Cassava Breeding, Agronomy Research and Technology Transfer in Asia

Proceedings of the Fourth Regional Workshop held in Trivandrum, Kerala, India, Nov 2-6, 1993.

CENTRAL TUBER CROPS RESEARCH INSTITUTE * TRIVANDRUM INDIA *

CIAT

ICAR

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Technical Editor : R.H. Howeler

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R.H. Howeler
Distribution of new cassava
varieties in Prachinburi, Thailand

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PREFACE

The Centro Internacional de Agricultura Tropical (CIAT), located in Cali, Colombia, has within the CGIAR system the world mandate for research on cassava production and utilization, while the International Institute for Tropical Agriculture (IITA), located in Nigeria, has responsibility for cassava research in Africa. In order to facilitate communication with national cassava research programs in Asia, CIAT established a Regional Cassava Office in Bangkok, Thailand, in 1983. Through this Regional Office for Asia, a network of cassava researchers in national research institutes and universities has been established with the objective of enhancing communication between researchers, either within or among the various cassava producing countries, in order to increase the efficiency of the research with the goal of improving production and utilization of cassava in Asia. In this regard, CIAT is working closely with researchers in national programs, mainly through collaborative research in cassava varietal improvement and agronomic practices.

To further enhance communication among the researchers in the network, CIAT has been organizing regional workshops at about three year intervals. The first workshop was held in Bangkok in 1984 to review the general situation of cassava in Asia, to identify constraints and set research priorities. The second workshop was held in Rayong, Thailand, in 1987 to review the first years' results in varietal improvement and to review all agronomic research that had been conducted prior to that date by national programs; this allowed the setting of research priorities in the area of agronomy for the future. The third workshop was held in Malang, Indonesia, in 1990 to review the research on varietal improvement and agronomy during the previous three years, as well as to review all research on cassava utilization aspects that had been conducted in various national institutes in the region. The latter activity was followed by a special workshop on root and tuber crops processing, marketing and utilization, which was held in the Philippines in 1991 and sponsored by CIP, IITA and CIAT. Proceedings of these various workshops have been printed and are available at the CIAT Regional Office in Bangkok. Finally, the fourth workshop was held in Trivandrum, Kerala, India, in November of 1993 to review the research in varietal improvement and agronomy conducted since the previous workshop and to discuss in detail the process and methodologies used in the transfer of technology in the various countries, with special emphasis on the transfer of new cassava varieties and cultural practices. Some papers on technology transfer were presented by people working in extension institutes and their presence at the workshop added a new dimension to our concern for improving the impact our research has on the lives of cassava farmers and processors. The papers presented during this fourth workshop are published in this Proceedings.

During the third workshop in Malang an Advisory Committee on Asian Cassava Research was established. The objective of this Committee is to advice CIAT on priority areas of research for the Asian Cassava Research Network, to decide about the distribution of funding for collaborative research projects, and to set the time, place and theme for the next workshop. After the initial meeting of the Advisory Committee in Malang, a second meeting was held from June 15-17, 1992, at MARDI, in Malaysia, while the third meeting was held in Trivandrum during the fourth workshop. During this last meeting the following members were elected:

Zheng Xueqin	SCATC, China	: Chairman
Kazuo Kawano	CIAT, Thailand	: Secretary
Bambang Guritno	BU, Indonesia	
G.T. Kurup	CTCRI, India	
Tan Swee Lian	MARDI, Malaysia	
Jose Bacusmo	PRCRTC, Philippines	
Charn Tiraporn	DOA, Thailand	
Pham Van Bien	IAS, Vietnam	
Reinhardt Howeler	CIAT, Thailand	
Rupert Best	CIAT, Colombia	: Observer

During the meeting it was decided to organize the fifth Workshop at SCATC, Hainan, China at the end of 1996.

CIAT would like to take this opportunity to thank the members of the organizing committee of the fourth Workshop for their hard work and dedication in organizing this event, which resulted in an excellent workshop and a very interesting field trip to Kanniyakumari, as well as a visit to the Central Tuber Crops Research Institute. All workshop participants appreciated the excellent work of the local organizing committee comprising mainly staff members of CTCRI. Many thanks.

R. H. Howeler
CIAT, Bangkok
November, 1994

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OPENING REMARKS TO THE 4TH ASIAN CASSAVA RESEARCH WORKSHOP

Kazuo Kawano
Coordinator
CIAT Regional Cassava Program for Asia

Good morning! Distinguished guests and colleagues. It is very gratifying to see many faces again in this 4th Asian Cassava Research Workshop. On behalf of all the cassava researchers in Asia, I would like to thank our Indian friends at CTCRI for the preparation and organization of this Workshop today. The Workshop is an opportunity, or an open forum, for reporting what we have been doing and learning what others have been doing. For this, the Workshop program is well organized and it leaves little doubt that everyone of us here is well aware of this important Workshop characteristic.

The other important objective of this Workshop is to define where our future emphasis should be and how best we could achieve that. There are abundant occasions where anyone of you exchanges views and discusses about possible cooperations through informal meetings. This type of interaction is in many meetings the most important function in real terms. To promote this interaction, we organized several smaller network meetings, such as on Cassava Agronomy, Cassava Germplasm, and Cassava Biotechnology.

The focus of this Workshop is on technology transfer and we plan to have a panel discussion on the final day. How we organize this panel discussion will be decided after we hear all the presentations. Thus, your input to this matter is welcome.

Before giving the chair to Dr. Kurup, I would like to make one technical comment. Everybody is well aware that CTCRI has been doing very fine cassava varietal improvement work. There are several highly recommendable varieties and it is natural that breeders in other countries are interested in trying those advanced cassava materials from CTCRI in their own environments. However, as you will see during our field observation, Indian cassava is very commonly infected with cassava mosaic disease, which does not exist in other parts of Asia. Accidental introduction of this virus disease can be extremely dangerous, destructive and long lasting. Thus, please be well aware that it is a very basic understanding among us cassava researchers in the world to refrain from moving living cassava materials from mosaic infected areas to non-infected areas.

I believe no further introduction is neccessary. I would like to ask Dr. G.T. Kurup, Director of CTCRI, and Chairman of the Asian Cassava Research Advisory Committee to chair the first session of the workshop.

INAUGURAL ADDRESS
ROLE OF CASSAVA IN THE RURAL AND INDUSTRIAL DEVELOPMENT OF INDIA

K.L. Chadha
Deputy Director General (Horticulture)
Indian Council of Agricultural Research
Krishi Bhavan, New Delhi

INTRODUCTION

It gives me immense pleasure to be here with you this morning to participate in the 4th Asian Cassava Research Workshop being held in India. I, on behalf of ICAR, CTCRI and its staff and on my own behalf welcome you all to this workshop. This workshop has been organized at the right season when you can enjoy your stay at Trivandrum, the historic city and capital of Kerala. Moreover, it is time that we are talking about exploitation of bio-diversity for providing food to the millions. Cassava is one crop which forms a staple food for the poorest of the poor as well as rich, and more so in this state of Kerala. This crop also sustains many agro-based food processing and starch industries and plays a vital role in the rural development of the country.

Cassava (*Manihot esculenta* Crantz) is believed to have been grown in India for more than a century. It was introduced in India either by the Portuguese during the 17th century or brought from South America in 1840. However, the rapid spread of cassava cultivation in this part of India is attributed to a famous nineteenth century ruler of the former Travancore State, which later became an integral part of the State of Kerala. This ruler encouraged cultivation of popular varieties of cassava from Malaya and other places to overcome rice shortages, especially among the low income group, consisting mainly of small farmers and laborers. The ability of cassava to supply adequate calories at a lower cost encouraged its maximum use among vulnerable social groups. While the cultivation of cassava spread widely in Kerala as a food crop, it slowly became an industrial crop in the neighboring state of Tamil Nadu. Cassava is at present cultivated in 13 states with a total production of 5.67 million tonnes from 289 thousand hectares of land.

Distinguishing Features of Cassava

Because of the high photosynthetic efficiency and the subsequent synthesis of carbohydrates, cassava is rated as one of the richest sources of energy, besides being a treasure house which provides vitamins and minerals. Cassava possesses the unique strength of surviving under adverse climatic conditions and has tolerance to pests and diseases. It can be grown as a monocrop, intercrop or mixed crop under low fertility inputs. These are some of the features which attracted marginal farmers to retain cassava in their cropping systems. In the days of seasonal and national food shortages, cassava stood as a colossus against grinding poverty. During the world war periods the rural masses in Kerala stumbled upon the cultivation of cassava, which became a rage in the food history of the State.

Cassava in Rural Development

Cassava cultivation in Kerala and the northeastern states has proved that rural food security can be met by local measures only, which will help not only farm output but also promote rural employment. The production of a food surplus in response to guaranteed markets will provide additional income for producers, besides a continuous food supply in the rural areas. This additional produce can also be processed into various food products to suit the taste and need of the urban folk.

In rural areas of India, when food grain supplies are not ensured, it is essential to concentrate all efforts to foster new management to promote production of those foods that make up a large proportion of their diet. Ideally such food crops should be adopted to existing farming systems and be capable of producing high returns from land and labor within the constraints of unpredictable climatic conditions and limited inputs. In such a situation, at least in a few states, cassava emerged as a significant crop with multi-faceted uses for rural household food security. Changes in demand for cassava for human consumption depend on the income, relative prices and taste preferences. Some of the cross section surveys have indicated a negative relationship between cassava consumption and income. In the low income groups there will be an increase in consumption of cassava, while in the middle and upper classes increases in income will reduce the consumption of cassava.

Cassava in Food Security

In major cassava growing areas, cassava is used mainly for human consumption. The role of cassava in supplementing a food grain deficit has been growing since 1880. At first it was only used by the poorer people to supplement their rice diet during periods of scarcity, but gradually it became a subsidiary food even in normal years. In areas without rice cultivation, it became the staple diet for the poor. During food scarcity it played a major role in averting famines. However, the outcome of the Green Revolution has changed the food consumption pattern of the people in the country. The resultant depression in cassava consumption and production is not the only real cause of the recently experienced shift in the cropping system and change over to plantation crops. The low income generated from tuber crops as compared to other horticultural and plantation crops have placed cassava in the category of "orphan crops" in Kerala. To the contrary, cassava has emerged as a cash crop in Tamil Nadu, Andhra Pradesh and Maharashtra, since it caters to the needs of the massive starch and sago industry in these states. To maintain the rhythm in the supply of food materials and to keep pace with the geometrically increasing population, secondary or tertiary staple food crops like cassava have to be retained within the cropping system of marginal farmers.

Diversification an Answer to this Malady

Better post-harvest management and diversification for the production of value-added products is one of the methods to retain cassava cultivation. The government of India's decision to set up the much expected Agriculture Business Consortium will be a key to unlock the rural El Dorado, if meticulously executed. The tremendous scope of cassava to enter in the agri-business has been unequivocally proved in the agro-processing belt of Salem-Dharmapuri districts of Tamil Nadu. Mushroom growth of starch and sago factories with a massive turnover of one billion rupees worth of starch and sago, as per documented records, in spite of the various constraints experienced, give direct and indirect rural employment to thousands of people, besides promoting a crop in vast non-traditional areas where there is a limited water supply. Incidentally, with utmost pride and satisfaction, the principal Institute, CTCRI, functioning under the Indian Council of Agricultural Research, can claim that the varieties and package of practices released from the Institute are supporting at least seventy five percent of the raw materials required for a one billion rupees industry of starch and sago production in India.

Rural Processing Units

Cassava is branded as the poor man's crop in rural areas. In order to ensure rural employment and provide adequate remuneration to growers, the concept of cassava-based rural processing units have to be augmented. Even so, many food items can be made out of cassava with little technological inputs. Wafers, chips, pappads, dried chips for animal feed, rava, porridge powders etc. can be made out of cassava in the villages. Cassava farmer's cooperative processing units with adequate governmental and institutional support could be an innovative idea, where our farm enterprises can yield not only more food, but also more productive jobs and higher income in rural areas, serving as an antidote to poverty and unemployment. The possibilities for cassava-based massive and tiny rural industries are enormous and in the years to come it has to be moulded into a reality for a stable rural economy.

Animal Feed

In spite of the scientific knowledge generated about the possibilities of utilizing cassava as a carbohydrate supplement in animal feed formulations, feed manufacturers do not utilize cassava in view of its high cost relative to other carbohydrate sources. The practice of cassava growers in Kerala to use dried cassava chips as cattle and poultry feed could be improved and encouraged by introducing technologies for nutritional improvement with locally available protein sources. Ensiling of cassava as well as protein enrichment following solid state fermentation are some of the low cost technologies for adoption in rural areas for increased animal productivity.

Cassava Based Industrial Development

Cassava can be used as a raw material for a number of value-added industrial products, such as starch, sago, liquid glucose, dextrin, vitamin C, gums and high-fructose syrup. Most of the items mentioned are industries which will easily fall in the group of "growth industries". Industrial starch finds its application in various fields. The major consuming industries are the cotton and jute textile industries and the paper and hard-board industry. Maize starch has established itself as a major competitive product to cassava starch. The textile and jute mills in north India have developed a built-in preference for maize starch due to the prolonged use of the same. But in the south, cassava starch is being used in large quantities by most of the consuming industries. Introduction of high yielding varieties, released by CTCRI, and the adoption of a package of practices will help to reduce the cost of production, thereby reducing the price of the product further.

Liquid glucose and dextrose are widely used in the food and pharmaceutical industries. Both these sectors are in a rapidly growing stage. The government of India has included liquid glucose and dextrose in the list of items that are likely to have a sustained demand and have scope for investment. Since there is a substantial growth in food and pharmaceutical industries, naturally the demand for liquid glucose and dextrose is bound to go up in the future. Cassava starch, which possesses some advantageous physio-chemical and structural properties, can be easily converted to liquid glucose and dextrose. Many factories have been established recently with this objective.

Cassava can serve as a nucleus for many industries with the application of biotechnology, especially fermentation industries. In India, two companies have already started building up the infrastructural facilities for the production of alcohol from cassava. Sorbitol and vitamin C plants, using cassava as a raw material, have been established in Madhya Pradesh. Since glucose produced from cassava can be easily isomerised to high fructose syrup, commercial ventures in this line could be initiated to release the pressure on cane sugar utilization. In Tamil Nadu already one company has started to produce high-fructose syrup from cassava.

Cassava continues as the unchallenged raw material for sago production in India. The small sago units established in the early forties have paved the way for the establishment of a strong agro-industrial network in India. Integrated approaches for improving sago processing under sophisticated environments will open up new markets within the country as well as abroad.

Industrial units with diversification for a variety of cassava-based value-added products can survive against any competition and market fluctuations. The enormous potentialities of cassava as a raw material for industry will be an insurance for the thousands of marginal farmers with respect to marketing of their produce. The prosperity of Indian villages depends mainly on the farming community and the reasonable income generated from their produce. Cassava, the crop of the poor, is not an exception to this.

I am sure that this Workshop will deliberate the various issues of production, protection and processing of this crop. Some of the specific problems, like developing varieties or hybrids which can tolerate extremes of temperatures and drought, varieties having shorter duration, which can fit in the cropping systems; developing cassava-based inter- or mixed- cropping systems under various perennial crops, developing cassava-based sequential cropping systems in the cereal crop areas; focussing intensive research on cassava mosaic disease, including identification of different strains, purification, serology and virus indexing using the ELISA technique; and also assessing the effect of CMD-free planting material in the primary and secondary spread of CMD, as well as reducing the incidence of the disease and developing resistant varieties, need special discussion. We hope to get clear-cut directions for future research on the above aspects after the deliberation.

