The Relevance of CIAT's Cassava Researches in the Asian and Pacific Region[1]

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The potentialities of cassava to produce abundant carbohydrates per hectare at minimum inputs are well documented. It is a crop that has the ability to adapt itself to diverse climatic and cultural conditions and can survive long periods of (4-6 months) drought. While it constitutes one of the worlds' staple food crop, it is exclusively a tropical crop and is mostly grown on small farms. It generally requires less labor, less cost of production and less care in management than the cereal crops.

The most important use of cassava is as human food. It is eaten extensively in those countries in which it is produced. The exception perhaps is Thailand, which exports most of its production to Europe for the animal feed market. Cassava is the major source of calories for people in certain West and Central African countries, and in localized areas of Brazil, India and Indonesia, up to 80 percent of the calorie intake is derived from this crop (Nestel and Cock, 1976). Current FAO estimates indicate that more than 50 percent of the annual

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global production of about 105 million tons are consumed by humans. Phillips (1974) has projected that by 1980 consumption will rise to about 71 million tons. Aside from its use as food, cassava of late has stirred unusual interest in international trade because of its considerable potential as a source of animal feed and more interestingly its use for the industrial production of starch and alcohol.

Evidence indicates that cassava must have originated and was first cultivated in the Western Hemisphere several thousand years ago. However, it was only about 300 years ago that it was introduced to Africa, and more recently, into Asia. Today, it is produced in about 90 countries. However, 80 percent of the world's production comes from only 10 countries (six from Africa, three from Asia and one from South America) and nearly 60 percent from only four (Table 1). The six leading producers are Brazil, Indonesia, Nigeria, Zaire, Thailand and India, whose combined population is approximately 25 percent of the world (World Almanac, 1977).

The fact that cassava is now grown throughout many densely populated tropical countries and that annual world production currently exceeds 105 million tons of raw roots, underscores the agricultural significance of the crop in winning the war against the food-population imbalance. In spite of this, the research expenditure, effort and attention it has received from highly qualified scientists and national agencies had been very modest. It has been estimated that in 1970 the total amount spent annually for cassava research from all sources was less than $200,000 (Canadian). Even the 1975 figure

Table 1. World production of cassava in 1975.

Country	Area 1000 ha.	Production million tons	Production % of total	Yield t/ha.
Brazil	2147	27.2	26.0	12.7
Indonesia	1500	12.9	12.3	8.6
Nigeria	1000	10.0	9.5	10.0
Zaire	1050	9.2	8.8	8.7
Thailand	429	6.4	6.2	14.8
India	384	6.3	6.0	16.5
Burundi	185	4.1	3.9	22.2
Tanzania	746	3.6	3.4	4.8
Mozambique	450	2.3	2.2	8.4
Ghana	200	1.8	1.7	9.0
Angola	120	1.6	1.5	13.3
Modagascar	224	1.4	1.3	6.3
Colombia	165	1.3	1.2	8.0
Paraguay	80	1.1	1.0	14.3
Sudan	234	1.1	1.0	4.8
Central African Republic	210	1.1	1.0	5.2
Uganda	340	1.0	0.9	2.9
12 Countries producing more than 0.4 million		7.6	7.2	
61 Countries producing less than 0.4 million		5.2	4.9	
TOTAL		105.2	100.0	

Source: FAO Production Yearbook, 1975.

(in excess of $3 million Canadian) is still comparatively small in relation to the total value of the crop and especially if compared with the research expenditures for some other crops e.g. rubber, tea, etc. The special effort therefore of the Canadian International Development Agency (CIDA) through the International Development Research Center (IDRC) in supporting cassava research and programs in developing countries deserves commendation.

Currently, two international centers are working on regional or global problems related to cassava — in addition to their supporting the efforts of national agencies in developing or strengthening local cassava programs: the International Institute of Tropical Agriculture (IITA) in Nigeria, Africa; and the International Center for Tropical Agriculture (CIAT) in Colombia, South America. The program in Africa involves research with other root crops. The work on cassava is primarily oriented towards the production of materials resistant to african mosaic disease, the most important cassava disease which causes yield losses of up to 80 percent. At CIAT, the multidisciplinary Root Crop Program involves over 20 scientists working full-time on cassava. CIAT is emphasizing cassava in its program not only because of its importance as a food crop in Latin America, but also because it is the original home of the plant, and the continent possess the widest range of germplasm in the world. The basic objectives of the Program at CIAT are four-fold:

First — To collect technical information and develop the technology required to obtain a high production of carbohydrates per hectare with minimum inputs in regions where cassava is presently cultivated.

Second — To develop production technology of cassava in regions of acid, infertile soils since there are more than 300 million hectares in the Latin American tropics and Asia with these characteristics. Since cassava adapts well to these conditions it is possible to use such lands, which are currently unproductive, for the production of large quantities of carbohydrates, to help alleviate the problems of hunger in the Third World.

