2.13	1.87	2.20	2.40	10.0	2.0
(Sincelejo)	2	4.57	4.57	1.85	1.60	2.47	2.86	8.0	12.0
	3	4.20	3.34	1.90	1.40	2.21	2.38	0.0	17.0
El Mamón	1	4.43	3.72	1.94	1.51	2.20	2.40	12.0	0.0
(Corozal)	2	4.09	3.39	1.80	1.49	2.27	2.28	12.0	6.0
	3	3.75	2.73	2.00	1.78	1.87	1.53	6.0	4.0
Mean		4.10	3.60	1.87	1.59	2.20	2.32	7.6	6.6

D. CASSAVA FLOUR FOR HUMAN CONSUMPTION

1. Background

The second phase of the IDRC financed project to determine the technical and economic conditions required for the development of a rural cassava flour industry in Colombia got under way in May 1989.

The first phase studies of the cassava-wheat flour system (CIAT Cassava Program Annual Report, 1984, 1985, 1986) included cassava production and market surveys on the Atlantic Coast Region of Colombia, on-farm testing of improved cassava production technology, economic studies of the milling and baking industry, the development of a small scale processing plant for the production of high quality cassava flour and laboratory and consumer acceptance trials of composite flour bakery products. The results of this work indicated that, under the prevailing price and cost structures for cassava and wheat in Colombia, it is economically feasible to produce cassava flour at a competitive price compared to wheat flour. It was therefore proposed to enter a second or pilot project phase which is briefly described below.

2. The Pilot Project

The second phase of the project, which will be executed by CIAT, the Universidad del Valle (UNIVALLE) and the Colombian Integrated Rural Development Fund (DRI), seeks to integrate the production, processing and marketing components of the cassava flour system under the real socio-economic conditions of a cassava growing region. The results will be utilized by DRI, if warranted, to promote replication of rural cassava flour processing plants and utilization of the product in the Colombian food industry.

The activities that will be carried out during the second phase in the areas of processing, production and marketing are the following:

a. Processing

The technology developed for the production of dried cassava chips and flour will be implemented and evaluated in a rural pilot plant managed by a farmers' cooperative with initial assistance from CIAT and DRI. The plant site will be selected using appropriate criteria and the plant itself built by a local construction firm.

The operation of the pilot plant will provide reliable data on variable and fixed costs of production and sufficient product for promotion among potential consumers. The principal parameter for measuring the efficiency of the plant will be the conversion factor of fresh cassava to dry cassava chip which should be in the order of 2.75:1. Special attention will be paid to monitoring the microbiological quality of the end product. Modifications to the process will be introduced according to the results obtained during the first year of operation.

The pilot plant will initially produce dry cassava chips that will subsequently be contract milled in a commercial wheat mill located either in Barranquilla or Medellín. An economic and technical evaluation of two small scale milling systems, a hammer mill plus a cylindrical screen and a roller mill with a horizontal vibrating screen, will be undertaken with a view to producing cassava flour at the drying plant. The most suitable milling equipment will be transferred to the pilot plant.

b. Production

An agreement will be entered into with local farmers to supply raw material to the pilot plant using improved low-input technology for cassava production in association with maize and yams. A comparative evaluation of traditional and the improved production systems in terms of yield and production costs will be undertaken to give an indication of farmers' ability to implement the improved production methods. This use of improved technology on a semi-commercial or pre-production scale will also provide the opportunity for demonstration to extensionists and farmers.

c. Marketing

Market research will be conducted at national, regional and local levels to identify potential consumers of cassava flour among food processors. A set of flour-containing food categories with potential for substitution will be selected a priori and the corresponding food processors will be surveyed in two stages. In the first stage, general information on the characteristics of the industries will be obtained (types of products, processes used, volumes and prices of raw materials employed) and a sample of cassava flour will be provided for use in substitution trials. Subsequently, in the second stage, the processors will report on the results obtained, the substitution levels achieved and their buying intention. This research should identify a number of potential clients to whom the production of the pilot plant may be sold. Further, larger scale trials may have to be taken with these clients.

For small to medium scale food processors without the infrastructure to carry out product development, UNIVALLE will be responsible for laboratory studies on product formulations for use in promotional work and for technical assistance to these processors. Initially, studies will concentrate on inclusion of cassava flour in pastas, "manjarblanco" (a milk-based sweet) and "coladas" (beverage type drink).