With these words, I once again welcome you all and wish you a good stay at Trivandrum. I also wish the deliberations a success.

I hereby inaugurate the 4th Asian Cassava Research Workshop.

SPECIAL ADDRESS
SAGOSERVE - A SUCCESS STORY IN THE CASSAVA INDUSTRY OF TAMIL NADU

Vishwanath Shegaonkar, I.A.S.,
Managing Director, Sagoserve
Salem, Tamil Nadu, India

Genesis of the Industry

It is true that until recently, i.e. before CIAT appeared on the scene of cassava production and research activities, there was little international awareness of the importance of cassava to millions of the worlds' poorest people. But in India, particularly in Kerala and Tamil Nadu, cassava production is not a recent phenomenon. The Maharaja of the erstwhile State of Travancore had given encouragement to make cassava the most popular crop in Kerala. Today, though Kerala ranks first in cultivation and production, Tamil Nadu stands first with respect to productivity and processing of cassava.

In Tamil Nadu, cassava was first used to manufacture starch and sago by one Thiru Manickam Chettiar of Salem Dt., way back in 1943. Even though the methods adopted by him for the purpose were crude and primitive, they stimulated the farming community to grow cassava on their fields. However, it was only after the Second World War, that the cassava industry could make progress in Tamil Nadu when the import of starch and sago from foreign countries increased.

To prosper, the native cassava industry, then called the "Sago and Starch Manufacturers of Salem District", appealed to the government to ban such imports. It was the late Thiru C. Rajagopalachari, the first Governor General of Free India, who was instrumental in helping these cassava processors of Salem district in his capacity as the then Civil Supply Minister of the Interim Government of 1946. This small step in the right direction proved a giant leap for the development of the cassava industry in and around Salem district of Tamil Nadu. Today, there are about 800 sago and starch manufacturing units in Tamil Nadu, mostly situated in and around Salem.

Salem, a Land of Starch and Sago

Out of 800 starch/sago units in the State, about 650 units are located in Salem district, because this area offers several advantages for the promotion of the cassava industry:

- Favorable weather conditions
- Availability of high quality cassava roots
- Cheap labor

Hence, the district is known as the land of starch and sago. Today this industry has been meeting about 80% of the demand of the country for cassava-based food preparations. In the industrial areas, and over the passage of time, this industry has created potential employment in rural areas for about 500,000 skilled or unskilled persons, and left an indelible mark on the rural economy of Salem district. In short, cassava has now become the backbone or sheet anchor of the village economy.

The Need for a Cooperative (SAGOSERVE)

Though the successive governments in the State and in the Union helped this industry in and around Salem, marketing operations posed many problems, such as price fluctuations, warehousing, advancement of credit, and also other exploitating tendencies on the part of middlemen in the trade, particularly when there was no properly regulated marketing floor. Many times, the manufacturers of starch and sago had to sell their finished products at a depressed price in the open market.

To get over these vagaries of cassava marketing, and in order to build the cooperative structure, a few stalwarts of the industry came forward in 1981 and formed a Cooperative Society - "The Salem Starch and Sago Manufacturers' Service Industrial Co-operative Society Ltd.,", which is now popularly known as 'SAGOSERVE'. Today, it has 720 sago units as its members with a sales turnover of 0.8-0.9 billion rupees annually.

Main Objectives of the Society

Sagoserve is an industrial cooperative venture dealing with the marketing of starch and sago throughout the country. Its main objectives are:

- To advance credit to its members
- To create an effective marketing floor
- To ensure good remunerative prices for cassava finished products
- To extend warehousing facilities
- To protect producers from exploitative tendencies of middlemen
- To increase and develop cassava plantations in the area
- To generate additional employment and income for rural people, particularly down trodden people.

Marketing Devices and Tender System

To remove the problems of price fluctuations and subjectivity in the marketing of cassava finished products (i.e. starch and sago), it was decided to adopt a new marketing device to sell members' goods, called the "Daily Tender System". It is now proved beyond doubt that formation of marketing cooperatives like Sagoserve in the small-scale sector can play a pivotal role in stabilizing the price structure of agro-products, besides serving as an instrument against exploitative tendencies in the trade.

This tender system has been doing well, has the full cooperation of members and registered traders, and, therefore, has been widely accepted by the producers, traders and the management of the organization. Sagoserve and its marketing methods have helped the cassava marketing to become more and more organized and now the very existence of Sagoserve ensures reasonable prices to the producers. This has indirectly stimulated farmers to cultivate cassava on additional land.

Besides providing a marketing forum through registered traders, Sagoserve has taken a few administrative measures to promote business in and outside of Tamil Nadu, such as:

- Direct sales (limited)
- Supply of quality goods
- Conducting of exhibitions throughout India and publishing of brochures in various Indian languages to disseminate information regarding organization and cassava products
- Undertaking marketing tours by the Managing Director personally to create good rapport with the buyers and to build up confidence.

All these measures brought good results, like the creation of demand-pressure and competitive prices for the cassava finished products.

Phenomenal Growth of the Society and Industry

When Sagoserve came to existence as an industrial co-operative in 1981 under the provisions of the Tamil Nadu Co-operative Societies Act 1961, it could initially market cassava products worth 4 million rupees only, belonging to its 168 founding members. Today, about 720 starch/sago industries are under its fold, achieving an all-time record of marketing goods worth 900 million rupees annually. The phenomenal growth of this nascent industry was possible due to the pivotal role played by the organization in extending marketing promotional facilities, credit advancement and warehousing to its members, which were conspicuously wanting before the establishment of the Society. As the prices of cassava finished products are now higher, due to an organized market, the planters of cassava are also in turn assured of good prices for their roots from processors. In 1981, when the Society was formed, the fresh root price was Rs. 0.37/kg. Today it has been increased four times to Rs. 1.55/kg. However, unlike the cassava processors, the farmers are yet to be organized.

Role of Research Organizations in the Promotion of the Cassava Industry

The progress the cassava industry has achieved in Tamil Nadu would not have been possible in the absence of research activities and support given by organizations like the Central Tuber Crops Research Institute (CTCRI) in Trivandrum; the Tamil Nadu Agriculture University in Coimbatore, and the Central Food Technological Research Institute (CFTRI) in Mysore. They have undertaken various steps to improve plant production, physiology, soil management, agronomy, microbiology, pest control and post-harvest handling, including modernization etc., and have passed on their results for implementation.

Improved cassava cultivars, like H-1687, H-226, A-97, H-165, H-2304 have been developed and released by CTCRI for cultivation. H-226, with a duration of 10 months and a yield of 30-35 t/ha, is already under cultivation in and around Salem. This yield of 30-35 t/ha is considerably higher than the national average cassava yield of 19 t/ha.

Incentives Offered by the Government

It would not be out of place to express our gratitude to the successive State and Central governments, which offered capital support and other incentives to develop this industry and the cooperative organization, Sagoserve.

Incentives:

- Concessional TNGST rate of 2%, if the produce is marketed through Sagoserve, compared with 5% in the open market
- Abolition of the Central Excise duty
- Single point tax system
- State participation in the share capital (10 million rupees) structure of the society.

These incentives have also played a major role in the elimination of middlemen in the cassava trade and have enhanced the marketing of cassava products through Sagoserve, achieving very encouraging results in sales turn-over and collection of taxes, besides the earning of good remunerative prices for the members' goods.

Scope for Consumption

As we all know, present cereal production does not match the rate of population growth in many developing countries like India. In such a situation, there is a sure place for cassava, both for human consumption and as animal feed, besides its wider uses in industry.

In India cassava sago is being used in various food preparations, eg. sago vada, khichadi, pappad, chiwada, paisam (khir), laddu, halwa, chikki, etc.

Cassava starch has wider uses in both edible items as well as in industrial products, such as:

- Food products, like bread, cake, ice cream cones, flour, sweet cookies, vermicelli, soup

mixes, confectionary and biscuits
- Non-food products, like paper, textile, laundry, pharmaceuticals/alcohol, glucose/fructose, pulp/glue, plywood/adhesives, vermilion and water colors etc.

Cassava chips are also used for human food as well as for animal feed.

Dr. Kurup, Director of CTCRI in Trivandrum, has rightly observed in one of his articles on Root and Tuber Crops, that tremendous possibilities exist for the diversification and utilization of cassava in food, feed and industrial products. For that purpose, CTCRI has developed various types of processing equipment and technologies, which have to be transferred to the users with great vigor.

To widen the horizon of marketing of cassava products, it is very important to pay attention to the better post-harvest operations of the crop and to the production of value-added items through the development of appropriate machinery.

Modernization of the Cassava Industry

According to our rough estimate, 250 thousand tonnes of sago and starch are manufactured from cassava roots in Tamil Nadu annually by about 800 sago/starch industrial units. Most of these units use age-old machines, which result in a low level of productivity. Secondly, the processors are not in a position to maintain a high quality of the products by the use of modern science and technological devices. This is due to their lack of quality consciousness, their inability to make heavy investments in equipment, as well as a lack of awareness with regard to management and economics.

CTFRI, in Mysore has also emphasised the need for modernization of this industry in and around Salem, but without much success. This is only due to the heavy investments required. There is no doubt about the need for modernization in the cassava industry, since the marketability of cassava finished products depends on the percent viscosity, moisture, foreign materials, and ash, as well as on the pH value. If this industry were to be modernized, then the farmers and the processors could increase their bargaining power to dictate prices. The management of Sagoserve has not yet made much headway in persuading the producers to accept modernization as a new thrust area in this industry.

Other Constraints in the Cassava Industry

After many discussions with various people involved in the cassava industry, and from my own experience, the following are the most important constraints in this industry, besides modernization:
- Marketing problems and low profitability

- Low demand and price fluctuations
- Non-availability of improved varieties which are responsive to fertilizers
- Lack of application of appropriate fertilizers
- Non-availability of short-duration varieties
- Storage problems in view of bulk production, particularly when the shelf life of fresh roots is very short
- Lack of awareness among the mill-owners regarding product quality and its impact
- Lack of adoption of better economic and management practices by the owners of sago mills.

Despite all these constraints prevalent in the cassava industry, this crop has occupied a top position among all root and tuber crops. If we make conscious and tireless efforts to mobilize public opinion favorable to this neglected crop and to diversify its uses into food and non-food items, we would be able to elevate cassava to a secondary staple, if not a staple in all countries, for the majority of the people belong to the poorer sections of mankind. For this, the most important requirements are the application of research and development activities on the ground and the presence of strong upright leadership.

GETTING APPROPRIATE TECHNOLOGIES TO USERS: THE RESEARCH PERSPECTIVE

Louise Sperling[1]

INTRODUCTION

I have been asked to speak today on the issue of technology transfer: the overall concept, and general principles. As most of us here are research managers or scientists, I shape my remarks through the lens of a research perspective: when, how, and to what extent, should researchers in the agricultural sector be involved in technology transfer? The questions put forward within this general presentation are questions that each of you might ask in reference to your own cassava research and development (R&D) projects.

DO LINKS MATTER ?

It takes time and money to develop technology transfer links. Do they really matter? Conventional wisdom dictates that at least with simple innovations, such as varieties, "good technologies move by themselves".

Systematic studies assessing the effects of research-user-transfer agent links are scarce, although several outstanding examples come to mind:

-The International Service for National Agricultural Research (ISNAR) from 1987-1993 conducted 17 country case studies under the umbrella "Research-Technology Transfer Linkages" (Eponou, 1993). The impetus for the study was "a growing awareness that technologies in developing countries were not reaching farmers, particularly resource-poor farmers. A principal reason for this was found to be poor linkages between research organizations and technology transfer agents". Among other key findings, strong research-transfer linkages led to direct yield increases on-farm (Engel, 1990; Ortiz *et al.*, 1989), enhanced relevance of research, and more rapid feedback (Merrill-Sands *et al.*, 1990).

-While no analysis has yet been done of the costs of ignoring links in agricultural research in developing countries, a study in a closely related area offers some alarming signals. Research and Development (R&D) and marketing in private sector industrial companies offers parallels to NAR's challenges in that on-farm research and technology transfer perform similar functions to those of marketing in industrial firms (Merrill-Sands *et al.*, 1990). A comprehensive review assessed the impact on product development of 150 randomly selected R&D projects in 38 firms in the US (Souder, 1980, reported in Merrill-Sands *et al.*, 1990). Analysis showed that slightly more than half

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had linkage problems, which were classified as mild or severe.[2] Among those with "mild" linkage problems, one-third of the projects failed; those with "severe" linkage problems had a two-thirds failure rate.

We can always argue that industrial products are more complicated than many of those we deal with in agricultural research, but an example from Rwanda brings the issue closer to home. Follow-up studies of bean variety diffusion -- a low-cost, easy-to maintain, self-pollinating crop-- showed that transfer from farmer-to-farmer was both relatively slow and restricted. Initial diffusion started at the third season, and farmers distributed mainly to family, close friends or neighbors---but certainly not all who asked (Sperling and Loevinsohn, 1993). The simplest of technologies was "moving itself", but highly inefficiently. Substantial potential benefits were lost by both the research system and a large body of future users.

So, coming back to our original question: do "good technologies move by themselves"? Sometimes, sometimes with great inefficiency, and sometimes not at all. Such uncertainty should not be acceptable to research managers and scientists who spend years working on agricultural technologies.

IN A TECHNOLOGY TRANSFER SYSTEM: WHO ARE THE KEY ACTORS?

In thinking about researchers' role in technology transfer, scientists first have to identify with whom they collaborate in the process, that is, who are the potential users and who are the potential transfer agents?.

For example, for the case of cassava, users may include the independent growers, perhaps producers' organizations, consumers and even small industry. Within each of these categories, there are still other divisions, such as richer and poorer farmers. These diverse users might have different priorities in terms of, say, preferred cassava characteristics. The challenge for the researcher is to balance the user priorities, and/or develop a series of options to meet user needs. For each product developed, user profiles might shift. **Figure 1** suggests that the needs of varied user groups have to be anticipated and that one might have to give conscious preference to some users over others. The contrast between the potential user profile in Product A and Product B sketches how the importance of specific user groups can shift with the development of new products: some categories of users might be added or lost, and the proportional importance of user groups might change. As an extreme example, those farmers (users)

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[2] A "mild" problem might be one in which there was poor communication or complacency about the relationship, for example, "I don't care about extension". Severe problems entailed negative relationships between groups, ranging from lack of appreciation of the other's contribution to distrust and outright hostility, a typical attitude being: " Extension is an easy job: not like real research."

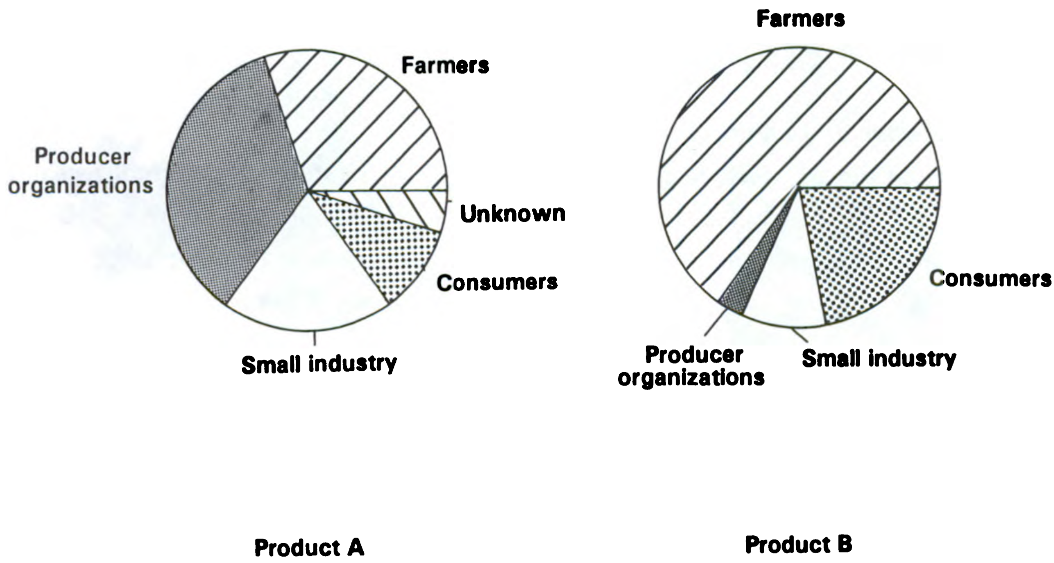

Figure 1. Who are the users ?

involved in soil management research are probably not the same collaborators in chip/ pellet research. Both user groups need to be involved in research, but the research system will probably link with them differently.