Third — To provide information on the research and new technologies developed, to the national research agencies of the producer countries so that they can increase production, and potential producers to initiate their own programs; and

Fourth — To use training and personal contacts to help establish and improve systems of production in countries interested in initiating or increasing their cassava production.

Given the above objectives, let us now examine the more outstanding results of CIAT's researches and see how much of it can be transferred or used under our conditions in Asia and the Pacific specifically on: physiology; varietal improvement; pest and disease control; and cultural practices.

As was indicated initially, the first objective has been to collect technical information and to develop the technology necessary to increase the cassava production. As a consequence, a Cassava Information Center was created, charged with compiling all the existing information in the world on this crop, and to place it at the disposition of the users through: summaries of articles or abstracts, photocopies and specialized monographs. Presently three volumes of summaries have been published containing a total of more than 4,000 documents. Copies of these 'Abstracts on Cassava' are available and can be requested through the Information Center. Of more recent activity, is the Programs' undertaking in reviewing and translating into English, indigenous scientific literature on cassava in such countries as Thailand and Indonesia. These 'Reviews' will form part of a growing reference collection on cassava for use by interested cassava scientists, workers and researchers all over the world.

At the same time, a fundamental basis of the cassava program is the accumulation of genetic material, which was begun in 1969, inorder to collect and evalute different cassava cultivars under field conditions. The CIAT experimental station has since organized the largest germplasm bank for cassava in the world. It now contains some 2,500 entries encompassing the greatest genetic and morphological variability available up to the present. It is from this germplasm bank where CIAT develops new hybrids for field testing at different agro-climatic conditions, realizing full well that one of the least expensive input and one which serve as the basis of the technology being developed for the low income farmers, is the use of improved varieties. As with the Documentation Center, the CIAT's Cassava Gene Bank is at the service of cassava breeders throughout the world.

Physiology: Plant type

The production of any crop depends on the total dry matter production and the proportion of that dry matter deposited in the useful parts of the plant. An efficient plant is one that has a correct balance between the source of production — the leaves, and the product sought — in the case of cassava, the roots. Crop growth rate (CGR) in most crops increases as leaf area index (LAI) increases up to a certain level, above this level CGR may stay constant or decline. In the case of cassava, studies at CIAT by the cassava physiologist have shown that CGR increased with LAI to about 110 g m^{-2} wk^{-1} at LAI 4; above this level it declined rapidly (Figure 1). Root growth rate showed a marked decline from 45 g m^{-2} wk^{-1} at a LAI of 3 to 3.5 to less than 20 g m^{-2} wk^{-1} at a LAI of 4.2 (Figure 2). These data confirm the hypothesis that the optimum LAI for root growth in cassava is 3 to 3.5 during the bulking period.

The identification of an optimum leaf area index for root yield (CIAT, 1975) maybe the most signficant contribution of cassava production physiology to the breeders' work up to the present. The optimum LAI found that exists between 3 and 3.5 stays phenotypically constant over a wide range of temperature variation, although the genotype which attains the optimum LAI may be different under