3. Activities executed in 1989

a. Processing

Pilot plant site selection

The following criteria were used to select an appropriate site for the pilot plant: land availability, potential for increasing cassava yield, availability of cassava roots, potential for harvesting twice per year, service infrastructure, proximity to terminal markets, institutional presence, socioeconomic importance of cassava and current institutional support. Six sites in the Atlantic Coast region were originally proposed but two were discarded early in the decision process. A field questionnaire was designed and implemented to collect data on the remaining four sites: Chinú (Córdoba), San Juan de Betulía (Sucre), Palmar de Varela (Atlántico), and Pivijay (Magdalena), in order to evaluate them according to above criteria. Chinú, which was finally selected as the site for the cassava chip pilot plant, has three farmer cooperatives. COOPROALGA was selected to operate the cassava chip plant.

Pilot plant design

A preliminary draft design of a pilot plant with a capacity of 300 tonnes was made and handed to the architectural firm selected to prepare the final design, consisting of building, hydraulic and electrical plans and a detailed budget. Due to higher than budgeted building and equipment costs amounting to US$ 80.000, the plant was scaled down to

175 tonnes at a cost of US$ 55.000 and provisions were taken for future increases in plant capacity. Price quotations were requested and received from three local construction firms. Construction in Chinu is expected to start in November 1989.

Improvement of processing equipment

The experimental plant for producing cassava flour (CIAT Cassava Program Annual Report 1986) has been in continual operation during the year and a number of modifications have been introduced in the equipment to improve functionability and process efficiency.

The unit containing the selection table, root washer and chipping machine has been modified to improve its reliability and security. These changes included the following:

The electrical controls have been placed in a readily accessible and convenient position for operators.

The area of the selection table has been increased and the method of feeding roots to the washer changed: instead of using a shovel, selected roots are placed in sacks that hang from hooks and then deposited inside the drum.

Root washer

- the cylindrical steel drum's size has been augmented to raise root-holding capacity from 80 to 150 kgs and its weight has been reduced from 108 to 92 kgs.
- the friction-based power transmission to the root washer was changed to a positive sprocket and chain transmission which required the installation of a universal joint to absorb axial and radial drum movements.
- the opening and closing mechanism for the drum's hatch has been improved.
- a blocking mechanism has been installed to protect workers when opening the hatch.
- the area of the mesh receiving waste material has been increased and its design simplified in order to facilitate removal of waste material.
- the water spray in the mounting axle was modified to improve water distribution inside the drum.
- the size of the tilted hopper was increased and its form changed to facilitate and speed up the unloading of washed roots.

Coupling of washing and chipping machines

- pulleys and belts have been located in well protected areas to avoid accidents.
- a drive shaft transmits power to both the chipping machine and the root washer. The 3.6 hp motor is located in the chipping machine housing.

- a belt tensor makes it possible to operate the chipping machine independently from the root washer.

<u>Chipping machine</u>

- the height of the structure has been increased by 10 cms.
- the materials of the blades in the cutting disc and in the feed hopper have been changed to stainless steel
- the trolley's capacity and maneuverability have been enhanced

Drying trials

Certain cassava varieties are giving unacceptably high levels of HCN in the dried product (greater than 100 ppm) and preliminary drying trials are being conducted to assess the effect of three drying temperatures on cyanide elimination in cassava chips. Chips are being dried in an electrical oven.

Premilling trials

A premilling machine is being operated in an animal-feed plant managed by a farmer cooperative in Betulia, Sucre. Its performance is satisfactory, but the discharge hopper's round aperture will be increased. Machine plans are also being revised.

Comparison of two methods for measuring cassava chip moisture

IDEMA, the Colombian government agricultural marketing agency, is interested in purchasing cassava chips. Since chip moisture is a basic quality factor, IDEMA has to calibrate its moisture-measuring instrument to determine actual chip humidity levels. This calibration requires knowledge on the correlation between moisture measurements at IDEMA and those obtained by the freeze-drying method, the standard proposed by CIAT (CIAT Cassava Program Annual report 1988). Both institutions are conducting trials for this purpose.

Analysis of cassava chip plant operations

Processing operations were analyzed and organized to determine minimum time and labor requirements. The operations considered included root selection, washing, chipping, artificial drying, premilling and packing.