The profile of transfer agents may be no less diverse: perhaps formal extension, producer organizations, small industry. Less conventional transfer agents are also becoming increasingly important to research: those who control access to radio, TV, as well as the more usual extension booklets. With both more and less conventional transfer agents, there are many direct researcher transfer links. That is, researchers themselves are heavily involved in extending technologies---and with a broader range of actors than is often presumed.

The challenge is for researchers to anticipate user and transfer agent needs early enough to both ensure the relevance of a product and set it on its way toward broader diffusion.

IN A TECHNOLOGY TRANSFER SYSTEM: HOW ARE ACTORS LINKED?

Given the three principle actors in technology development--researchers, users, and transfer agents -- how might links be conceived so as to maximize research-transfer efficiency? Three common models are reviewed below.

1. The Transfer of Technology Paradigm

The Transfer of Technology (TOT) paradigm is a mode of agricultural research which started in the early 1950s and remained among the dominant ways of conducting research/extension until the late 1980s. It still reigns in many of the national programs I've worked with, particularly in the breeding departments. **Figure 2** sketches some of the major tenets of the TOT model, with which most of you are probably familiar.

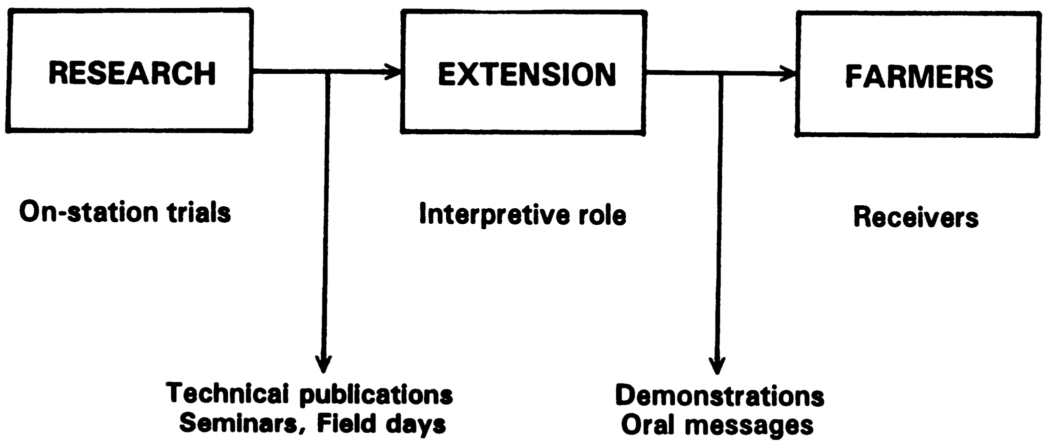

Figure 2. Conventional transfer of technology (TOT) research and extension model.

Basically, researchers working on station develop and finish technologies. Such technologies are passed to extension agents through field days or technical publications, and extension agents in turn try to convince farmers of the utility of the research product through controlled plot demonstrations or perhaps community meetings. The model has been widely critiqued in that it promotes a linear mode of product development: scientists design a product, then extension sells it to the farmer. It allows for little or no feedback and can only pass uniform, fixed messages. The model has proven inappropriate where: a) technologies must be adapted to on-farm conditions; b) where technologies have to meet the demands of heterogeneous environments; and c) in the case of complex technologies, where users must learn and adjust new management techniques (e.g. the case of IPM or soil erosion management). This top-down system has worked reasonably well to meet the demands of resource-rich farmers, with relatively simple technologies. It has also worked relatively well for producers of high-value commodities, for example coffee producers, who can make their needs known either directly or through their own advocacy groups (Ewell, 1989).

2. Farming Systems Research/Extension

On-farm research, including its most well-known variant, Farming Systems Research (FSR), grew partially in response to some of the shortcomings of the TOT model of research. To anticipate heterogeneous agro-ecological conditions as well as farmers' socio-economic needs, research had first to move on-farm, and then study the entire system in which farmers manage to produce crops and sustain their households. Researchers worked in multidisciplinary teams in order to design technologies which were well-adapted to existing farming systems **(Figure 3).**

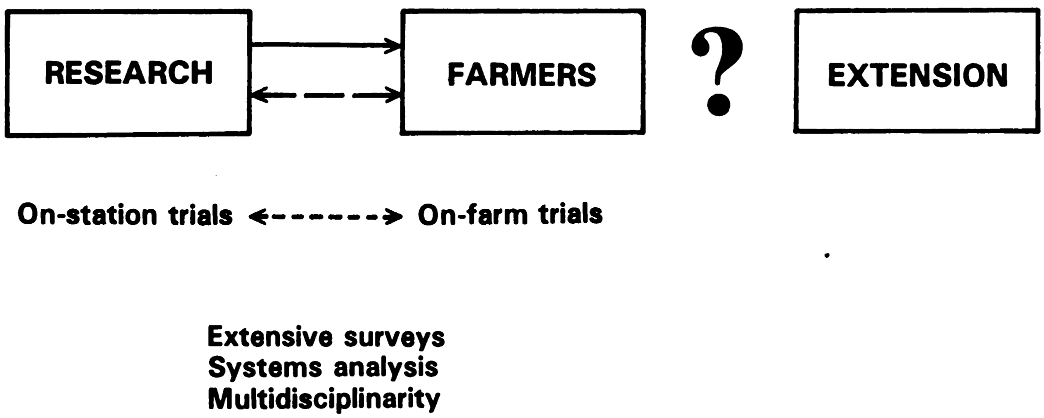

Figure 3. On-farm and Farming Systems Research.

FSR research has been practiced in so many guises that one has to be cautious about generalizing on its form. Researchers have had direct interaction with farmers. It does represent an important move towards site-specific research--that is, research targeted towards a specific user situation and agro-ecological environment. Given direct researcher user interaction, the FSR paradigm should aid in adapting and passing information on complex technologies.

Criticisms of the FSR approach come in at least three areas. While on-farm trials proliferated, the relationship between on-farm work and on-station research remained unclear: on-farm researchers had difficulty changing priorities of station research, and the feedback link from on-farm trials or surveys to station laboratories was notoriously weak. Second, in its earlier form, extension was virtually absent from the FSR paradigm;

technologies were to diffuse out from on-farm trials. Only later was extension added as an integral part of FSR (becoming FSR/E), although the mode of cooperation remained undefined. The role of the user (farmer) also remained ambiguous. While these users where consulted (and studied *ad nauseam*), researchers retained prime decision-making on research priorities as well as potential solutions to be tested. Certainly, there has been a good deal of analysis on the successes and failures of the FSR approach (e.g. Tripp 1991; Chambers and Jiggins, 1987).

3. Participatory Research Perspective

A research paradigm and the researcher-user-transfer agent relationship needs to be shaped by well-formulated R&D goals. Through time, the number of goals set seems to be multiplying as the research system explicitly tries to reach a range of clients (men, women, poor, rich), in very varying environments (low and high potential) and with technologies that are both sustainable and which stabilize a production system. In **Table 1**, I outline a list of possible goals of the ideal research system. Indeed, the current demands on such national and international systems are formidable.

The goals indicated in **Table 1** suggest a research system which has built-in flexibility, but which also integrates expertise of all actors--researchers, users, transfer agents--relatively early in the R&D process. Technology development, to be able to offer multiple options and to target those options, has to be a highly interactive process, even from the initial stages of technology development. **Figure 4** sketches the evolution needed-- from the more linear models of TOT and FSR to interconnecting partnerships. The intensity of interaction needed will depend on the type of technology being developed and the relative heterogeneity of both socio-economic needs and agro-ecological environments.

As this model of more client-oriented "Participatory Research" is relatively new, I give examples from Rwanda to suggest how such partnerships can be realized and what researchers' roles might be.

MOVING BEAN VARIETIES IN RWANDA: RETHINKING R&D ROLES IN VARIETAL RESEARCH[3]

Bean breeding within the national system of Rwanda, in Central Africa, parallels many western formats. The formal program at The Institute of Agronomic Sciences (ISAR) focuses efforts on yield, with disease resistance a secondary consideration. Further, while 250 cultivars are initially screened, only 2-5 may be eventually tried on-farm. Breeders search for a few widely-adapted cultivars to accommodate large-scale centralized

3 This section draws directly from the published paper of Sperling *et al.*, 1993.

Table 1. Important requirements of an effective research–user–technology transfer system.

1. Development of a research system which can:

Anticipate users needs

- know diverse users needs
- offer multiple options
- perhaps offer prototype technologies which can be shaped to user needs

Have positive impact in both heterogeneous and homogeneous environments

- offer multiple options
- suggest flexible/adaptable product designs

Have some success with complex as well as simple technologies

- flexible research designs (components rather than packages)
- understand the information/management systems as well as the physical products which need to be transfered ("tools of management")

2. Development of a transfer system which can:

- reach diverse user groups
- pass on multiple messages (and feedback)
- exchange ideas on options (and feedback)
- help develop management/skills among farmers as well as suggest specific physical technologies

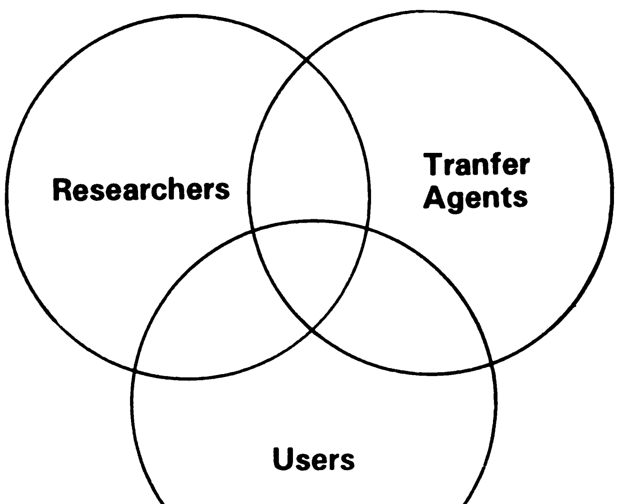

Figure 4. Relationships among researchers, users and transfer agents in more "Participatory Research".

seed production (Davis, 1990). Breeding procedures take inspiration from the TOT model. Farmer feedback comes from occasional on-farm trials at the last stage of a 5-7 year (9-14 season) selection sequence.

The lack of farmer consultation in Rwandan bean research represents an important missed opportunity. With some 600 varieties grown nation-wide, farmers have been exposed to a great range of genetic diversity and at any one time, may manage up to 30 varieties in varietal mixtures. Farmers constantly experiment with varieties and have developed stable and productive mixtures; in fact, in several regions, station breeders have a hard time out-yielding the best local varieties (CIAT, 1985).

Further, farmers' planting conditions are highly heterogeneous and their need for a range of cultivars is great. For example, beans are variously intercropped (e.g. under bananas or climbing up maize) and grown on soils of differing fertility; farmers target bean types to production niches. Varieties are also evaluated in terms of at least 15 characteristics, each having a range of acceptability for different user groups, e.g. the poor generally prefer shorter-cycle cultivars.

So, on the one hand, there was considerable genetic expertise among Rwandan farmers, and, on the other, challenging breeding conditions, such as heterogeneous environments and complex user needs. The formal breeding format paid heed to neither of these. In 1988 researchers from the Centro Internacional de Agricultura Tropical (CIAT) and ISAR proposed a selection format on-station, which might better draw each actor's comparative advantage. Breeders have access to "exotic" materials and knowledge (see Scheidegger in CIAT, 1990). They are able to screen a large range of international and national germplasm for yield potential, as well as for their response to stresses, most particularly pathogens, which may not be fully comprehended by farmers. Farmers have the edge in much that is local, "indigenous" or practical. They cultivate in several soil types, in varying associations, and in different seasons. Further, farmers are astute judges of local socio-economic variability.

The system of farmer participatory selection had three major steps: the identification of farmer bean experts; their evaluation of on-station trials; and their subsequent testing at home of cultivars selected from on-station plots (Sperling, 1992). The on-station evaluations were conceived not only to screen sets of cultivars for farmer acceptability, but to encourage dialogue among breeders, pathologists and farmers. Key points in assessing this approach were the correlation between farmers' and breeders' selection criteria, and the degree of agreement among farmers' evaluations, both within and between regions.

The on-farm trials aimed at comparing the performance of farmer-selected cultivars with those selected by breeders under the conventional scheme. Both the immediate yield and longer-term use of the two sets of cultivars were important in assessing the utility of the new approach. We also considered whether the experimental framework could address problems of the standard program, such as lengthy testing, difficulties in anticipating farmer needs, and promotion of limited genetic diversity. The results are presented, in brief, below.

Results of Farmer Appraisal of On–station Trials

The evaluations on-station provided a number of insights into the way farmers assess cultivars:

- Firstly, farmers select for a range of characteristics including but not restricted to a variety's observed yield in the field they are assessing. The varieties they chose were among those with higher yields, but many were in the middle range. **Table 2** lists the principal positive characteristics farmers cited and compares their frequency in the entire pool of varieties to their frequency in the subset chosen for home testing. Traits for which there is significant selection are of two types. The first comprises preferences, the aspects of the plant that are valued. Here, in addition to yield, farmers look for early maturity. Less important to these largely subsistence-oriented farmers are grain color and shape, for which markets often exert pressure for uniformity. Second, farmers judge varieties in relation to their expected performance in very different and diverse

Table 2. Most frequently cited positive attributes of bean varieties in on–station breeding trials evaluated by 78 farmers at Rubona, Rwanda during 4 seasons, 1988–1990.

Attribute	Frequency (%) among: All varieties (n=1072)[1]	Varieties chosen for home testing (n=198)
High yield	44	68***
Performs well under bananas	28	41***
Performs well under adverse conditions:		
- on poorer soils	13	29***
- in heavy rain	32	46***
- in drought	11	12 NS
Early maturing	23	38***
Nice grain color	13	16 NS

[1] Evaluations of individual varieties.

*** = frequencies in the two columns differ at P<0.001,

NS = not significant

home conditions, in intercropped fields, on poorer soils, in heavy rain (linked to disease resistance) and with respect to other stresses likely to be encountered off-station.
- Secondly, within the three regions (low-, mid- and high-altitude), farmers were in significant agreement on the overall performance of the 15 varieties, as measured in appreciation scores during on-station evaluations **(Table 3).** As these statistics suggest, however, the degree of concordance was not total, nor would one expect it to be, given the variability in farmers' agronomic and socio-economic conditions. Some varieties stand out as widely utilizable within a region, while others are judged appropriate for more specific niches.
- Thirdly, the comparison of evaluations scores among farmers in different regions also showed a significant accord, although the degree of consensus was considerably less, in both seasons, than within any one region **(Table 3).** While a few varieties are recognized

Table 3. Agreement among farmers in appreciation scores they assigned to varieties in on-station trials during two seasons, as measured by Kendall's "W" (All values significant at P <0.001).