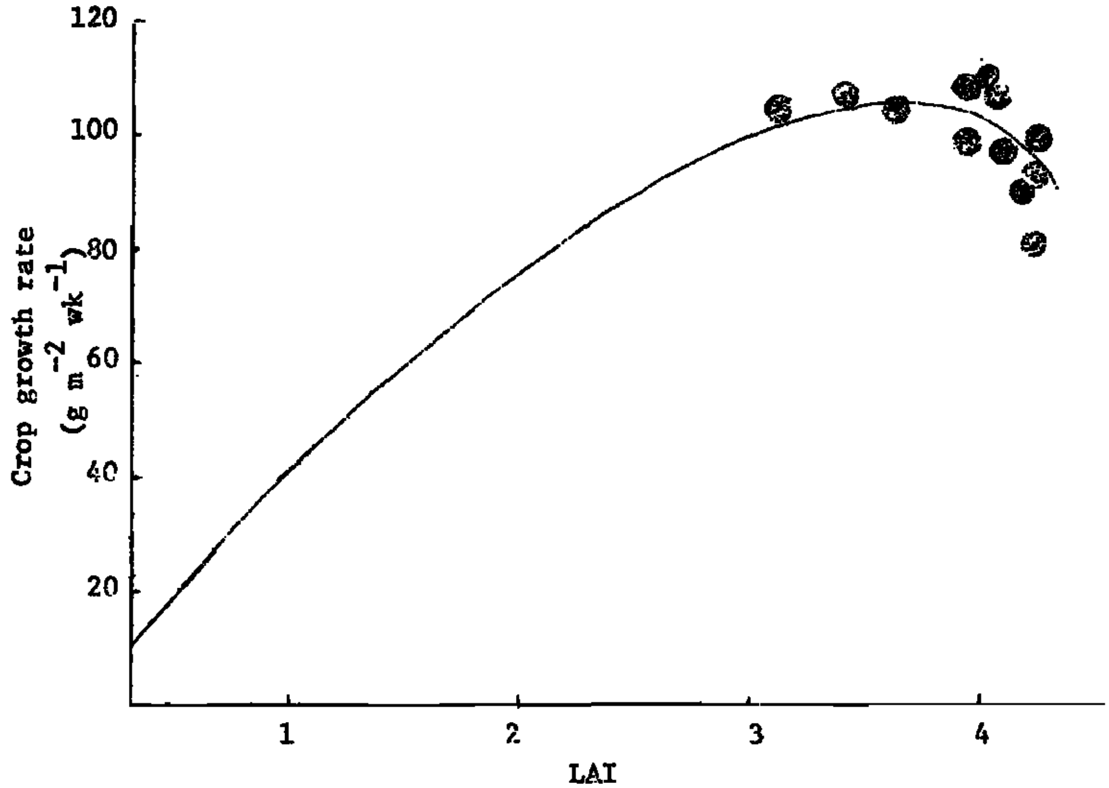

Figure 1. Crop growth rate of M Col 113 as a function of LAI.

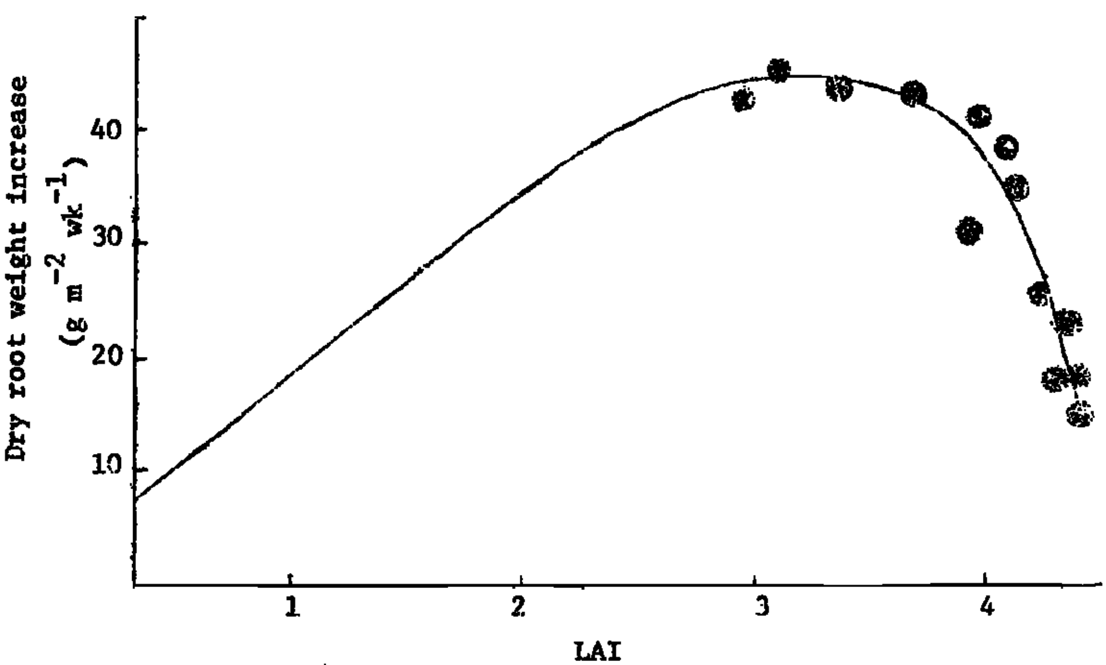

Figure 2. Root weight increase as a function of LAI in M Col 113.

different temperatures (CIAT, 1976; Kawano, 1977). This important piece of work leads to a conclusion that to obtain the highest yield, a cassava population must reach the optimum LAI as soon as possible and maintain it as near as possible until harvest time. Analysis of the components of leaf area suggests that long leaf life and late branching are the most important among others (CIAT, 1975; 1976).

Varietal Improvement

Since the beginning of the cassava breeding program, there have been numerous requests for genetic materials from many parts of the world. A total of 21,270 hybrid seeds and 50,100 open-pollinated seeds have been distributed to 28 countries (Table 2), excluding the seed materials sent through 25 participants who completed an intensive production training program last February 14, 1978.

The productivity of existing cassava germplasm is generally far below the potential of the species because limited attention has been given to the genetic improvement of the species. However, after several years of work, at CIAT it can be safely predicted that attaining the maximum level of productivity is easily within reach. To date, the CIAT cassava breeding program has hybrid selection which can outyield local cultivars by 50 to 150 percent under a wide range of environmental conditions (CIAT, 1975; 1976). Some of the superior materials can be recommended as cultivars and distributed to national cassava programs in the tropics in the near future.

Table 2. Summary of the distribution of cassava genetic materials, 1973-76.