It was concluded that a minimum of four workers are required per plant. Special formats were designed to gather key data on labor and time resources required in processing operations.

b. Production

Twenty three hectares of cassava in association with maize and or yams in 41 farmer-managed preproduction plots with areas ranging from 1.250 m2 to one hectare were established during April-May using improved technology. Thirty two percent of these plots are planted in the cassava-maize-yam association. Most of the cassava production will be purchased by the pilot plant at market prices. These plots will be used to determine and demonstrate actual yield and economic advantages of the improved technology. The agronomic practices applied include mechanical soil preparation, stake selection and chemical treatment, pre-emergence weed control, fertilization (for yam), pest and disease control when appropriate and plant density. Varieties planted are V 156 and V 109 (maize), Criollo pelado (yam), and Venezolana and P 12 (cassava).

A smaller number of hectares will be planted in September and October to ensure availability of roots during the June-September processing period.

c. Marketing

Market research

A three-stage market research plan was developed which is to be implemented at three geographic levels in Colombia: locally (Chinu's area of influence), regionally (Atlantic Coast), and nationally (main cities). In the first stage, addresses of manufacturers of key preselected flour-containing food categories are obtained. Manufacturers are surveyed in stage 2 and a cassava flour sample is distributed for use in substitution trials. In stage 3, results of substitution trials are obtained and a buying intention for cassava flour is requested. The main output of this research is a list of food categories where there is potential of substituting wheat, rice and maize flours with cassava flour due to the latter's cost advantage or characteristics.

This three stage plan was first implemented in the Cali area, where fifty five large, medium and small manufacturers were contacted. The study ended in September. Preliminary results indicate that the following food categories offer potential for partial or total substitution of other flours: processed meats, sweet cookies, cakes, breadings, porridge mixes, low-cost soup pasta, spices, ice-cream cones and milk-based sweets. In addition, the following traditional products produced on a small scale exhibited potential: meat pies (empanadas), "tamales", cassava bread (pandebono and pandeyuca), and fried maize buns (buñuelos), Table 18.

Market research started nationally in August. Surveyed areas include Bogotá, Medellín, Barranquilla, Cartagena, Montería, Santa Marta, Sincelejo, and the four towns in Chinu's area of influence. More than 200 food processors have been interviewed and supplied with cassava flour samples and a promotional pamphlet on cassava flour.

TABLE 18. Food categories in which food processors in Valle del Cauca, Pereira and Popayán expressed positive buying intention after conducting substitution trials with cassava flour.

Category	Raw materials substituted	Substitution level, %	Sample monthly demand, t	Advantage of cassava flour
Sweet cookies	-wheat flour	10	50	More crispness
Processed meats	-wheat flour -sour cassava starch	100	17	Better water absorption
Porridge and soup mixes (includes Bienestarina, Cartago)	-wheat flour -rice flour -corn flour -plantain flour	10-40	62	Higher yield
Breadmaking	-wheat flour -sour cassava starch	3-20	21	Lower cost Better taste
Spices	-rice flour -corn flour	50-100	22	Lower cost
Milk- and fruit-based sweets	-rice flour -corn starch	50-100	4	More shine and taste
Low-cost soup pasta	-rice flour -corn flour	20-35	8	Lower cost
Ice-cream cones	-sweet cassava starch	100	2,5	More rigid
Meat breading	-wheat flour	15-30	3	More crispness
Traditional products (includes cassava dumplings, "tamales", meat pies, etc.)	-cassava -corn starch -precooked corn flour -plantain flour	30-50	1	More crispness

* Sample monthly demand refers to the sum of cassava flour volumes that could be purchased by companies included in the sample and expressing a positive buying intention. Since many more companies within each category were not interviewed, it does not reflect total demand for each category.

Three wheat mills were contacted in Barranquilla in order to mill cassava chips produced in the pilot plant at Chinú. The project is awaiting response from one, Generoso Mancini, which expressed interest in this activity.

Cassava flour price determination

A deflated model was developed to determine the profitability of a cassava chip pilot plant based in Chinú. The model assumes subcontracting of the milling operation with a wheat mill in Barranquilla. Assuming an annual plant capacity of 300 tons, the plant can sell the ton of cassava flour for Col$117,973 or US$284 to generate an internal rate of return (IRR) of 8%. With a plant capacity of 175 tons per annum, the price per ton of cassava flour would have to be increased to Col$127,315 or US$307 to obtain an identical IRR. Both prices are competitive versus wheat, maize and rice flour (Table 19).