Region	1989 A		1989 B	
	Farmers	W[1]	Farmers	W[1]
Low-altitude	11	0.44	16	0.47
Mid-altitude	18	0.32	27	0.55
High-altitude	5	0.82	8	0.74
Total (all three regions)[2]	**34**	**0.18**	**51**	**0.34**

[1] On the scale 0 to 1; 0 = no agreement
1 = perfect agreement

[2] All farmers considered together, without regard to region.

as "winners" or "losers" nationwide, regional differences result in farmers having varying concerns. Such regional variability indicates a need to decentralize selection early in the screening process.

The interpretation of the concordance results rested on the assumption that farmers' scoring is meaningful, i.e. that farmers' true appreciation of a variety is captured in their assessments and that they can indeed project from on-station trials to actual planting conditions. However, other interpretations are possible: high concordance scores may be the result of farmers sharing similar (erroneous?) myths regarding varietal performance;

low concordance scores might be produced by randomness in farmers' judgements. A critical test of the reliability of farmer evaluations was the actual performance on-farm of the varieties they selected.

Results of Farmer Designed and Managed On-farm Trials

Trial Data

Farmer participants showed they have considerable expertise in predicting which varieties from on-station experiments will perform well in their own plots. The 21 bush bean cultivars they selected over four seasons outperformed their local mixtures 64-89% of the time, with average production increases of up to 38% **(Table 4).** Direct comparison with breeder selections was not possible as very few routine on-farm trials were conducted in the same region and years. However, analysis of trial data during the period of greatest ISAR on-farm activity, 1987-1988, showed that the varieties breeders selected

Table 4. Performance on-farm of varieties selected from on-station trials by Rwandan farmers vs. those selected by breeders.

Season	No. of trials	Trials where new variety outperformed local mixture (%)	Yield increase of new variety over local mixture (%)
Farmer selection - Central Plateau			
1989 A	11	73 NS	3.9 NS
1989 B	19	89 **	33.4 **
1990 A	36	64 NS	12.9 NS
1990 B	18	83 **	38.0 *
Breeder selection - Central Plateau			
1987 A	32	34 NS	-8.8 NS
1988 A	45	49 NS	-18.9 NS
1988 B	15	53 NS	0.7 NS
Breeder selection - Countrywide			
1987 A	131	51 NS	6.7 *
1987 B	83	41 NS	-6.0 NS
1988 A	204	50 NS	2.6 NS
1988 B	204	50 NS	7.6 *

* = P<0.05

** = P<0.01

NS = not significant

for the Central Plateau (mid-altitude area) outperformed the local mixture 34-53% of the time, but with negative or insignificant production increases. Countrywide, trials in the same years were slightly more promising; breeder selections outyielded local mixtures in 41-51% of on-farm trials, with the highest average increase being 8% in any one season. Even though farmers selections had to satisfy a range of preferences, they still performed better than the varieties breeders chose with respect to yield, the scientists' primary criterion. The proportionally greater yield difference of farmer selections during the March to June season (season "B") may be related to the better adaptation of ISAR/ CIAT varieties during periods of disease pressure; farmers' actively selected for this trait by seeking cultivars which "resist rain" **(Table 2).**

Longer-term Varietal Use

Follow-up studies, carried out with farmer experts in mid-1991 confirmed the wisdom of their choices. Analysis of the average survival rate of the 106 selections (representing 21 cultivars) showed them to compare quite favorably with the very best of releases from ISAR's standard program: the farmer-selected set had a 71% chance of being grown for six seasons compared to 61% for the very popular bush bean "Kilyumukwe" in the Central Plateau (Sperling and Loevinsohn, 1993). These figures highlight the longer-term adaptation of closely-targeted varieties.

Compatibility with mixtures also favored the continued use of farmer-selected varieties: 32% of the varieties retained were found in newly-constructed mixtures (composed principally of improved varieties) and 35% had been incorporated into the existing blends. Such compatibility helps maintain the existing genetic diversity and probably stems from two features of the station selection process: farmers can choose varieties they feel will complement their local cultivars (in cycle, growth habit, soil fertility requirement, etc); they are also permitted multiple choices, hence they often select cultivars which are easily blended together.

Discussion: Farmer Involvement in Varietal Research

The Rwanda example suggests a novel partnership between researchers and farmers, in which the two are involved early on in research decisions. The role of formal breeders shifts from offering "the solution" to offering "many options". Under such a format, the role of transfer agents, here seed multipliers and extension specialists, will have to shift, from offering one or two varieties, to offering a large number of possibilities. In the Rwandan example, only farmers were incorporated early on into station research, as most of the bean production is for home consumption and farmers themselves are important seed multipliers. In more commercialized settings, it would also make sense to collaborate with transfer agents, such as large-scale seed industry or middlemen wholesalers-- if producers' needs might diverge from consumers' needs.

MOVING BEAN VARIETIES IN RWANDA: RETHINKING R&D ROLES IN SEED TRANSFER RESEARCH

New bean varieties can help boost small farmer agriculture. While they require few inputs and little maintenance, they realize their worth only when they can be accessed and sustained by smallholders. African national programs continue to devote the lion's share of their budgets to varietal improvement, but the "research" component often stops once the genetic material is identified. Multiplication and diffusion of seed are regarded as functional tasks with the outcome that formal seed systems are relatively standardized and centralized.

Seed Systems Diagnosis

Diagnostic studies of seed systems by researchers in Rwanda analyzed both the formal and informal channel performance. The formal system--government seed multiplier and development project partnership--fell short on a number of important counts. Production costs were high, 2-6 times the sale price, which meant that all new seed was subsidized. Disease pressures were intensified in centralized multiplication farms and only very limited volumes of seed could be produced in any one season. Most important, a limited clientele was touched by the formal seed system, perhaps 1 in 600 farmers.[4] Diagnosis of the informal system, in contrast, suggested a number of opportunities. Farmers regularly used up to eight informal channels. Informal seed channels existed to reach different types of farmers. Costs of both multiplication and distribution remained low.[5] The challenge for research was to effectively build on the strengths of the informal system. Here I sketch the diffusion experiments planned and carried out by researchers:

Seed Diffusion Experiments

A prelude to the diffusion experiments was the design of a simple product delivery package-- of interest to seed purveyors (i.e. merchants) and seed users (i.e. farmers). Small quantities (options of 50, 100 and 250g) of highly productive varieties (both bush and climbing beans) were packed in heat-sealed plastic bags along with an identifying leaflet. (This format parallels that used by street vendors for selling peanuts). From the merchants' point of view, the self-contained, premeasured bags made distribution a

[4] A fuller discussion of research methods and findings of the formal system analysis can be found in Sperling, 1991; Sperling *et al.*, 1994; and CIAT, 1990.

[5] A fuller discussion of research methods and findings of the informal seed system analysis can be found in Sperling, 1992.

clean and generally quick process. Farmers saw such "test" sizes as a low risk investment and the finished packets suggested a reliable product (that is, of standard quantities and of research-proven varieties). The leaflet describing basic varietal characteristics (printed in Kinyarwanda, the local language) made the new technology accessible to all; direct collaboration with an extension agent or development agency became unnecessary (CIAT, 1990).

CIAT itself experimented with two local channels as test distribution outlets, local country stores and centralized open markets. Four types of packages were made available (see Scheidegger in CIAT, 1991):

1) 250 g of a single bush variety
2) 250 g of a single climbing variety
3) set of 4 bush varieties (50g each)
4) set of 3 climbers and a sample of *Sesbania macrantha* (50g each)

In terms of production costs: bags, labor for packing, and labels represented US$0.02 per unit of a single variety or $ 0.05 per unit of a set of varieties; seed (at market price) $ 0.10 and 0.08, respectively. Packages were sold to vendors at $ 0.12 per unit.

In September 1991 (just before sowing time), ten country store owners (all those contacted) readily took about one hundred of these packages on commission. These shops typically serve a range of 1000 to 3000 farms and commercialize 1-3 tons of seed of local mixtures per season. Merchants sold the packages to farmers at US$0.16- $0.24 (average $0.20) per unit. Farmers thus paid on average US$ 0.80/kg (single variety) and US$ 1.00/kg (sets) of bean seed of new varieties; the going rate for local cultivars hovered around $0.40 per kg. Demand appeared greatest for packages of single varieties, with bush beans sought before climbers. Merchants sold the most preferred packets within 2-3 days and showed great interest to continue the experiment.

Sales at the village market were logistically more difficult as the handy plastic packages were easily stolen (as opposed to local mixtures normally sold in bulk). As more farmers can be reached through open markets, the traditional sprawling merchandise display may need to be modified if vendors continue with the sales. The single market merchant contacted disposed of 140 packages in two hours.

This set of distribution experiments confirmed that farmers are ready to pay for new varieties at two to three times the open market price of local seed. Merchants, in turn, obtain profits from handling the sales, and the country store seems to be an effective channels for reaching large numbers of farmers.

Discussion: Seed Diffusion Experiments

Such seed sale/diffusion proves to be an easy activity for development projects/ NGOs to pick up. With limited effort, results are impressive: reaching small farmers quickly. Using market channels, similar experiments have been conducted in Zaire, Uganda, Tanzania, and Ethiopia. Diffusion of improved varieties has also been tested through non-seed outlets, nutritional centers, charitable organizations and agricultural training schools. Particularly with nutritional centers, a new range of clientele, generally unreached by extension efforts, showed unusual enthusiasm for the new varieties (Sperling *et al.*, 1991).

The beauty of the small seed packet technique is at once its simplicity and impressive potential for impact. In Rwanda, we have calculated that with a mere 5 tonnes of seed, we can reach 100,000 farmers or just under 10% of the population. Getting the same seed out, but more quickly and widely, translates into discounted social benefits jumping from 5 to 8 million US$ for each variety (Scheidegger, personal communication).

Two points are particularly important in the above discussion of seed system analysis and experiments. First, the transfer model for seed has to change, both to increase impact and to accommodate a changing research agenda. Research and transfer need to co-evolve together. Second, the research system itself in Rwanda did research on "transfer systems". This concern with transfer was seen to be within its mandate, because it was realized that access to improved seed is of equal importance to its breeding/selection.

CONCLUSION

This presentation suggests that researchers have a role, quite early on, in anticipating needs of the transfer process. From the first stages of technology conception, researchers should be aware of both user and transfer agent needs and might benefit from active participation of both in actual product design. Within this particular cassava network, researchers are currently working on a range of products: fresh cassava, cassava chips/ pellets, soil management practices to sustain cassava production. For each initiative, researchers might ask the following questions to assure relevance of product design as well as efficiency in transfer possibilities:

- What is the full range of potential users?
- Who (what) are the potential transfer agents?
  (Is it necessary to stimulate the creation of others?)
- How does research link with users and transfer agents?
  (Do we sufficiently make use of their own expertise?)
- Are the links constructed for achieving maximum impact?
  - understanding users' needs?
  - providing flexible/adaptable research and transfer designs?
  - providing multiple options?

For those of you who still ask: "How important is technology transfer to my role as a researcher?" I would answer: "Central-- if you want to have impact". One of my research colleagues, Dr. Roger Kirkby, states the matter even more directly: "Scientists should be evaluated for adoption--not for papers"

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FOCUSING BASIC RESEARCH FOR CASSAVA VARIETAL IMPROVEMENT

Carlos Iglesias, Meredith Bonierbale, Mabrouk El-Sharkawy, Carlos Lozano, Anthony Bellotti and Christopher Wheatley [1]

ABSTRACT

Cassava is an important energy-rich food for millions of people in tropical developing countries. The crop has reached that status after thousands of years of evolution under diverse agro-ecosystems, movement of germplasm within and across continents, and more recently, through scientific genetic enhancement. Understanding that process will help in focussing the strategy for the development of basic research toward varietal improvement. This review analyzes the potential of genetic improvement as a tool for socio-economic development, briefly covering some of the basic breeding objectives and how they relate to constraints and challenges in cassava production and utilization. An analysis on cassava genetic resources, the assembly, maintenance and characterization of existing genetic diversity is presented. It also refers to methodologies for the creation of new genetic diversity, selection from within that diversity, and some of the progress made from a multi-disciplinary and multi-institutional approach to gene-pool development in cassava. Finally, some of the major challenges and opportunities in basic research to sustain cassava genetic improvement are discussed and a continued and increased emphasis on broad-based breeding programs for cassava in developing countries, combined with the use of biotechnology when appropriate, is advocated.

INTRODUCTION

Maintaining the world's largest and most comprehensively characterized *Manihot* collection enables CIAT to develop improved cassava germplasm adapted to the major production regions in Latin America, Africa and Asia. Obtaining new and useful genetic combinations depends on a sound knowledge of cassava's interactions and responses to biotic and abiotic stresses, the crop's inherent quality characteristics and the development of appropriate and effective breeding methodologies. The germplasm improvement process at CIAT has led to the development of gene-pools for broadly defined agro-ecosystems, from which further breeding or adaptive selection can effectively be done by national programs.

This paper describes how basic and strategic research is integrated with applied

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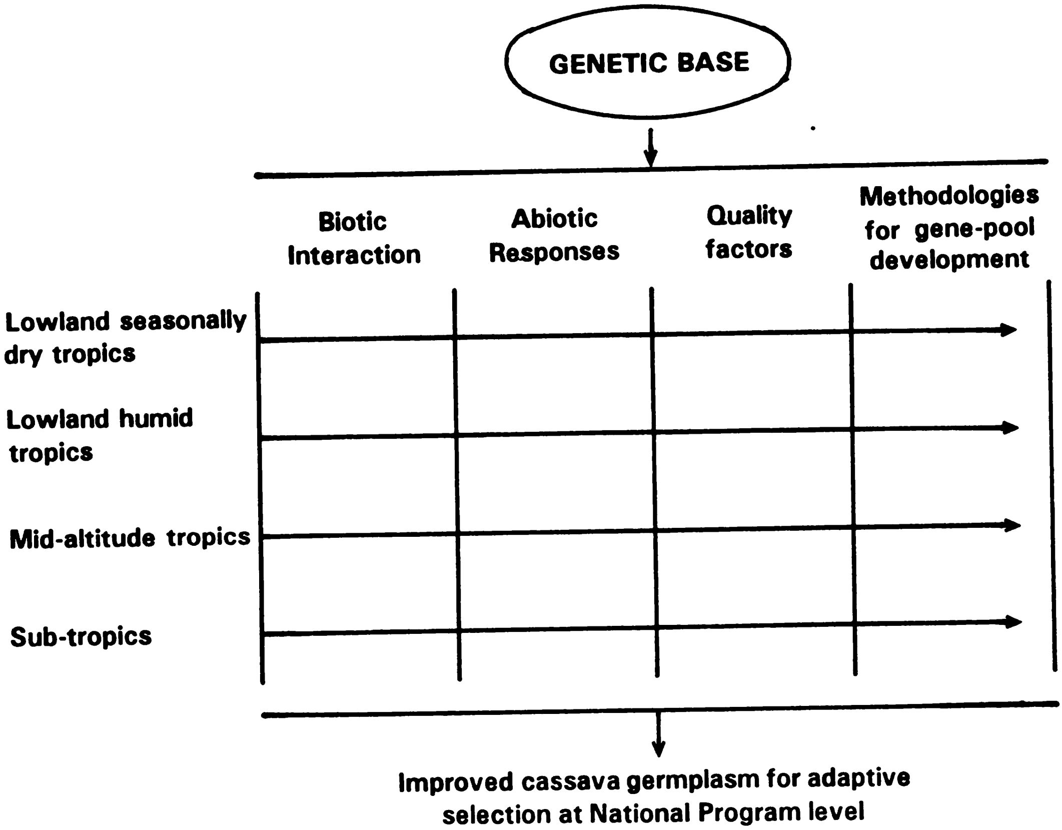

Figure 1. Interaction among disciplines for cassava germplasm development

germplasm development in a multi-disciplinary approach. **Figure 1** illustrates the flow of genetic information, knowledge and interaction among disciplines from the genetic base, through gene-pool development activities, towards the final goal of improved germplasm.