Country	Hybrids	Open-pollinated seeds	Stakes
Brazil	4,400	2,000	20
Mexico	200		160
Venezuela			200 (Entomology)
Ecuador			20 (Agronomy)
Nicaragua			6
Dominican Republic			6
Trinidad	600		6
Jamaica			6
Bahamas			6
India	1,300		
Thailand	3,900	4,500	
Malaysia	900		
Philippines	1,450		12
Indonesia	900		
Taiwan	1,200		6
Japan	2,000		12
Australia	900		50
New Zealand	300		
IITA (Nigeria)	1,550	41,500	
Kenya	400		6
Tanzania	1,000		
Tonga	350		
Samoa	350		
Seychelles	250		6
Hawaii			6
United States		1,000	
Canada		100	
United Kingdom		1,000	
TOTAL	21,750	50,100	528

Source: Cassava Production Systems Program, CIAT, 1976.

Perhaps of particular interest to cassava breeders and workers was the work at CIAT showing that harvest index can be employed in selection as a key factor for maintaining a high efficiency of genetic work, thereby shortening the time whereby new hybrids can be evaluated and selected for regional trials.

At CIAT, studies on the relationships between single row and population trials have shown that there is no correlation between root yield data obtained in single-row trials and those obtained in population trials, Figure 3. Since the valid yield data should come from replicated population trials, the root yield data obtained in single-row trials have virtually no meaning. However, harvest index data obtained in single-row trials are highly correlated with those in population trials, Figure 4. In population trials, harvest index is highly correlated with the root yield, Figure 5. As a consequence, in the single-row trials harvest index is a better indicator of true yielding ability than the yield itself. This occurs as a result of competition between genotypes. Genotypes with high vegetative vigor and low harvest index can occupy a larger space resulting in higher root yield in seedling in single-row trials. However, when these types are planted in populations, they do not yield well.

Harvest index is an indicator of the balance between leaf and stem growth and root growth. There exists an enormous genetic variation in this character and it is highly heritable (Kawano, 1977). Thus harvest index is a highly effective character for use as an indicator for the selection of cross parents, seedling selections and single-row