TABLE 19. Price comparison between cassava flour and alternate raw materials

Raw material	Price per kg [1]	Ratio [2] Cassava flour price/ Traditional flour price
Wheat flour	178	0.70
Sour cassava starch	351	0.36
Sweet cassava starch	290	0.43
Corn starch	323	0.39
Rice flour	150	0.83
Yellow corn flour	145	0.86
White corn flour	200	0.63
Precooked corn flour	240	0.52
Plantain flour	150	0.83

(1) US$1 = Col$417, November 1989.

(2) Assuming a cassava flour price of Col$ 125 produced on the Atlantic Coast of Colombia.

E. PRODUCTION AND UTILIZATION OF CASSAVA STARCH

1. General Context

Starch is, after cellulose, the main sugar containing material synthesized by higher plants from solar energy. It is a natural source of energy, especially for human consumption. For many centuries, man has extracted starch from cereals, roots or tubers and through fermentation, prepared many staple foods like bread, beer etc.. With the development of science and technology, starch has now become a raw material for many industrial uses. Indeed, the functional properties of both native starches and starches which have been modified by chemical or enzymatical treatment to improve their rheological properties find many applications in food processing and other industries such as those for the manufacture of textiles, gums, adhesives, paper, drilling mud... In addition, starch, being a polymer of D-Glucose, is a raw material of outstanding importance for the production of many derived products by chemical, enzymatic or biotechnological treatments, for example:

- products of hydrolysis (maltodextrins, glucose, maltose syrups, cyclodextrins...)
- products of isomerization (fructose syrups, maltulose, isoglucose...)
- products of hydrogeneration (maltitol, mannitol, sorbitol...)
- products of fermentation (Ascorbic acid, furfural...)

Each of these product has specific functional, technological and nutritional properties which give them specific uses in the different areas of the food, chemical or pharmaceutical industries.

World starch production is about 20 x 10^6 t/y extracted mainly from corn (13 x 10^6 t), potato (4 x 10^6 t) and wheat (1 x 10^6 t). The starch extraction and utilization industry consists of few large scale, high technology firms using patented processes.

Among starchy plants, cassava is one of the best sources of starch because the starch content on a dry matter basis is about 85%. Nevertheless, cassava starch represents only a small fraction of the starch industry. Annual production of cassava starch for industrial uses is about 0.8 x 10^6 t, mainly in Brazil (for the national market) and Thailand (for export to Japan or EEC). Various reasons exist for this:

- Cassava is a staple food plant in tropical countries and more than 80% of the production estimated at 140 millions of tons a year is for human consumption,

- Little or no research has been undertaken on the characterization of cassava starch, its specific functional properties, its potential uses, or the potential for modification of the amylose or amylopectin contents.

- There is an absence of an efficient technology for the small scale extraction of cassava starch that is adapted to the production and to the post-harvest characteristics of the crop.

Nevertheless, small scale cassava starch industries do exist in some tropical countries where the product has specific uses in traditional food industries, typically, for the production of "sour starch" as in Brazil and Colombia. Sour starch is a fermented starch, whose specific functional properties are irreplaceable for the manufacture of traditional breads with cheese ("pandebono", "pan de yuca", "biscoito", "pao de queijo"...). With this specific market niche, these small scale starch industries have maintained their position alongside the often complementary large scale starch industries.

2. Collaborative Project CIAT-CEEMAT/CIRAD [1]

The fermented starch industry presents some characteristics which make it especially suitable for research and development.

- It is essentially a small scale, traditional activity (e.g. small plants called "rallanderias"), but with a real socio-economic importance to the local economy. The promotion of a small scale food industry in rural areas like this must allow the stabilization of populations by creating employment and generating resources, adding value to local production and traditional technologies.

- Sour starch is the basic ingredient of many traditional products rooted in local food customs. Working with sour starch also provides the opportunity for development of new products making use of its specific properties.

- Sour starch is a raw material for secondary transformation industries at a different scale (small bakeries or large companies), and also a product which may be packaged for selling to groceries or supermarkets. The starch production and marketing system is the perfect example of a "food chain", with many economic participants (farmers, starch producers, intermediaries, trade cooperatives, processing industries, retailers, consumers...).

- There is a strong demand for sour starch in the market, which is apparently not satisfied. As regards native starch, (called "sweet starch") for industrial use in the substitution of corn starch, there is an interesting possibility for market diversification.