THE GENETIC BASE

The world cassava germplasm collection was the basis for all of the breeding work at CIAT, from which several improved varieties were derived. For example, the recently released variety MM 92 in Malaysia has the pedigree [(MCol 755 x MCol 1813) x MCol 1684] x [MCol 655A x MCol 1515]; thus, all the parents are from the CIAT collection. This collection increased to 5,500 accessions, which imposes some limitations for conservation, characterization and evaluation purposes. Consequently, a representative sample of 630 accessions was selected as a **core collection** (Hershey *et al.*, 1993). Different indicators of genetic diversity were used to stratify the whole collection prior to random sampling of accessions. **Table 1** presents the number of accessions chosen from each country based on geographical origin, diversity for morphological traits and a-b esterases, as well as *a priori* selections. The definition of a core collection will certainly lead to a better understanding of, and more effective access to, the variability

Table 1. Accessions from the CIAT cassava germplasm collection included in the core collection according to different parameters.

	Number of clones for distinct parameters				
Origin	Geographic origin	Morphological diversity	Diversity of esterase	A priori selections	Final number in core
Argentina	2	4	0	3	8
Bolivia	1	2	0	3	3
Brazil	110	13	15	20	101
China	1	0	0	2	2
Colombia	111	15	13	14	146
Costa Rica	9	7	5	4	23
Cuba	10	5	1	2	18
Dominican Rep.	2	2	0	4	5
Ecuador	25	6	0	4	32
Fiji	1	0	0	2	2
Guatemala	8	6	0	2	15
Indonesia	1	0	2	5	7
Malaysia	8	0	1	6	15
Mexico	14	6	0	2	20
Panama	6	2	0	2	9
Paraguay	25	8	3	7	40
Peru	63	10	3	2	76
Philippines	1	0	0	2	2
Puerto Rico	1	2	0	4	7
Thailand	0	0	0	4	4
United States	0	0	0	4	4
Venezuela	41	9	3	3	55
CIAT clones	0	3	5	27	33
IITA clones	0	0	0	3	3
Total	**440**	**100**	**51**	**121**	**630**

Source : CIAT, 1992 b

within the cassava germplasm, particularly for those characters requiring highly specific and expensive evaluations, which may be difficult to apply to the entire germplasm collection. Our main interest is to determine the extent of variability within cassava and to search more intensively within the promising collection. The core collection is intended to be duplicated at other institutions in the world. Another subset of the whole collection, prioritized for breeding purposes, is the **elite clone collection,** which represents a high concentration of desirable alleles and combinations of them.

Efforts have been måde to increase the efficiency of collection maintenance by the identification and elimination of duplicates. A set of traits less influenced by the environment were used for preliminary grouping of accessions (CIAT, 1992b). After analyzing 78% of the total germplasm collection, 1282 single clone groups were detected. The other groups included from 2 to 39 potentially duplicated accessions. The first batch of groups planted in the field showed an apparent 31.2% duplication for aerial part traits. Based on root traits, the level of duplication dropped to 22.6% **(Table 2).** Duplicates will be subjected to esterase analysis and those that are confirmed will be fingerprinted using M13.

Table 2. Identification of duplicated accessions in the whole CIAT cassava germplasm collection.

Number of accessions/group	Number of groups	Total number of accessions	Number of potential duplicates	% duplication
2	119	238	48	20.2
3	71	213	38	17.8
4	37	148	46	31.1
5	18	90	22	24.4
6	9	54	11	20.4
7	7	49	9	18.3
8	6	48	7	14.5
9	6	54	10	18.5
12	4	48	15	31.2
13	2	26	9	34.6
16	1	16	7	43.0
Total	**280**	**984**	**222**	**22.6**

Source: CIAT, 1992 b

For germplasm conservation, the potential of cryopreservation for long-term storage of cassava clones, seeds and pollen has been recently researched. Using a standard variety (MCol 22), the use of small shoot tips and purified cryoprotector increased shoot formation (Escobar *et al.*, 1993). Direct inmersion in liquid N_2 gave both higher recovery and shoot formation rate than slow freezing **(Table 3).** Once the procedure is standardized for different genotypes it would be used as a long-term and relatively cheap method of conservation of cassava germplasm.

Table 3. Effect of shoot-tip size, cryoprotection and freezing rate on viability and shoot formation after freezing in liquid N_2 (var. MCol 22).

	Average values (%)[1]	
Treatment	Viability	Shoots
Shoot tip size	71a	57a
Small (0.5-1 mm)	14b	0b
Large (2-3 mm)		
Cryoprotection		
Sterile DMSO (ampules)[2]	90a	44a
Standard DMSO[2]	83ab	33a
Without cryoprotection[2]	60a	11b
Cryoseeds	67ab	0b
Freezing rate[3]		
Fast	86a	57a
Slow	68b	29b

[1] Averages with the same letter are not significantly different at 0.05 level.

[2] Shoot tips were dried prior to freezing.

[3] Fast = direct inmersion in liquid N_2; Slow = slow cooling at 0.5°C/min.

Source: Escobar *et al.*, 1993.

Considerable efforts are also being made in the areas of collection, characterization and use of wild *Manihot* genetic resources. Preliminary findings have indicated some traits with high frequency within several wild relatives of cassava **(Table 4).** Efforts will concentrate on those traits with limited variability within cassava germplasm and on desirable new sources of genetic diversity. Once the genetic diversity in wild *Manihot* is characterized, there would be a need for support studies in the area of species inter-relationships and crossability, in order to make the useful genetic diversity available for cassava improvement. **Figure 2** summarizes the relationship and relative

Table 4. Manihot species with potential use in breeding.

Species	Swollen Roots	HCN	Comments
M. aesculifolia	+	High	Close relative of *M. esculenta;* large variation
M. alutacea	-	High	Cold tolerance; resistant to soil toxicity
M. angustiloba	+	High	Drought tolerance
M. anisophylla	NA	NA	Cold tolerance
M. anomala	+	Low-high	High photosynthetic rate, adapted to humid conditions; variable gene pool
M. attenuata	NA	NA	Cold tolerance
M. brachyandra	+	NA	Grow in N.E. Brazil with considerable root production
M. brachyloba	-	NA	Resistant to mealybug
M. carthaginensis	+	NA	Drought tolerance; salt tolerant
M. caerulescens	+	Medium	Drought tolerance; rubber producer
M. davisae	+	High	Drought tolerance
M. dichotoma	-	NA	Resistant to mealybug; high photosynthetic rate; CMD & BSV resistance; Paraiba 10 cultivar from cross with *M. esculenta*
M. epruinosa	+	NA	Grown with considerable root production
M. falcata	-	Medium	Potential for breeding small stature plants
M. foetida	-	NA	High photosynthetic rate
M. glaziovii	-	NA	Drought tolerance; CBB, CMD & BSV resistance; used in several breeding programs; mealybug resistance
M. gracilis	+	Low-medium	High root protein
M. grahami	-	High	Resistant to *Coclosternus manihoti,* cold tolerance
M. longepetiolata	-	Medium	Dwarf cultivars
M. nana	-	Low-high	Dwarf cultivars
M. oaxacana	+	High	-
M. paviaefolia	+	Medium	Adaptation to poor soils
M. peltata	NA	High	Resistant to soil toxicity
M. pentaphylla	+	Medium	Adaptation to limestone soils; highly variable species
M. pringlei	+	Low	Resistant to CMD
M. procumbens	-	High	Tolerant to poor soil
M. pruinosa	+	Low	Adaptation to limestone soils
M. pseudoglaziovii	-	NA	Resistant to CBB, drought tolerance
M. pusilla	NA	Medium	Dwarf habit
M. quinquepartita	+	NA	Mealybug resistance
M. reptans	-	High	*C. manihoti* and CBB resistance
M. rhomboidea	+	High	-
M. rubricaulis	NA	NA	Drought and cold tolerance
M. stipularis	-	Medium	Resistance to soil toxicity and cold dwarf horticultural use
M. tomentosa	-	High	Drought tolerance
M. tripartita	+	Low-med.	Adapted to long dry season
M. tristis	+	High	Adaptation to soils of granitic origin, high root protein
M. walkerae	+	High	Adaptation to soils of granitic origin, high root protein
M. zehntneri	+	Low-med.	-

Source: Byrne, 1984.

importance of the different *Manihot* genetic resources as the basis for gene-pool development.

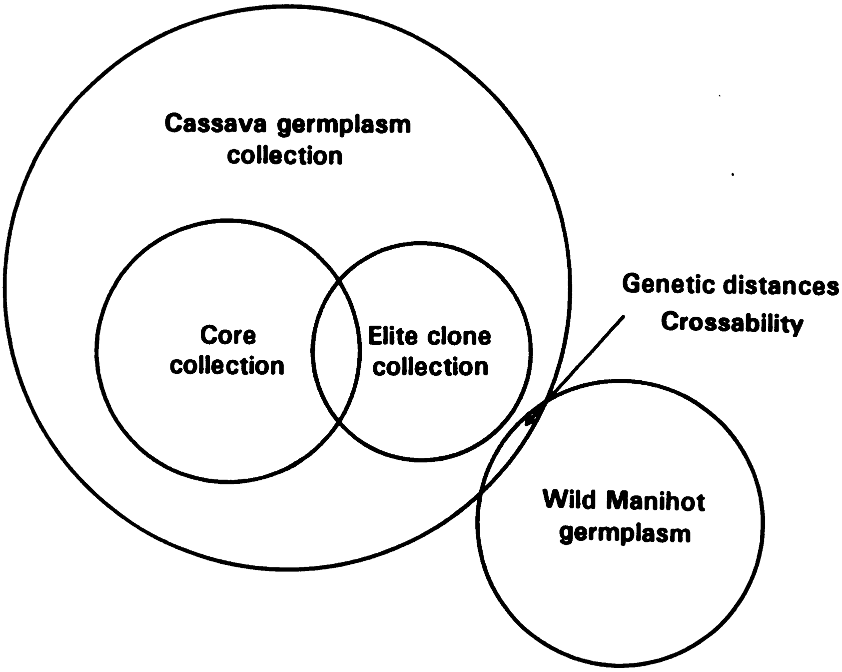

Figure 2. Relationship among Manihot genetic resources.

GENE-POOL DEVELOPMENT

The evolution of cassava across a range of edapho-climatic conditions has resulted in a wide genetic diversity with respect to adaptation to specific environments. This constitutes the basis upon which genetic improvement has proceeded at CIAT. The principal characteristics and constraints of the major cassava growing regions were taken into consideration when designing a breeding strategy (Hershey, 1984). Cassava is generally cultivated without purchased inputs under marginal conditions, subject to fluctuations in physical and biotic factors, most of them outside the farmers' control. One of the main objectives is to develop improved cultivars that can produce reliably under field conditions. Given the wide range of environmental and production systems, it is impossible to obtain a single genotype with adaptation to the majority of growing conditions.

Cassava growing environments were classified into various edapho-climatic zones (ECZ), so that the expected variation among zones would be greater than the variability within zones. The classification was based on the association among climate, soil and biotic factors over wide areas in the tropics. **Table 5** presents a description of the four majoı zones considered for germplasm development along with representative regions and evaluation sites in Latin America. The strategy has been to select one or more testing sites in Colombia representing the major conditions for cassava growing in a defined zone. The rationale behind this is that the gene-pools developed at those sites will provide an improved genetic base for adaptive selection in regions with homologous conditions. The breeding scheme used for the development of gene-pools for each of the broadely defined zones is presented in **Table 6**, along with the traits of importance and average number of individuals evaluated at each stage.

The top genotypes selected for each ECZ are incorporated into the elite clone collection; they are kept *in vitro* for their transfer to national programs, and they are used as parents to generate segregating progenies for further selection, either by CIAT or by the national programs.

RESEARCH SUPPORT FOR GENE-POOL DEVELOPMENT

Continued progress in cassava breeding at CIAT has relied on understanding the physiology of root yield and quality, and the mechanisms of biological and physical stress resistance or adaptation; their inheritance and their interaction with the environment, cropping system and market channels.

An effective interaction and support from different disciplines to the efforts in gene-pool development has been at the core of our strategy. The support from other disciplines has been evident in: assessing priority traits within ecosystems, identifying sources of genetic resistance or adaptation, developing routine screening methods, and assisting during the evaluation and selection process within each ecosystem.

Biotic Interactions

To demonstrate the complexity of the problem two important biotic constraints will be discussed: cassava root rots and cassava burrowing bugs.

Root rots are the most important pathological problems of cassava, especially in those areas where the crop is planted during succesive cycles or in flooded areas, in badly drained soils and/or during abnormally heavy rainy seasons. Root rots are induced by more than 28 reported bacterial and fungal species, of which *Ersinia carotovora, Xanthomonas campestris* pv. *carotovora, Diplodia manihotis, Scytalidium* sp., *Fusarium* spp., and *Phytophtora* spp. are the most important. Each species requires certain edapho-climatic conditions, which restrict their incidence and spread to specific regions. Consequently, research directed to controlling root rot problems in cassava is site specific and should integrate a set of control practices, one of them being varietal resistance. Due to the site specificity and the considerable variation for the causal agents, the development of standard laboratory and/or greenhouse screening techniques could

Table 5. Revised description of gene pools for defining cassava germplasm development.

No.	Description	Representative countries/regions	Main sites for breeding work
1	Subhumid tropics	Mexico (Yucatan peninsula); NE Brazil; NE Thailand; Domin. Rep.; N. Venezuela	Media Luna Carmen de Bolivar
1LC	Subhumid tropics; low HCN	Colombia (Atlantic Coast & Santanderes); Panama (Coclé); subhumid belt of Africa; Ecuador (NW coast)	Media Luna Carmen de Bolivar
2	Acid soil savannas	Mexico (Tabasco); Plains of Colombia & Venezuela; Brazil (Cerrado)	Villavicencio Carimagua
2LC	Acid soil savannas; low HCN	Cuba; W Africa savannas; Philippines; Panama (Ocu)	Villavicencio Carimagua
3	Humid tropical lowlands	Amazon basin (Brazil, Colombia, Peru); West Java & Sumatra; Malaysia; S. Vietnam	Villavicenio
3LC	Humid tropical lowlands; low HCN	Equatorial West Africa	Villavicenio
4LC	Mid-altitude tropics; low HCN	Andean zone; central Brazilian highlands; mid-altitude areas of Nigeria, Cameroon, East Africa	Palmira Santander de Quil.
5LC	High-altitude tropics; low HCN	Andean zone; Rwanda; Burundi	Popayán Mondomo
6	Subtropics	S Brazil; Argentina; China; N Vietnam	Sta Catarina (Brazil)
6LC	Subtropics; low HCN	Cuba; Paraguay; S Africa	Sta Catarina (Brazil)
7	Semiarid	NE Brazil	Guajira Sto Tomas NE Brazil
7LC	Semiarid; low HCN	NE Colombia; (Guajira) semiarid belt of West Africa; Tanzania; Mozambique; Ecuador (coast)	Guajira Sto Tomas NE Brazil

Note: Low HCN gene pools can also move to equivalent ECZs indicated for low/high HCN pools, but not *vice versa*.