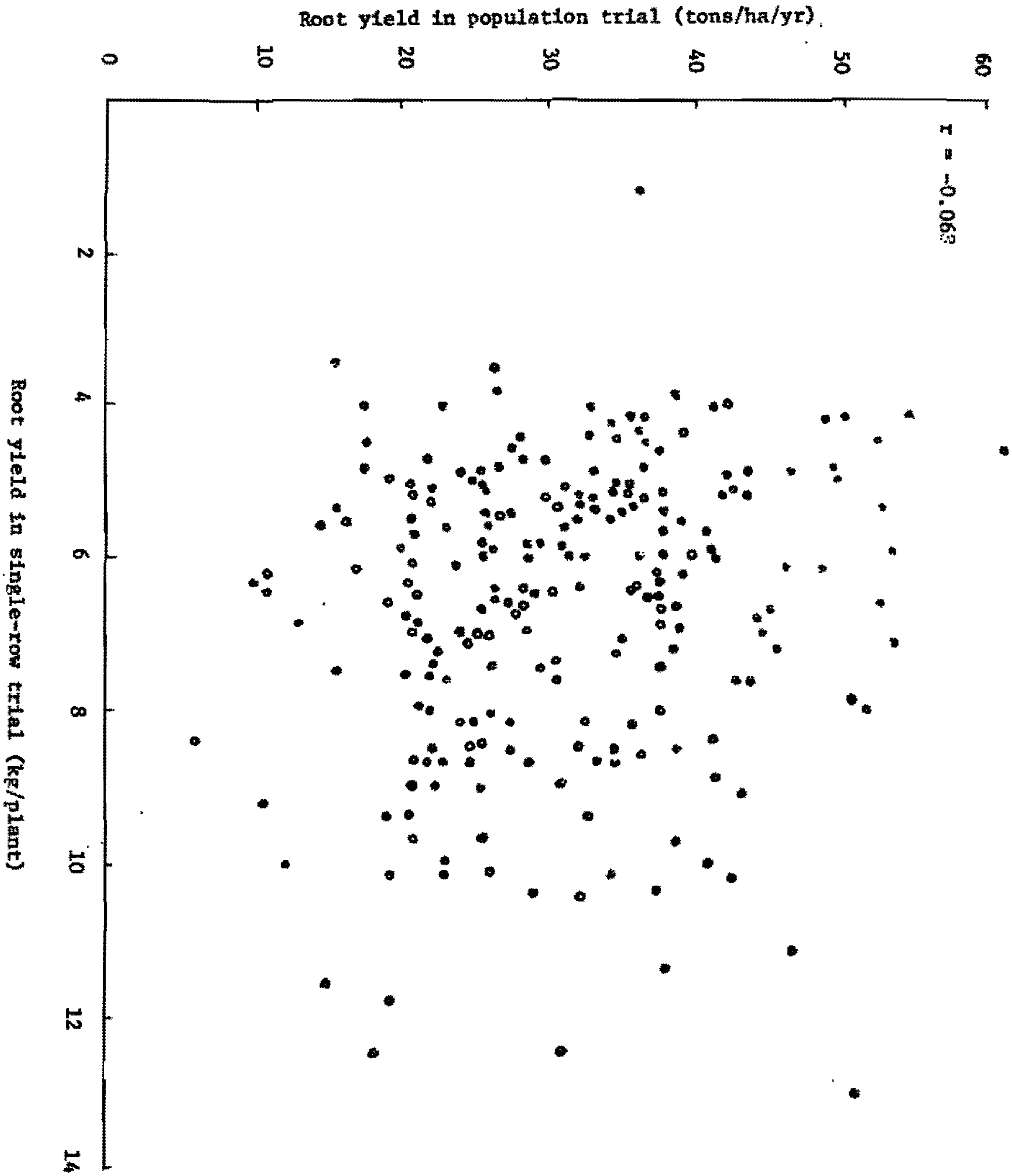

Figure 3. Relationship between root yield data weight in fresh weight in single-row trial and that in population trial at CIAT.

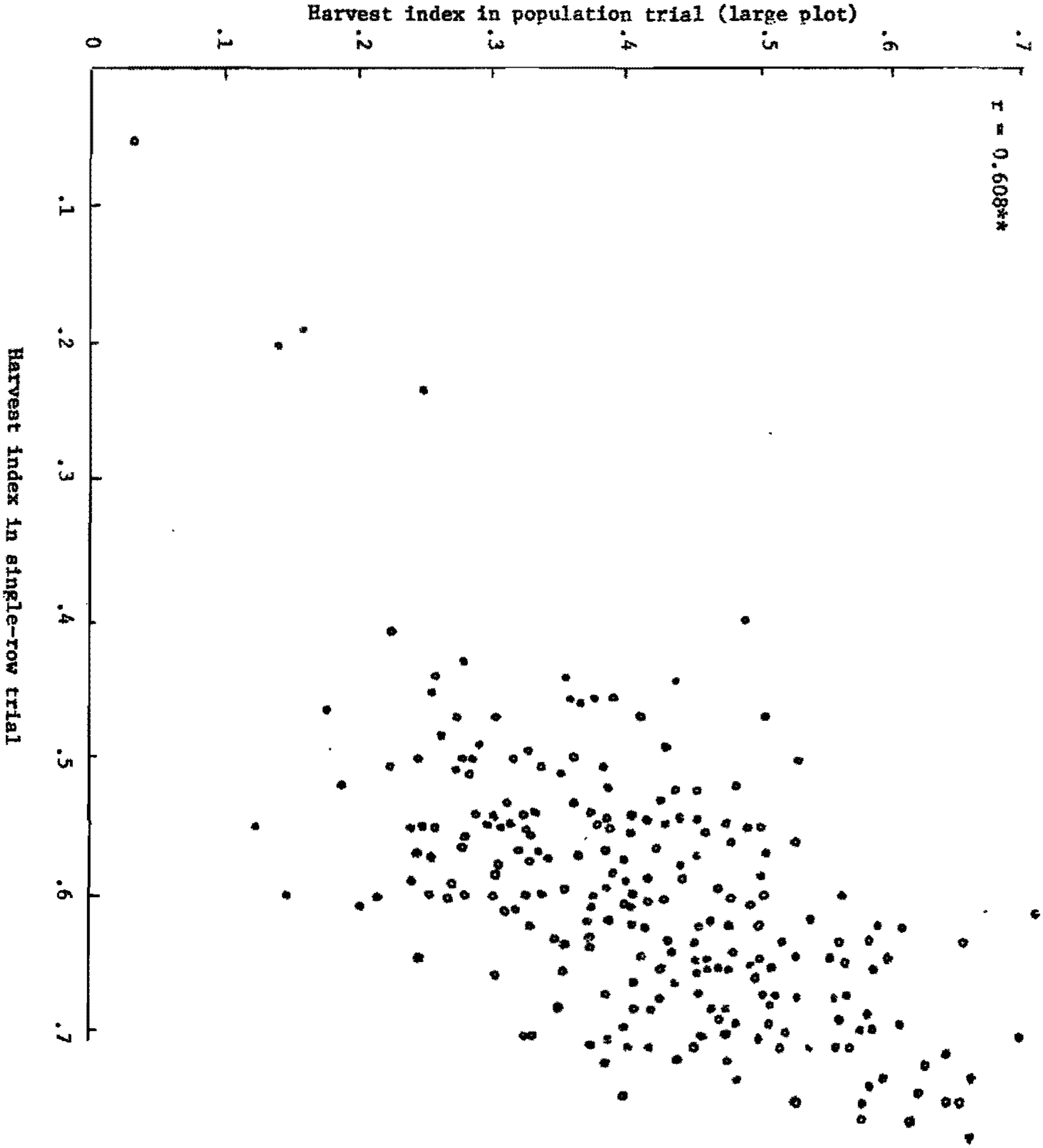

Figure 4. Relationship between harvest indices in single-row trial and population trial at CIAT.