- The basic biochemical phenomena involved in the extraction and fermentation processes are unknown, but involve the modification of starch granules. This is an excellent opportunity for basic research to increase our understanding of cassava starch that is directly applicable to process and product improvement.

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[1] CEEMAT (Centre d'Etudes et d'Expérimentation du Machinisme Agricole Tropical) is the department especialized in food technology of CIRAD (Département du Centre de Coopération Internationale en Recherche Agronomique pour le Développement), Montpellier, France.

This is the background therefore behind the initiation of a new program in 1989 on "Production and utilization of cassava starch" as part of the agreement between CIAT and CIRAD/CEEMAT.

For defining research priorities compatible with local needs, the following methodology has been used:

- Analysis and diagnosis of the traditional process technology.
- Inventory of the existing technological solutions and a study of the possibility of transfer or improvement of these technologies.
- Organization of workshops on this theme, with the participation of researchers, producers, users, etc.
- Definition of research themes and constitution of multidisciplinary teams.

3. Preliminary work

The main conclusions of the technological diagnosis of the traditional process (see Figure No.1) in Colombia are the following:

- A technology with some degree of mechanization but with very low efficiency (see Figures Nos.2 and 3) of the process, with starch losses of about 25%,
- The absence of unbiased widely accepted parameters for quality evaluation of sour starch,
- A great variation in product quality, which penalizes the users of the second transformation (e.g. bakeries) and reduces potential demand,
- A lack of knowledge of the effect of raw material quality on starch quality and on extraction yields,
- Poor microbiological and physico-chemical quality of the extraction water, which negatively affects starch quality,
- Environmental polution by waste water contaminated with organic matter (starch) and cyanide.

A first workshop was organized in Santa Catarina, Brazil (3-7 July) with the participation of 25 representatives from Argentina, Brazil, Colombia, Ecuador, Bolivia and Paraguay. Some CIAT coordinated interinstitutional actions were agreed upon:

- Technical assistance to Paraguay and Ecuador to undertake a technological diagnosis of the starch extraction plants.

Table 20. Priority areas for research on cassava starch, collaborating institutions and objectives

Theme	Partners	Product
Standardization of analytical assays - Physico-chemical parameters for starch characterization - Inventory and evaluation of the different methods - Setting up of assays adapted for cassava starch	CIAT, ONDRI IIT, CIRAD INRA-Nantes UNESP Botucatu	Publication of a technical report
Characterization of cassava sour starch - Definition of quality criteria for sour starch - Evaluation of expansion power - Correlations with physico-chemical parameters	CIAT, CIRAD UNIVALLE, IIT, UNESP Botucatu	Quality standards for the evaluation of sour starch
Influences of raw material - Characterization of native starch - Study of extraction yields - Evaluation of starch quality	CIAT, INRA, Nantes UNESP	Technical suitability of different cassava varieties
Effect of technical parameters on process efficiency - Extraction and sedimentation - Drying - Storage conditions	CIAT SEDECOM UNESP	Recommendations on the process management
Study of fermentation - Identification of micro-organisms involved in the process - Influence of fermentation on the modification of starch granules - Study of the enzymatic systems involved	UNIVALLE IIT	Understanding of the basic mechanisms
Equipment technology - Improvements of existing equipment - Design and construction of new equipment - Process Engineering	CIAT, CIRAD UNIVALLE SEDECOM Un. Autonoma	Establishment of an experimental plant in CIAT and a pilot plant in Cauca

- Constitution of an informal network to promote information exchange.

A second workshop was organized in CIAT on the 27th and 28th of September with some 50 persons coming from research, production, utilization, commercialization and industry in Colombia.

The interest of all partners in the research was very great indeed, and the following priorities were established: Technical suitability of the raw material; industrial use and quality of sweet starch; sour starch quality; equipment and process improvement, water treatment. Working groups were set up in each of these areas.

4. Work in progress

The preliminary studies so far completed have allowed the definition of several research programs on the themes identified in the two workshops. A network of collaborative research institutions has been established to carry out these priorities. Table 20 presents the different areas of research with the partners concerned and the objectives for each area.

Two research areas of critical importance for the project, and which are no yet in place are:

a) On agronomic aspects (varieties, farming system, productivity...) to determine effect of raw material characteristics on product properties.

b) On economic aspects (market studies on sour and sweet starch) to identify market channels, cost structures and demand for starch.