Source: CIAT, 1992 a.(P. 17)

Table 6. Parameters of the cassava selection scheme practiced at CIAT.

Evaluation stage	Major traits considered	Site and replications	Selection pressure	Number of genotypes	Planting material multiplication	Time span (years)
Sexual seed produced						2
F_1	Pests and diseases	1 site 1 plant	80%	5000		0.5
F_1C_1	Pests and diseases Plant and root type	1 site 1 plant	15-20%	4000		1
Observational trial	+ Harvest index + Dry matter content + HCN	1(2) site 6 plants	20-25%	700		1
Preliminary yield trial	+ Root yield + Number of commercial roots	2 (3) sites 20 plants	20-25%	160		1
Advanced yield trial	+ Cooking quality	2 (3) sites 25 plants 3 replications	25-30%	36	200	2
Regional trial (On-farm)	+Adaptability to farmers' systems and preferences	6 (10) sites 64 (100) plants 3-4 replications		10	2000	2

help to effectively detect sources of resistance to different pathogens. A standard methodology has been developed at CIAT for phytophtora, fusarium, diplodia and scytalidium root rot (CIAT, 1992a). As shown in **Table 7**, the evaluation of the elite clone collection showed a wide range of reactions. There were clones resistant to one but highly susceptible to the other pathogen. A group of clones with none or reduced symptoms for both pathogens have been selected as the basic material for future recombination and selection in sites where root rots are caused by those agents. The reaction of some of the clones have been confirmed under field conditions. The correspondence between laboratory and field evaluations is an important aspect to select sources of resistance that are effective in farmers' fields.

Cassava burrowing bugs (*Cyrtomenus bergi*) are present in the soil feeding on cassava roots throughout the crop cycle. Root damage increases with plant age and can reach a level of 80% of the roots with more than 50% reduction in starch content. Field screening for genetic resistance is difficult due to the uneven pest distribution and

Table 7. Relationship between damage caused by species of Phytophtora and Fusarium in cassava roots artificially inoculated.

Clones	% damage caused by *Phytophtora*	% damage caused by *Fusarium*
Low–low		
CM 3401-2	0.0	0.0
CM 3281-4	0.0	8.7
MMal 2	0.0	9.1
Low–high		
MBra 383	1.9	36.5
SG 104- 57	0.0	37.7
CG 165- 2	0.0	42.4
High–low		
CM 3306- 4	62.0	0.0
CM 2967- 8	45.0	4.7
CM 2177- 2	59.7	5.9
High–high		
MVen 156	64.3	38.1
CG 1141- 1	65.7	39.0
MCol 2215	61.3	51.7

Source: CIAT (on-going work)

fluctuations in pest populations over time. Feeding preference for low cyanide clones results in considerable root damage compared to minimal damage incidence on high cyanide clones.

Mortality occurs when nymphs feed on cassava roots, but is considerably higher on high cyanide roots **(Table 8).** Measurements of stylet length during the first two nymphal instars indicate that feeding is confined to the cassava root peel. Since cyanide content in the peel and parenchyma can be genetically manipulated independently, the screening methodology for sources of resistance to burrowing bugs could emphasize the identification of genotypes with a thickened peel that contain high cyanide concentrations or other compounds that might induce resistance (Bellotti and Arias, 1993).

Abiotic Responses

Tolerance to drought is one of the basic characteristics for the adaptation of cassava germplasm to semi-arid environments. Within a project for cassava germplasm development in semi-arid Brazil, leaf conductance to water vapor was evaluated as an indicator of the capacity of different accessions to prevent water loss under prolonged drought. Considerable variation was observed in leaf conductance with values ranging from 1.0 to 9.0 mm/sec. A group of 26 genotypes with values between 2.2 and 5.0 was pre-selected as a source of genetic tolerance to prolonged dry periods. The majority of these genotypes were selected for Preliminary Yield Trials at the location where the measurement was made (Quixadá), and at other locations in semi-arid Brazil, as well as in Advanced Yield Trials across NE Brazil **(Table 9).** Results indicate that physiological

Table 8. Mortality of Cytomenus bergi nymphs feeding on cassava roots with relation to stylet length.

Instar	% mortality		Stylet	Peel
	CMC 40 (low HCN)	MCol 1684 (high HCN)	average length (mm)	thickness (mm)
I	26	40	1.4	
II	30	42	1.9	
III	0	2	2.9	2.0-2.5
IV	0	0	3.5	
V	0	0	3.9	
Total	**56**	**84**		

Source: Bellotti and Arias, 1993.

traits measured at representative sites could be used as indirect selection criteria to achieve broad adaptation for semi-arid conditions (Iglesias *et al.*, 1992).

Tolerance to drought has also been evaluated under induced prolonged water stress at different stages of the crop cycle, and some physiological/morphological traits associated with tolerance were identified. **Table 10** presents results on the performance of genotypes under controlled mid-season water stress in the field (CIAT, 1992b). Hybrid clones showed no (CM4013-1) or a moderate (CM4063-6 and SG536-1) reduction in dry root yield due to water stress. These genotypes had been previously selected under seasonally dry conditions in Media Luna (northern Colombia), which appears to be an

Table 9. Sources of resistance in Brazilian cassava cultivars to water stress and their relationship with final selection.

Clone	Lc(mm/s)[1]	Selected varieties for:					
		Preliminary Yield Trial locations					
		Itaberaba	Petrolina	Araripina	Quixadá	Advanced Yield Trial	Polycross semi-arid
Platina	5.00	x		x	x	x	x
Casco Roxo	4.70	x			x		x
Sacai	4.64	x	x		x	x	x
Sao Pedro Mirim Pampas	4.63						
Saracura	4.45		x		x		
Sapa R-16	4.22	x	x	x	x	x	x
Olho Verde II	3.86	x			x		
Mamao Branca	3.84	x	x	x	x	x	x
Pangola	3.81	x			x		
Do Céu	3.70	x	x	x	x	x	x
Sipeal-02	3.52	x	x				
Grande I	3.48	x					
Aparecida	3.37	x					
Rosa	3.17				x		
Sutinga Branca	2.95	x		x	x		
Milagrosa	2.81	x		x	x	x	x
Clone ESB-83	2.80		x	x	x		
Caravela	2.75		x				
Cigana Preta	2.74	x		x	x		
Batata I	2.54						
Cacau Vermelho	2.38		x		x		
Saracura I	2.36	x	x	x	x	x	x
Casca Grossa	2.29		x		x		
Engana Ladrao	2.26		x		x	x	x
Vassourinha Roxa	2.23						
Gemedeira	2.01	x	x	x	x	x	x
Total	**26**	**19**	**17**	**10**	**13***	**9**	**10**

[1] Lc= leaf conductance to water vapor, measured in mm per second.

Source: Iglesias *et al.*, 1992.

appropriate site for selection for adaptation to water stress. Under field conditions these genotypes showed a reasonable capacity to retain leaves under severe water stress. Leaf retention has become a trait of primary interest in the development of improved cassava gene-pools for semi-arid conditions.

Research on cassava photosynthesis has revealed a close relationship between leaf net photosynthesis measured under field conditions and root yield. Selection for high net photosynthesis in parental material may lead to higher yields when combined with other yield determinants, such as high leaf area index and harvest index. A preliminary field screening of the core collection has revealed that genotypes of sub-tropical origin (Argentina) showed significantly higher rates of average leaf photosynthesis and lower intercellular CO_2 **(Table 11)** than those from tropical areas (Brazil) (CIAT, 1992b). Similar results were obtained during evaluation of genotypes from *Manihot grahamii*, a

Table 10. Root and top yields, total biomass (dry t/ha) and harvest index at final harvest (11 mo) as affected by 3 months of mid-season water stress, commencing 90 days after planting at Santander de Quilichao, Colombia (1991/1992).

	Unstressed				Water stressed			
Clone	Roots	Tops	Total	HI	Roots	Tops	Total	HI
CM4013-1	10.9	7.5	18.4	0.59	11.5	3.9	15.4	0.75
CM4063-6	13.3	3.7	17.0	0.78	11.9	2.2	14.1	0.84
SG536-1	12.2	4.5	16.7	0.73	9.9	3.8	13.7	0.72
MCol 1505	11.1	5.2	16.3	0.68	7.3	2.9	10.2	0.72
Average	11.9	5.2	17.1	0.70	10.2	3.2	13.4	0.76
% change due to stress					-14	-38	-22	+9

Source: CIAT, 1992b.

wild cassava relative of sub-tropical origin. This finding has led to the selection of parental materials with high levels of photosynthetic activity, which could be combined in crosses with clones contributing excellence for other yield components to improve final root yield.

Cassava is usually grown in marginal low-fertility soils and with no or reduced levels of chemical amendments. Therefore, it is important to select materials that are able to produce well under limited availability of soil nutrients and at the same time having the ability to respond when those nutrients are added to the soil. Advanced breeding clones have been field-screened for their capacity to tolerate low levels of phosphorus and potasium (CIAT, 1992b). Genotypes with a high adaptation index

(Table 12) are being incorporated into gene-pools targeted to regions where the level of those nutrients in the soil are a constraint for cassava production. Modifications of

Table 11. Average leaf photosynthetic rate (μmol CO_2 $m^{-2}s^{-1}$) and intercellular CO_2 (μmol mol^{-1}) determined in accessions of the cassava core collection in CIAT, Palmira, 1991/1992.

Accession	Photosyn. rate	Intercellular CO2	Accsion	Photosyn. rate	Intercellular CO2
MArg 11	32	73	MBra 258	22	143
MBra 12	30	82	MBra 273	22	128
MBra 110	30	74	MBra 77	22	145
HMC 1	29	87	MBra 233	22	144
MArg 2	28	95	MArg 12	22	146
MBra 132	28	88	MBra 416	22	151
MBra 172	27	83	MArg 15	22	139
MArg 13	27	105	MBra 356	22	156
MBra 359	27	127	MBra 191	21	145
MBra 71	26	111	MBra 383	21	162
MArg 7	26	119	MBol 1	21	147
MBra 85	26	112	MBra 309	21	148
MArg 9	26	110	MBra 453	21	159
MBra 190	26	97	MBra 400	21	169
MBra 124	26	100	MBra 329	20	159
MBra 403	25	131	MBra 435	20	173
MBra 162	25	108	MBra 337	19	177
MArg 6	25	115	MBra 158	19	137
MBra 242	24	133	MBra 325	18	169
MBra 299	24	133	MBra 237	17	173
MBra 165	24	114	MBra 335	17	195
MBra 243	23	132	MBra 450	17	196
MBra 405	23	143	MBra 328	17	182
MBra 73	23	134	MBra 311	16	188
MBra 217	23	140	MBra 315	16	191
MBra 404	23	151	MBra 335	14	187
MBra 125	23	129			
LSD 5%	6.2	44			
Average of accessions according to origin:					
Argentina	26	112			
Brazil	22	141			
P<	0.0001	0.0001			

Source: CIAT, 1992b.

plant architecture could also be an important step toward a more efficient use of soil nutrients. The approach being considered includes the development of semi-dwarf gene-pools, from which short varieties could be developed and combined with production practices that enhance nutrient recycling. Stabilizing productivity without increasing pressure on limited natural resources is of paramount importance for sustainable agriculture.

Quality Factors

Root and leaf quality traits are increasingly recognized as critical for both traditional and new markets. Recently, the defined core collection was evaluated for cyanide content in root peel and parenchyma. Results showed that it is possible to select accessions with extremely low levels of cyanide in root parenchyma, while retaining considerable accumulation in the root peel. A hot-spot for low cyanide genotypes was the highland region of Colombia. The 15 clones with the highest and lowest total

Table 12. Fresh root yield and low-P or low-K adaptation index of highly adapted germplasm, as determined in Santander de Quilichao, 1989–1990.

	Fresh root yield (t/ha)		
Clone	Zero P	75 kg P/ha	Low-P adaptation index[1]
CM 489-1	41	41	1.74
CG 913-4	40	41	1.65
Mean of all clones	28	35	1.00
	Zero K	100 kg K/ha	Low-K adaptation index[1]
CM 507-37	30	66	2.22
MVen 25	29	53	1.74
Mean of all clones	21	42	1.00

[1]Low-nutrient adaptation index = $\frac{\text{(Yield at zero nutrient) (Yield at high rate of nutrient)}}{\text{(Mean yield at zero nutrient) (Mean yield at high rate of nutrient)}}$

Source: CIAT, 1992a, pp.3-5

cyanide contents were subjected to detailed starch functionality studies (Wheatley *et al.*, 1993). Results suggest that differences in starch viscosity characteristics, and hence behavior during traditional processing, are significantly different between high and low cyanogen cultivars **(Table 13).** For instance, clone MCol 2360 had a maximum viscosity of 168 and a viscosity at 90°C of 130 B.U., compared with mean values of 10 and 392 B.U. for low cyanogen clones, respectively. Contrary to findings in other starchy crops, there

Table 13. Mean values of amylose % and starch functionality characteristics for 15 clones of extreme low and high total parenchyma cyanogen content.

Characteristic	Low CN group	High CN group	Significant difference (P>)
Total cyanogen (mg kg^{-1}) in parenchyma, fresh basis	13	461.0	0.001
Amylose (%)	22.9	21.6	n.s
Gelatinization temp. (°C)	64.1	64.7	n.s
Maximum viscosity	509.5	359.5	0.0001
Viscosity at 90° C	391.5	230.2	0.0001
Viscosity after 20 minutes at 90° C	232.6	133.5	0.0001
Viscosity at 50° C	391.3	198.7	0.0001
Ease of cooking	10.2	6.3	0.0001
Gel instability	276.9	222.1	0.014
Gelification index	158.7	65.3	0.0001

Source: CIAT, 1992 b , p.51

was no correlation between percentage amylose and any of the starch functional characteristics or cyanide content. These studies have established the basis for genetic modification of cassava starch properties while maintaining low cyanide content.

Rapid post-harvest deterioration of cassava roots is a constraint for the expansion of fresh cassava markets. Previous reports have indicated a strong association between root dry matter content and physiological deterioration. Recent studies, using a standardized evaluation methodology over a wide range of genotypes under different environments (CIAT, 1992b), revealed high levels of genetic determination for the trait and low, non-significant correlation with dry matter content. This indicates the possibility of incorporating resistance to post-harvest deterioration within a selection index together with dry matter content, with relatively good chances for genetic progress. Clones with high levels of deterioration are being crossed to the others presenting reduced levels, in order to build up genetic stocks to study intrinsic biochemical processes involved in post-harvest deterioration.

Methodologies for Gene–pool Enhancement

Breeding Methodology

Cassava gene-pools are generated for broadly defined agro-ecosystems. Genotypes are evaluated across two or more representative sites within each of the ecosystems. The breeding scheme used at CIAT allows for evaluation of genotypes across ecosystems. In order to test the possibility of broadening the range of adaptation of future selections made at CIAT, a group of 220 elite clones was evaluated for two years in three different agro-ecosystems (mid-altitude, lowland humid tropics, and subhumid tropics). A cluster analysis using dry matter production per hectare resulted in six groups explaining 70% of the total variation (CIAT, 1992b). The majority of the clones presented specific adaptation to the ecosystem for which they were selected and relatively poor adaptation to the others **(Table 14).** A group of 23 genotypes was selected for their moderate to good performance in the three agro-ecosystems, constituting the basis for the development of gene-pools with broader adaptation across tropical ecosystems.