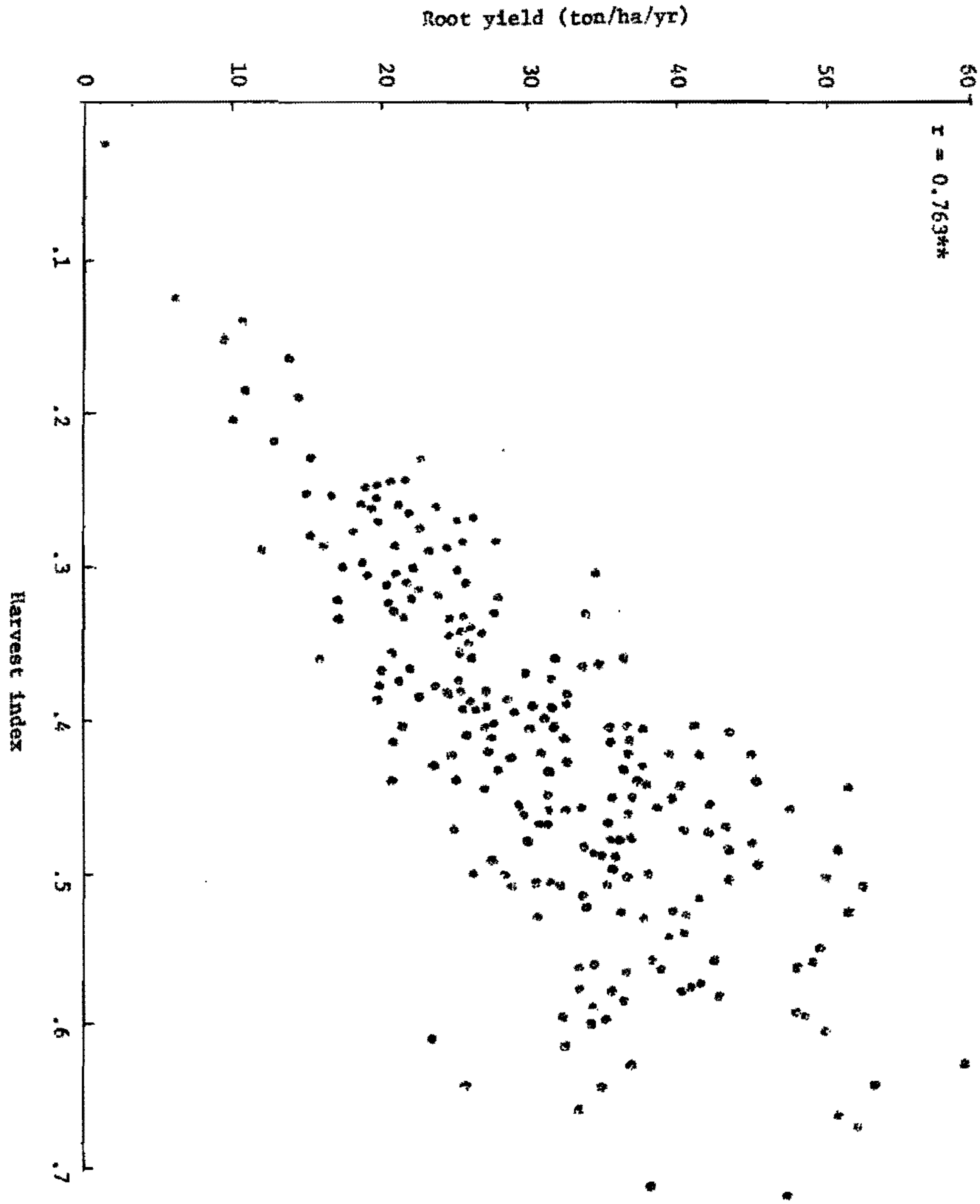

Figure 5. Relationship betwen harvest index and root yield (fresh weight) in population trial at CIAT.

trials. At CIAT materials which have a harvest index lower than 0.60 and 0.55 in seedling and single-row trials, respectively are already eliminated.

Pest and Disease Control

Until recently cassava was thought to be resistant to diseases and pests. However to date, cassava has been shown to be affected by more than 25 pathogens including fungal, bacterial, viral, or virus-like mycoplasmal agents (Lozano and Booth, 1974), and more than 90 species of insect pests (Montaldo, 1967; Bellotti, 1977). These diseases and pests can affect plant establishment and vigor, inhibit photosynthetic efficiency, or cause pre-harvest and post-harvest deterioration. Some causal agents are distributed worldwide, appearing endemically in almost all cassava plantations (Lozano, 1976; Terry, 1975a). Others are limited to geographical areas or continents possibly because their dissemination occurs mainly through the use of infected planting material for propagation (Lozano, 1972, 1975).