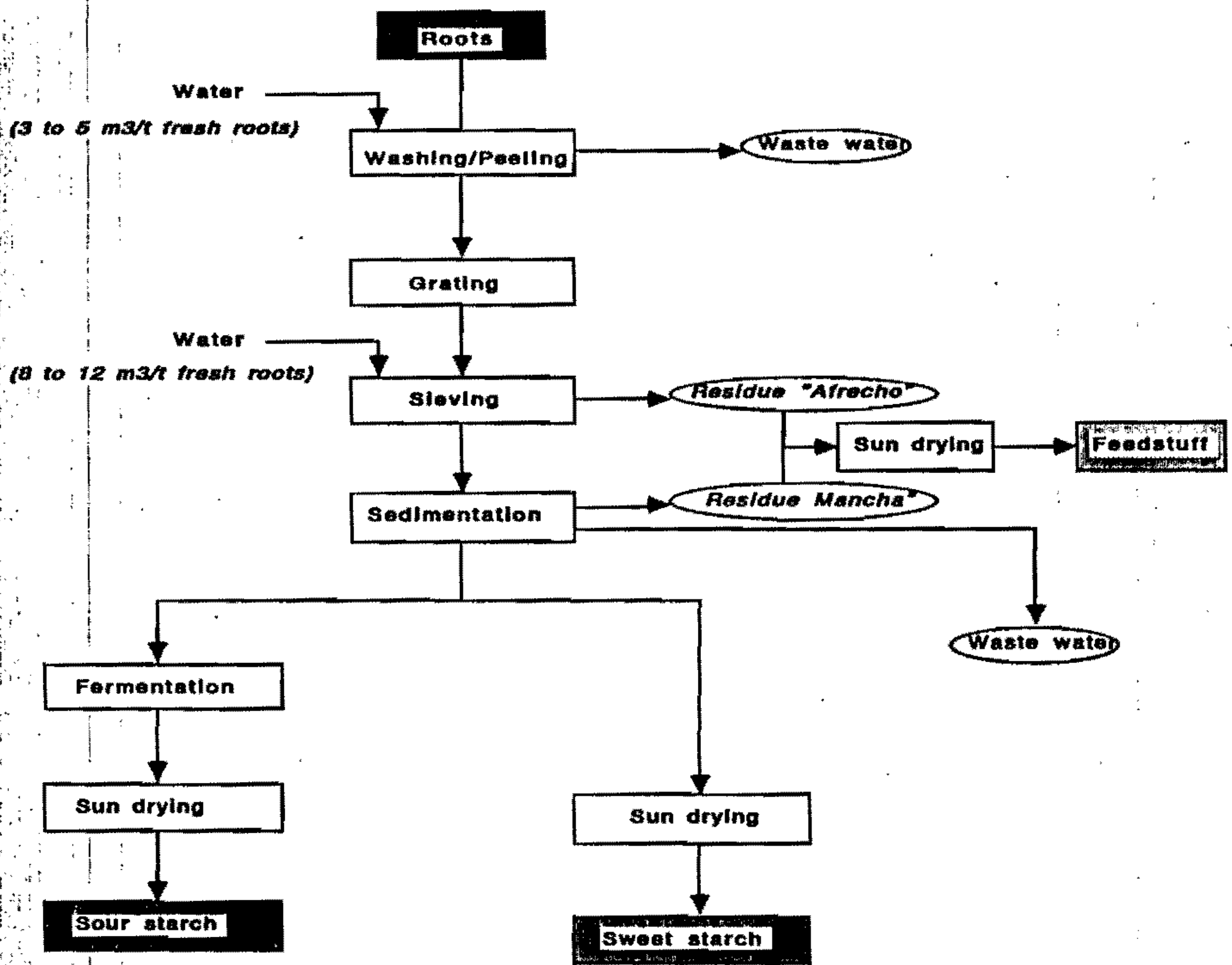

Figure n° 1 : Flow -sheet for the traditional starch extraction process

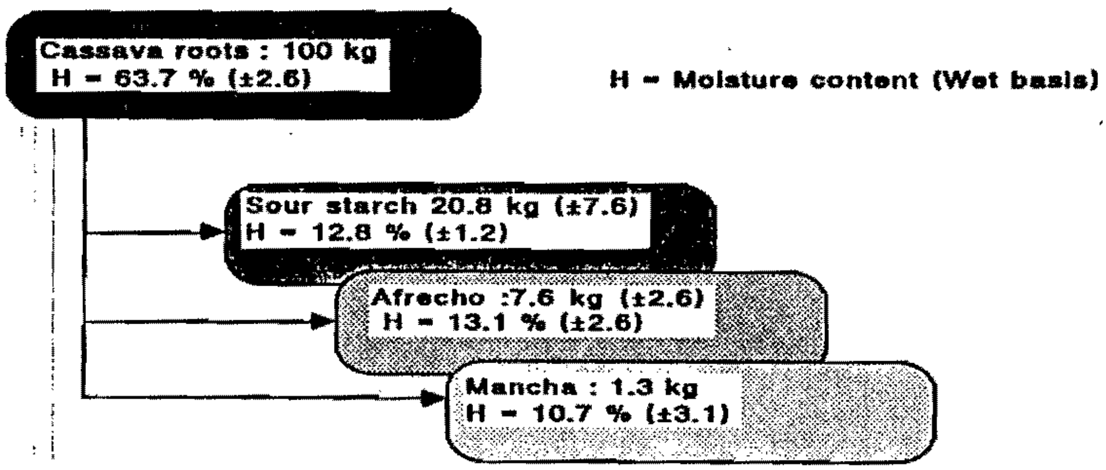

Figure n° 2 : Mass balance of the traditional process (wet basis) : means (±s.d.) for 15 "rallanderias"