Biotechnology and Cassava Improvement

Most of the research on biotechnological aspects of cassava is coordinated within the Cassava Biotechnology Network (CBN). The CBN concentrates on using biotechnology in solving constraints that are recalcitrant to traditional research approaches. The use of genetic engineering may open the way to the introduction of desirable genes into a heterozygous background without losing positive attributes in landraces or elite clones for any of the important agro-ecosystems. The efficiency of conventional breeding would then be enhanced every time a constraint is dropped from the list of selection criteria. It would certainly represent a fast way of incorporating new attributes into common varieties, as well as for pyramiding genes for resistance or tolerance to biotic and abiotic constraints. Genetic transformation will open the possibility of incorporating novel traits into cassava, making use of the genetic diversity outside the genus *Manihot.* The work being done in coding and transforming the sequence of virus coat proteins as a "coat-mediated" means of protection, is one of the examples of what could be achieved in the future (Roca and Thro, 1993).

The work being developed in the area of molecular markers and the construction of a molecular map for cassava will have profound consequences for the improvement of those traits that can not be easily measured, or that are not expressed under certain circumstances. Molecular-marker-aided selection can facilitate the process of gene-transfer from wild species to cassava, and the pyramiding of genes within the gene-pool development process.

There is a group of challenges or threshold technologies, whose development would have major impact on the application of future research in cassava. Among those breeding challenges, the following have been placed as high priority by the Cassava Biotechnology Network: a) optimizing cyanide content in cassava tissues; b) qualitative improvement in the potential for post-harvest storage; c) modification of starch characteristics for specialized markets; d) coupling an increase in tolerance to stress with mechanisms for preserving fragile environments; and e) an alternative for seed-propa-

Table 14. Grouping of elite clones according to their production of dry matter (t/ha) at three sites.

	Group	CIAT-Palmira	La Libertad	Media Luna
	1	2.01	5.96	2.49
	2	3.96	2.83	3.14
	3	2.28	4.43	5.84
	4	1.40	2.79	2.61
	5	6.89	4.17	4.17
	6	2.20	8.97	5.05

Clones in group 5 having relatively broad adaptation.

MBra 383	4.89	4.68	4.29
CG 1-37	4.52	7.05	3.51
CG 1-48	4.23	7.32	3.36
CG 6-71	2.77	6.15	4.70
CG 1372-5	6.70	6.87	2.99
CG 1534-10	2.70	6.65	3.18
CM 955-2	4.53	6.17	2.65
CM 1305-3	3.77	5.82	5.09
CM 2146-3	5.19	6.34	5.09
CM 2772-3	6.11	5.54	3.72
CM 2967-8	2.66	7.17	3.42
CM 3171-8	7.31	5.78	3.86
CM 3294-1	4.11	8.49	2.76
CM 3299-4	3.40	11.35	4.59
CM 3306-4	3.20	7.36	3.85
CM 3306-9	3.22	7.52	4.95
CM 3306-19	6.49	7.28	4.14
CM 3320-4	5.98	10.36	4.37
CM 3997-1	4.47	7.54	3.66
CM 4157-34	4.24	10.65	8.79
CM 4843-1	5.80	5.00	4.61
SG 557-6	5.82	6.81	4.84
SG756-7	7.78	6.45	4.10

Source: CIAT, 1992 b , p.111

gated cassava, preferably through apomixis, to overcome several constraints associated with vegetative propagation, such as fungal, bacterial and viral disease transmission.

CONCLUSION

A multidisciplinary approach and the focus of basic and strategic research toward the development of gene-pools have been the key to confront multiple stress factors together with yield and quality improvement during selection. As a result, a wealth of improved genetic diversity has been distributed to national programs, from which remarkable new cultivars have been derived. Progress is going to continue as long as an interdisciplinary team of scientists concentrates on the assessment of needs and constraints for specific ecosystems, study the basis of resistance, tolerance, or physiological traits, and develop screening methodologies that enhance naturally ocurring stresses during the selection process. A combination of classical and new research technologies will continue to provide high-yielding and stress-tolerant cultivars as one of the most important components for sustainable cassava production.

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RECENT PROGRESS IN CASSAVA AGRONOMY RESEARCH IN INDIA

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ABSTRACT

Cassava is an important crop in India, with an area of 289,000 ha and production of 5.6 million t of fresh roots in 1991. It is mainly cultivated in Kerala, Tamil Nadu, Andhra Pradesh and in the Northeastern states. A large variation in cassava consumption exists between urban and rural areas in India. About 70% of cassava production in Kerala is used for food. In Tamil Nadu, however, only 25% is used for human consumption, while the rest is used for industrial utilization, mainly for starch production. About 17% of cassava production in the country is used for animal feed. Cassava is used in industry for production of starch, sago, liquid glucose, dextrin, vitamin C, gums and high-fructose syrup.

Earlier agronomy research concentrated on the development of cultural practices and soil fertility management for cassava grown in monoculture. Recently, research has focused on the development of cassava-based cropping systems, soil fertility management with emphasis on micronutrients and bio-fertilizers (especially VA-mycorrhiza), low-input technology, water management and production practices for non-traditional areas.

Short-duration cassava cultivars were shown to produce higher root yields at closer spacing of 75x75 cm, while for cassava grown under coconuts a plant population of 8000/ha was found to be optimum. Under intercropping with groundnut or cowpea the paired-row cassava system performed best.

In acid infertile soils in Kerala, continuous cropping of cassava with application of only NPK chemical fertilizers resulted in a depletion of Ca, Mg, Cu and Zn in the soil. From the study on interrelationships of cations the optimum doses of K, Ca and Mg were found to be 146 kg K_2O, 56 kg Ca and 37 kg Mg/ha. Incorporation of $ZnSO_4$ at 12.5 kg/ha increased the root yield 12%. An NPK application of 50:62:62 kg/ha was sufficient for the cassava-groundnut intercropping system if the haulms of groundnut were turned back into the soil. For cassava grown under coconut an NPK rate of 50:50:100 kg/ha gave higher net returns. For rice-cassava sequential cropping on paddy soils the P application rate to cassava could be reduced to 25 kg P_2O_5/ha.

In calcareous soils of Tamil Nadu short duration cassava cultivars performed better at lower levels of NPK (75:25:75 kg/ha). Application of a liquid NPK fertilizer at the rate of 8-8-8 kg/ha was equally effective as the same rate applied in solid form.

Inoculation of VA mycorrhiza (VAM) enhanced the dry matter production, root yield and uptake of P, Cu and Zn in cassava. For successful field inoculation a nursery technique

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was developed.

To realize the production potential of high-yielding cassava, the application of NPK at 150:100:150 kg/ha and supplementary irrigation at an IW/CPE ratio of 1 were found necessary. In cassava-groundnut intercropping systems, supplementary irrigation during drought periods at 25 mm/week enhanced the yield of both crops. Studies on effects of subsoil moisture on cassava showed that a shallow water table (around 40 cm from the surface) depressed root yields.

INTRODUCTION

Among the tropical root and tuber crops grown in India, cassava is the most important. It is cultivated in a wide range of soils, climates and environmental conditions. In Asia, India ranks third in cassava production after Thailand and Indonesia. With respect to area it occupies the fourth position.

Area, Production and Yield

According to the latest statistics available, cassava occupies an area of about 289,000 ha in India producing 5.6 million t fresh roots. Data on area and production of cassava in India for the past decade **(Table 1)** indicate a declining trend until 1989. However, 1990 witnessed a 17% increase in area and a 21% rise in production. Cassava yields during the above period fluctuated between 16 and 20 t/ha. Cassava is one of the few

Table 1. Cassava area, production and yield in India during the past decade.

Year of harvest	Area ('000ha)	Production ('000t)	Yield (t/ha)
1981	321	5,868	18.28
1982	323	5,292	16.38
1983	302	5,341	17.69
1984	319	5,886	18.45
1985	305	5,662	18.56
1986	276	4,884	17.69
1987	265	4,814	18.16
1988	270	5,213	19.30
1989	239	4,469	18.73
1990	289	5,674	19.63

Source: Agricultural Situation in India.

Table 2. Cassava area, production and yield in the major producing states in India in 1981 and 1990.

Important cassava growing states	Area ('000ha)		Production ('000t)		Yield (t/ha)	
	1981	1990	1981	1990	1981	1990
Andhra Pradesh	14.6	13.0	112.6	101.0	7.70	7.80
Arunachal Pradesh	3.4	2.5	8.5	5.0	2.50	2.00
Assam	1.5	1.9	6.7	8.4	4.40	4.40
Kerala	248.1	205.0	3745.1	3763.7	15.10	18.30
Meghalaya	3.8	4.1	19.7	23.8	5.10	5.80
Tamil Nadu	48.5	58.4	1370.5	1747.0	28.30	30.00
Others	3.3	3.8	28.5	25.2	8.60	6.63
All India	323.2	289.3	5291.6	5674.1	18.20	20.00

Source : Agricultural Situation in India. 1981 Vol.35, 1992 Vol.46.

crops in which India's yield levels are higher than those obtained in other countries. According to the latest FAO statistics, the average cassava yield in India in 1992 was 21 t/ha, which was the highest in the world (FAO, 1993).

In India cassava is mainly cultivated in Kerala, Tamil Nadu, Andhra Pradesh and in the Northeastern states **(Table 2)**. Kerala ranks first with 72% of the area and 66% of production. Cassava finds a place in various cropping systems throughout Kerala. Traditionally, cassava production was confined to the hilly uplands having undulating terrain and infertile soils. Recent studies indicate that in terms of area about 40% of cassava is grown as an intercrop in coconut gardens, especially in the southern districts of the state. Recently, cassava cultivation has also been spreading to single crop paddy lands that lack enough water for growing more than one crop of rice (Nayar, 1992).

The next important cassava growing states in India are Tamil Nadu and Andhra Pradesh. Tamil Nadu with 20% of the cassava area planted contributes 30% of production, due to the very high yields of about 30 t/ha. Salem, Kanyakumari, South Arcot, Tiruchirapalli and Dharmapuri districts are the main cassava areas in Tamil Nadu. Except in Kanyakumari district, the crop is mostly grown under open conditions, with supplemental irrigation during dry months. In Andhra Pradesh cassava farms are concentrated in East Godavari and Sreekakulam districts. In these areas, even though it rains during only five months, cassava is grown successfully without irrigation but with the adoption of special nursery and transplanting techniques.

Cassava Utilization

Wide variation exists in cassava utilization among the states. In Kerala 70% of cassava is used for human food, while in Tamil Nadu this is only about 25% (Kurup, 1992). Also, in Kerala large differences in cassava consumption patterns exist between rural and urban households (CTCRI, 1991). Daily per capita consumption of cassava was reported to be 410 g in rural areas compared to 120 g in urban areas. In the Northeastern states also a major part of cassava production is utilized for human food by the tribal farmers. Most of cassava produced in Andhra Pradesh and Tamil Nadu is utilized in starch and starch-based industries, manufacturing sago, liquid glucose, dextrin, vitamin C, gums and high-fructose syrups. Data on state-wide utilization of cassava for animal feed are not available. It is roughly estimated that 17% of total cassava production is used for feeding animals, mainly as fresh roots, particularly in Kerala.

RESEARCH ACCOMPLISHMENTS

Research on cassava agronomy is mainly conducted at the Central Tuber Crops Research Institute (CTCRI) in Trivandrum, Kerala and under the All-India Coordinated Research Project on Tuber Crops (AICRPTC) at different State Agricultural Universities. Earlier research efforts concentrated on development of packages of practices for monocropping cassava. Recently, more attention is paid to the development of agronomic practices for cassava-based cropping systems, soil fertility management with stress on micronutrients and biofertilizers (especially VAMF), low input technology, water management and cultural practices for non-traditional areas. Salient achievements on these aspects, since the third Asian Workshop in 1990 are presented.

Agronomic Practices

Short-duration genotypes of cassava are preferred for sequential cropping and in non-traditional areas, where the rainfall distribution is limited to only a few months. Hence, experiments to develop agronomic practices for short-duration lines of cassava

Table 3. Effect of plant spacing on root yield (t/ha) of three short duration varieties of cassava planted with irrigation in Coimbatore, Tamil Nadu, India.

Plant spacing	I Season				II Season			
	H-119	CI-590	S-865	Mean	H-119	CI-590	S-865	Mean
90x90 cm	36.55	26.95	30.40	31.30	31.40	29.45	26.25	29.03
75x75 cm	40.15	39.90	37.95	39.00	37.70	32.15	29.15	33.00
Mean	38.35	32.93	34.18	-	34.55	30.80	27.70	-
CD (5%)	for spacing			0.78				0.91
CD (5%)	for variety x spacing			1.35				1.57

Source : Venkatachalam *et al.*, 1991.

were initiated under the AICRPTC (AICRPTC, 1991). Studies conducted at Coimbatore to evaluate the effect of spacing on three short-duration genotypes of cassava, i.e. H-119, CI590, and Sree Prakash, showed that under irrigated conditions all the above genotypes produced significantly higher root yields at the closer spacing of 75x75 cm **(Table 3).**

Intercropping cassava in coconut gardens is a common practice, especially in Kerala. The yield of cassava intercropped in mature coconut gardens is often reduced to 40-50%, since the shoot (stem + leaves) act as the major sink for carbohydrates. Field experiments were conducted for two consecutive seasons to study the effect of growth regulators (ethrel and cycocel) and planting density on two cassava cultivars, i.e. Malayan-4 (M-4) and Sree Visakham, intercropped under mature coconut trees (Nayar and Sadanandan, 1990). Cycocel at 1500 ppm was effective in retarding the vegetative growth and thereby enhancing the root:shoot ratio. Sree Visakham was significantly superior to M-4 in root:shoot ratio, indicating its ability to divert more photosynthates to the storage roots, even under the partially shaded conditions prevalent in coconut gardens **(Table 4).** A plant population of 8000 cassava plants/ha (cassava planted at

Table 4. Effect of variety, planting density and growth regulators on cassava intercropped under coconut trees.

Treatments/Varieties	Root yield (t/ha)		Root : Shoot ratio	
	I Year	II Year	I Year	II Year
Malayan-4	5.48	5.58	0.818	0.829
Sree Visakham	7.41	7.27	1.037	1.048
Plant population (spacing)				
20,000/ha (60x60cm)	5.69	5.67	0.508	0.532
8,000/ha (90x90cm)	8.12	8.24	1.113	1.120
5,000/ha (120x120cm)	5.53	5.38	1.161	1.160
CD (0.05)	0.34	0.04	0.010	0.010
Growth regulator				
Ethrel-500 ppm	6.49	6.40	0.917	0.933
Ethrel-1000 ppm	6.12	6.44	0.925	0.940
Cycocel-1000 ppm	6.49	6.38	0.920	0.926
Cycocel-1500 ppm	6.61	6.47	0.960	0.947
Check	6.53	6.44	0.923	0.941
CD (0.05)	NS	NS	0.018	0.010

Source : Nayar and Sadanandan, 1991.

90x90 cm except for 2 m diameter circles around each tree) was found to be optimum for intercropping under coconut trees, in which the coconuts were planted at a spacing of 7.5x7.5 m (Nayar and Sadanandan, 1991).

According to most previous reports, intercropping legumes like groundnut and cowpea with cassava causes a yield reduction of the main crop. Manipulation of spatial arrangements is one of the means to mitigate such yield losses. Experiments conducted by Meera Bai *et al.* (1991) showed that the paired-row system of planting cassava was beneficial in realizing higher yields of the main as well as the intercrop, i.e. groundnut and cowpea **(Table 5).** Higher net income was also realized from the paired-row intercropping system.