Of the two major diseases of cassava, probably the most important is the mosaic disease whose vector is the white fly. Although entomologists, pathologists and plant breeders are combining their efforts to bring it under control, they are still faced with many difficulties. The production of a disease resistant strain may well be the answer as control of the vector by chemical means could lead to the emergence of other problems as natural predators of disease vector would also be eliminated.

The second disease of major significance is bacterial blight. This has recently been identified in Southeast Asia and Africa (Nestel, 1975; Lozano, 1975). Control measures have been devised in recent research but the importance of strict quarantine measures for plant movement cannot be over emphasized. The transmission of infective agents to localities with no resistant species could decimate the local crop and cause many serious difficulties in the subsequent elimination process with concomittant grave economic losses.

Mites appear to be a universal pest of cassava. The *Tetranychus* mite (*T. urticae*) is recorded as a pest in Africa, Asia and the Americas, while the *Mononychellus* mite (*M. tanojira*) is reported in the Americas and Africa. Thrips, whiteflies, stemborers, leaf-cutter ants and cutworms attack cassava in Africa and the Americas. The cassava hornworm (*Erinnyis ello*), shoot flies (*Silba pendula*), fruit flies (*Anastrepha pickeli* and *A. manihoti*), and gall midges (*Cecidomya* sp.) attack cassava only in the Americas. Grasshopper feeding on cassava is restricted to Africa while white grubs, termites and scale insects are reported from Africa, Asia and the Americas (Schoonhoven and Bellotti, 1975).

As was pointed out earlier, the spread of pests and diseases is usually facilitated through the planting materials. Cassava is vegetatively propagated by planting pieces of stem cuttings; consequently, cassava pathogens can be disseminated easily by the movement of planting materials from infected to uninfected areas. Unless effective quarantine measures are practiced, any movement of cassava planting material represents a serious risk of disseminating these diseases and pests. It is against this background that the last Workshop for International Exchange and Testing of Cassava Germplasm, held at CIAT in February 1975 (IDRC/CIAT, 1975) made the following recommendations:

A. General recommendations

1. The expertise in pest and disease recognition available at CIAT and IITA should be utilized to train national crop protection specialists who could then return to their respective countries and conduct courses on pest and disease symptomology and recognition for quarantine purposes.

2. It is recommended that the smallest possible amount of planting material be imported; the smaller the amount the less the chance of its carrying a pathogen or pest. Inspection of this material, as well as post entry quarantine, will be simplified.

3. The implementation of the recommendations for minimizing the risk of disease and pest introductions is the joint responsibility of the donor and recipient.

4. These recommendations merely supplement existing quarantine regulations of recipient countries.

B. Recommendations relating to the movement of vegetative propagating material

1. Material should never be imported from countries where African mosaic disease and brown streak virus disease are present.

2. For importations from all other countries, the following procedures are recommended:

a. In the donor country

1) Use only select material from a disease-free source.

2) Treat the material with a combination of fungicide (Thiram or Chloroneb) and insecticide (Methamidophos or Carbofuran).

3) Handle material with extreme care; disinfect and sterilize all tools and packing materials.

b. In the recipient countries

1) Burn on arrival all material which shows pest infestation or disease symptoms.

2) Re-treat the material with fungicide and insecticide.

3) Establish the material in an isolated area and make regular and thorough plant inspections over a one-year period.

4) Burn any of the established plants with pest infestation or disease symptoms not found in the country.

3. In addition to these general recommendations, material being exported from a country where superelongation is known to be present should receive a hot water dip (50°C for 30 min.)(CIAT, 1974). Countries importing material from countries where cassava bacterial blight is know to be present should undertake shoot-tip indexing within twenty days of germination (Lozano and Wholey, 1974; Takatsu and Lozano, 1975).

C. <u>Recommendations relating to the movement of true seeds</u>

1. In the donor country

   a. Select the seed from disease-free plants.

   b. Select the best-quality seed (visually).

   c. Treat with a fungicide (Thiram) and an insecticide (Malathion).

   d. Handle the seed with care and disinfect and sterilize both handling and packing materials.

2. In the recipient countries

   a. Burn on arrival pest-infested or obviously diseased seed.

   b. Establish the material in an isolated area and make regular and thorough plant inspection over a one-year period.

   c. Burn any plant with pest infestations or disease symptoms not found in the country.

As a follow up to the above recommendations, a phytosanitary workshop to be participated by plant pathologists, entomologists and senior quarantine officers from Asia and the Pacific region will soon be held either in Manila or Singapore with the main objective of defining our quarantine requirements for cassava planting materials in the region.