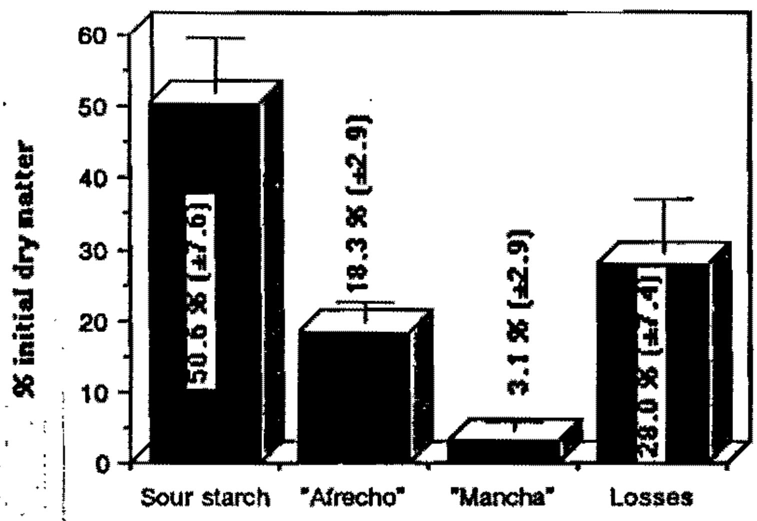

Figure n° 3 : Mass balance of the traditional process (dry basis) : means (±s.d.) for 15 "rallanderias"

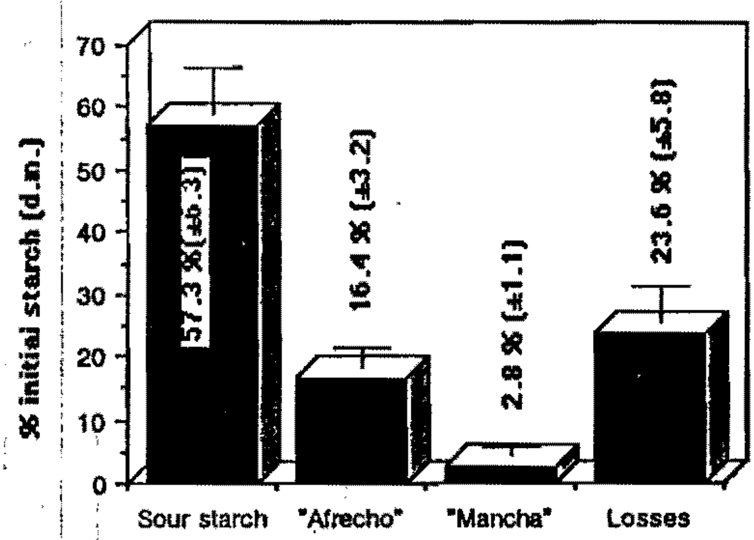

Figure n° 3 : Starch mass balance of the traditional process : means (±s.d.) for 15 "rallanderias"