Agronomic Practices

Much of the literature has reported that due to its high nutrient requirement cassava is a soil-depleting crop, especially with respect to potassium. This is not surprising for any crop that yields well, particularly on poor soils, will deplete the nutrient reserves in that soil (Cock, 1974). On the other hand, past studies (Birkinshaw, 1926) have shown up to 15 cassava crops being harvested continuously in the same farm with no significant decrease in the productivity of the soil. Nonetheless, the use of fertilizer to obtain high yields is essential, particularly if the crop is planted on poor soils (De Geus, 1967). In Latin America, farmers frequently say that excessive nitrogen actually decreases yield due to excessive top growth. At CIAT, fertilizer trials using up to 300 kg./ha. of N have not shown any negative nitrogen response. Although reports on the favorable responses of fertilizers to increasing cassava yields are numerous, the low value of cassava and the high price of fertilizers in some region, makes it uneconomical for the farmers to apply it. It is however obvious that yields can be increased by the judicious use of fertilizers.

The length and quality of planting material markedly influences yield. CIAT recommends that planting materials be taken from plants ranging from 8 to 18 months of age. The younger the plant, the more lignified should be the part of the stem selected for the cutting. The stake should contain from 5 to 7 nodes, measures at least 20 cm. and should have a pith diameter of equal to or less than 50 percent of the diameter of the stem. Before planting, the cuttings should be treated with certain fungicides/insecticides to protect it against soil-borne pathogens and to accelerate germination and rooting.

The results from studies on planting position — vertical, inclined, or horizontal — and planting on the flat or on ridges do not show any consistent trends. It is possible that different systems are needed for different soil and climatic conditions. For example, it has been observed that in very wet areas, planting vertically on ridges prevented root rots and effectively increase yield (Lozano, 1976).

Recent Advances at CIAT

Although research in all phases of the cassava production system at CIAT are vigorously pursued and is coordinated as one program, it is in the field of varietal improvement where perhaps a breakthrough is expected.

On the CIAT farm where the soil is fertile, several hybrid selections gave root dry-weight yields of 15 tons/ha./yr. or more, outyielding a local cultivar by 100 percent. This is without any application of fertilizer, fungicide, insecticide or irrigation (Table 3). On the soil of the Llanos Orientales of Colombia, which is so acid (pH 4.3), so high in aluminum (exch. Al 3.5 me/100 g, 85% saturation) and so low in phosphorus (1-2 ppm Bray II) that the majority of food crops can be grown only with a heavy application of lime and phosphorus, several hybrid selections gave root dry weight yields of 10 tons/ha./yr. with a moderate application of lime and

Table 3. Selected results of yield trials in three locations.

Location	Genotype	Root yield (ton/ha/yr) Dry wt.	Fresh wt.
<u>CIAT</u>	CM 309-211	17.9	50.8
	CM 308-197	17.6	50.3
	CM 323-30	16.6	48.3
	CM 308-1	16.3	43.3
	CM 321-15	15.9	46.1
	CM 321-170	15.8	47.8
	CM 317-16	15.4	48.1
	CM 307-135	15.4	44.0
	CM 309-84	15.4	41.1
	CM 152-12	14.7	45.0
	M Col 113 (local cultivar)	8.4	25.6
	Llanera (control)	7.9	24.7
	M Col 22 (control)	7.1	19.7
<u>Carimagua</u>	SM 92-73	10.6	33.0
	CM 323-52	10.0	33.0
	CM 308-197	9.9	30.6
	CM 314-2	8.4	25.7
	CM 323-99	7.8	24.3
	CM 323-142	7.5	26.0
	CM 309-2	7.5	23.3
	CM 321-88	7.1	21.5
	CM 305-11	6.9	24.0
	CM 323-41	6.6	24.0
	Llanera (local cultivar)	6.9	21.5
	M Col 22 (control)	6.0	19.4
	M Col 113 (control)	2.7	10.4
<u>Caribia</u>	CM 320-2	13.7	42.0
	CM 309-50	13.7	41.7
	CM 309-163	12.8	44.3
	CM 323-75	12.2	37.8
	CM 323-41	12.2	37.6
	CM 322-20	12.1	36.7
	CM 321-85	11.6	36.1
	CM 308-197	11.4	34.5
	CM 309-128	11.1	34.8
	CM 321-78	11.0	38.0
	M Col 22 (control)	11.4	33.6
	Llanera (control)	6.0	20.7
	Manteca (local cultivar)	5.0	18.1
	Montero (local cultivar)	4.3	12.6

phosphorus, outyielding a local cultivar by 50 percent. On the southern coast of Colombia, which is one of the cassava producing centers of that country, several hybrid selections yielded more than 12 tons/ha./yr. in root dry weight notwithstanding five months of dry season. These selections have outyielded local cultivars by more than 100 percent. A hybrid selection such as CM 308-197 did well in all of these locations, always exceeding the yields of corresponding local cultivars by 50-150 percent (Table 3). This is indeed way above current yields at the farm level of only 3 to 5 tons/ha./yr. in root dry weight.

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