Field experiments conducted earlier at CTCRI indicated that pruning cassava stems during periods of drought, i.e. at the 7-8 month stage, and retaining the plants for another 8 months, was effective in doubling the yield compared to harvesting at the normal time of 10 months (Ramanujam, 1987). Efficacy of this practice was tested at Coimbatore in Tamil Nadu and at Peddapuram in Andhra Pradesh. At Coimbatore pruning the cassava stems after 8 months and harvesting the crop after 16 months gave higher root yields (AICRPTC, 1991). On the contrary, at Paddapuram harvesting the crop at the normal time of 10 months was reported to be superior (ARS, 1991).

Soil Fertility Management

Effect of long term cropping and fertilizer application on soil fertility

A field experiment to study the effects of long term cropping and fertilizer application in an acid infertile Ultisol was commenced at CTCRI in 1977. The initial pH of the experimental site was 4.7 and available N, P and K were 119, 25 and 69 ppm, respectively. During the experimental period, N, P_2O_5 and K_2O were applied annually at 100 kg/ha, while farm-yard manure (FYM) and wood ash were applied at the rate of 12.5 and 2.65 t/ha, respectively. There were 18 treatment combinations as shown in **Table 6.** The changes in soil characteristics were monitored after 12 years (Kabeerathumma *et al.*, 1991). Soil pH was not affected by the treatments except in the case of continuous application of wood ash, which increased soil pH from 4.7 to 6.1. Prolonged application of ash substantially increased also the Ca and Mg contents. Continuous cropping of cassava with application of only chemical fertilizers reduced the Ca, Mg, Cu and Zn contents of the soil. However, treatments having FYM and ash were capable of maintaining adequate levels of the secondary and micronutrients. Soil organic matter contents decreased when unbalanced rates of chemical fertilizers were applied, but were maintained constant with a balanced application of N, P and K or with the application of FYM, with or without fertilizers. Annual applications of 100 kg/ha of K_2O and P_2O_5

Table 5. Yield of cassava and intercrops under different intercropping systems.

Treatments[1)]	Cassava root yield (t/ha)	Yield of first intercrop		Yield of second intercrop	
		Groundnut (kg/ha)	Cowpea (kg/ha)	Cowpea (kg/ha)	Blackgram (kg/ha)
1. Cassava monoculture (square planting)	19.46	-	-	-	-
2. C+G " "	21.77	819	-	-	-
3. C+CP " "	19.84	-	2,577	-	-
4. Cassava monoculture (paired-rows)	19.68	-	-	-	-
5. C+G "	22.21	929	-	-	-
6. C+CP "	22.22	-	2,145	-	-
7. C+G-CP "	22.34	938	-	25	-
8. C+G-BG "	21.55	908	-	-	Negligible
9. C+CP-CP "	20.45	-	1,501	35	-
10. C+CP-BG "	20.48	-	1,770	-	7
11. Groundnut monoculture crop	-	1,785	-	-	-
12. Cowpea + cowpea monoculture crop	-	-	2,701	916	-
13. Blackgram monoculture (Sept. planting)	-	-	-	-	852

1) C = cassava, G = groundnut, CP = cowpea, BG = blackgram.

Source : Meera Bai *et al.*, 1991.

Table 6. Long-term effect of farm yard manure (FYM) and chemical fertilizers on soil characteristics after 12 years of continuous cassava cropping at CTCRI, Trivandrum, India.

Treatment	% org.C	ppm P	K	Ca	Mg	Cu	Zn
Initial	0.70	12.5	34.5	45	24.8	0.52	0.82
N	0.38	10.6	16.8	15	8.0	0.25	0.20
P	0.26	114.5	20.1	35	21.5	0.13	0.14
K	0.48	11.1	71.7	18	6.3	0.30	0.27
NP	0.39	148.4	24.1	23	15.7	0.37	0.24
NK	0.50	12.4	53.7	20	9.3	0.27	0.44
PK	0.41	141.0	91.8	30	21.4	0.32	0.57
NPK	0.67	131.5	48.1	20	9.0	0.24	0.30
FYM + N	0.91	56.0	26.9	25	21.0	0.34	0.68
" + P	0.83	165.0	30.2	48	41.3	0.40	0.78
" + K	0.75	32.2	82.3	32	54.3	0.45	0.75
" + NP	0.87	133.0	26.9	24	7.8	0.40	0.54
" + NK	0.91	30.8	52.6	20	21.3	0.48	0.68
" + PK	0.74	112.0	85.1	30	21.8	0.43	0.67
" + NPK	0.98	131.5	48.1	30	20.6	0.44	0.70
FYM	0.96	55.3	35.8	40	48.5	0.37	0.67
Wood ash	0.49	11.2	102.5	240	136.9	0.54	0.80
FYM + Ash	0.50	13.2	96.3	280	146.2	0.56	1.05
Control	0.23	11.2	20.7	16	9.8	0.16	0.22

Source : Kabeerathumma *et al.*, 1991.

resulted in a marked build up of available K and P in the soil; the P-level became excessively high.

Interrelationships of potassium, calcium and magnesium

The influence of different levels of potassium, calcium and magnesium on the yield, quality and uptake of cations in cassava was studied at CTCRI for 3 seasons in a field experiment laid out in a second-order rotatable design (Mohankumar *et al.*, 1991). From this study the optimum doses of K_2O, Ca and Mg were found to be 146, 56 and 36 kg/ha, respectively. But the economic optimum dose of the above nutrients, which maximizes the net return, was computed to be 137:49:30 kg/ha. An increase in the levels of cations applied, also resulted in an increase in their concentrations in the soil and their uptake by cassava. However, a K antagonism was observed as higher levels of K decreased the level of exchangeable Mg and Mg uptake, and *vice-versa.*

Distribution and availability of micronutrients in soils under cassava

In India most cassava is grown on Ultisols, followed by Alfisols, Vertisols and Entisols. Since symptoms of Zn deficiency in Ultisols and Fe deficiency in Vertisols are often encountered in cassava fields, a systematic study was undertaken to assess the micronutrient status in major cassava soils in Kerala (Pillai *et al.,* 1991). It was found that the vertical distribution in the soil profile of the total amount of each micronutrient did not follow any definite pattern, whereas the amounts of available micronutrients decreased with increasing depth. However, unlike the other micronutrients, available B increased with depth in the profile **(Table 7).** All the soil types in Kerala were reported to be deficient in Zn and B; but they were found to be sufficiently supplied with Fe, Mn and Cu. Similar studies were conducted in soils of Tamil Nadu by Sheeja *et al.* (1992), who reported that Vertisols were found to be deficient in available Fe, Zn and B, wherease Alfisols were deficient in B and Zn.

Response to applied nutrients

Field experiments conducted at CTCRI showed that incorporation of $ZnSO_4$ at 12.5 kg/ha (in addition to the normal fertilizer dosage of 100 N, 50 P_2O_5 and 100 kg K_2O/ha) increased the root yield by 12% (CTCRI, 1992). However, application of Mg as $MgSO_4$ with the NPK fertilizer had no influence on the yield of cassava **(Table 8).** The response of three short duration genotypes of cassava, i.e. H-119, CI-590 and Sree Prakash, to levels of NPK was also assessed by Venkatechalam *et al.* (1991) in a Vertisol at Coimbatore. All the genotypes performed better at the lower level of 75N, 25 P_2O_5 and 75 kg K_2O/ha **(Table 9).**

In another experiment conducted at CTCRI the effect of time and duration of K application was studied in sand culture (Nair and Aiyer, 1990). The treatment receiving K at biweekly intervals from 0 to 4 1/2 months produced the highest root yield **(Table 10).** However, the highest K concentration in the youngest fully-expanded leaf blades was recorded under the treatment receiving K at biweekly intervals from 0 to 10 months after planting (MAP), though this treatment was not beneficial in maximizing root yield. Thus, K application beyond 4 1/2 months after planting resulted in luxury consumption of K and in a decrease in yield. This yield decrease is probably due to an imbalance in the absorption of Ca and/or Mg. **Figure 1** shows the relationship between root yield and the K concentration in YFEL-blades at 4 MAP. Critical levels of 1.95% K for deficiency and 2.4% K for toxicity were estimated.

Table 7. Vertical distribution of micronutrients in different profiles of cassava growing soils of Kerala.

Depth	Total micronutrients (ppm)					Available micronutrients (ppm)				
(cm)	Cu	Zn	Fe	Mn	B	Cu	Zn	Fe	Mn	B
Profile 1 : Alfisol in Neyyattinkara (Thriruvananthapuram)										
0-15	36	68	21990	350	63	0.28	0.22	3.36	54.06	0.17
15-30	41	66	22340	327	73	0.36	0.22	1.72	28.64	0.22
30-60	47	72	23065	324	105	0.26	0.28	1.18	10.50	0.14
60-90	45	61	21915	247	235	0.24	0.13	1.16	9.38	0.36
Profile 2 : Ultisol in Kundara (Quilon)										
0-15	49	83	19600	119	205	0.52	0.34	15.06	8.52	0.08
15-30	56	110	19895	123	280	0.32	0.16	11.82	9.66	0.07
30-60	59	98	21905	82	270	0.24	0.09	3.84	11.56	0.03
60-90	58	90	20185	82	350	0.26	0.19	3.66	6.48	0.13
Profile 3 : Entisol in Kayamkuram (Alleppey)										
0-30	16	35	5810	78	475	0.86	0.29	19.14	2.40	0.02
30-60	14	43	6585	85	525	0.48	0.19	5.48	3.44	0.06
60-90	18	74	7320	88	98	0.50	0.22	3.72	2.34	0.09
Profile 4 : Mollisol in Kulathupuzha (Thriruvananthapuram)										
0-15	37	51	17590	66	70	0.60	0.31	30.16	1.33	0.17
15-30	20	45	19750	54	16	0.38	0.31	24.90	1.09	0.17
30-60	20	43	20145	40	13	0.25	0.24	13.60	0.77	0.27
60-90	12	37	20975	54	4	0.20	0.30	8.32	0.58	0.30

Source : Pillai *et al.,* 1991.

Table 8. Response of cassava to the application of magnesium and zinc at CTCRI in Trivandrum, Kerala, India.

Treatments	Root yield (t/ha)
NPK (100:50:100kg/ha)	19.30
NPK+Mg (20 kg/ha)	17.78
NPK+$ZnSO_4$ (12.5kg/ha)	21.85
NPK+Mg+Zn	18.79
F-test	NS

Table 9. Influence of two levels of NPK fertilizers on the yield of three short-duration cassava cultivars in Coimbatore, Tamil Nadu, India.

Levels of	I Season				II Season			
N-P_2O_5-K_2O (kg/ha)	H-119	Cl-590	S-856	Mean	H-119	Cl-590	S-856	Mean
100:50:100	37.45	33.30	34.15	34.97	33.85	29.70	27.35	30.30
75:25:75	39.25	32.55	34.20	35.33	35.25	31.90	28.05	31.72
Mean	38.35	32.93	34.18	-	34.55	30.80	37.70	-
CD (5%)				0.78				0.91

Source : Venkatachalam *et al.,* 1991.

Table 10. Effect of duration of K application (equivalent to 100 kg K_2O/ha applied at biweekly intervals as nutrient solution) on the root yield at 10 months and the K concentration of leaves at 4 and 10 months of two cassava cultivars grown in sand culture at CTCRI, Trivandrum, Kerala, India.

Duration of K application	Root yield (kg/plant)			Potassium in YFEL-blades (%) At 4 months		Potassium in YFEL-blades (%) At 10 months	
	H-2304	M-4	Mean	H-2304	M-4	H-2304	M-4
T1 = no K applied	1.42	1.38	1.40	0.45	0.38	0.41	0.35
T2 = 0 to 1.5 months	2.33	1.92	2.13	0.95	0.90	0.92	0.86
T3 = 0 to 3 months	3.13	2.75	2.94	1.36	1.25	1.24	1.10
T4 = 0 to 4.5 months	6.92	4.08	5.50	2.32	1.98	2.05	1.74
T5 = 0 to 10 motnts	3.32	3.15	3.23	2.64	2.35	2.28	1.99
T6 = 4.5 to 10 months	2.05	2.17	2.11	0.85	0.80	0.83	0.78
T7 = 3 to 4.5 months	3.35	3.63	3.49	1.20	1.05	0.98	0.87
T8 = 1.5 to 3 months	2.72	2.03	2.38	1.52	1.38	1.35	1.26
T9 = 1.5 to 4.5 months	2.57	2.20	2.38	1.25	1.10	1.11	0.98
Mean	3.09	2.50					
CD (0.05) for V :	0.137			0.121		0.099	
CD (0.05) for T :	0.291			0.201		0.143	

Source : Nair and Aiyer, 1990.

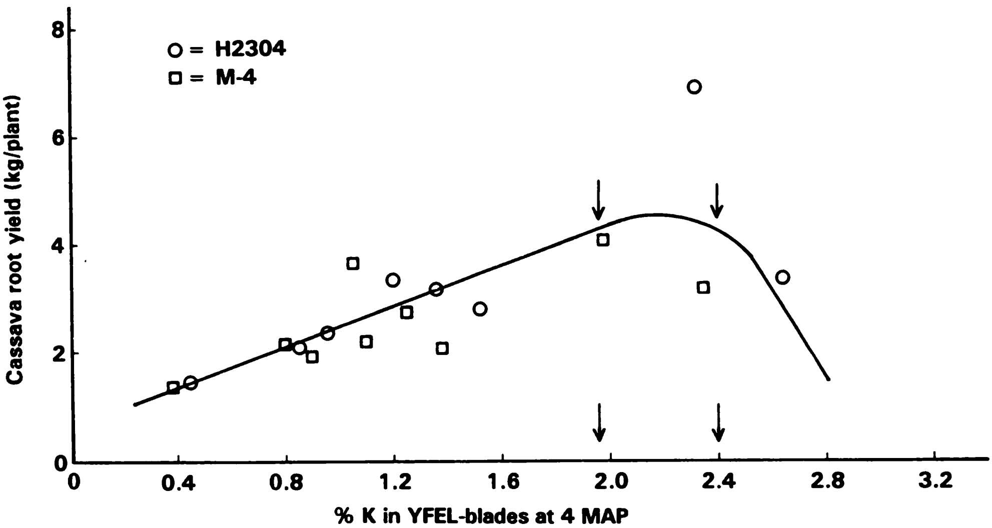

Figure 1. Relation between cassava root yield at 10 months and the K concentration in youngest fully expanded leaf (YFEL) blades at 4 months after planting in sand/nutrient solution culture at CTCRI, Trivandrum, India. Arrows indicate critical levels for deficiency and toxicity.

***Source** : adapted from Nair and Aiyer, 1990.*

Effect of slow-release nitrogen fertilizers on cassava

Nitrogen fertilizers, especially urea, are subject to various losses under tropical conditions. The use of slow-release N fertilizers and nitrification inhibitors are reported to be effective measures for improving N use-efficiency. Hence the effect of some slow-release N sources on cassava was studied (Vinod and Nair, 1992). The N-sources were urea, neem cake-coated urea, urea super-granule and rubber cake-coated urea, each applied at the rate of 50, 75, 100, 125 and 150 kg N/ha. Urea super-granule and neem cake-coated urea increased the various growth parameters of cassava. Highest number of roots and highest root yields were obtained with application of urea super-granule or neem cake-coated urea **(Table 11)** and at the highest rate of application of 150 kg N/ha.

Response of cassava to liquid NPK fertilizer

Ease in handling, lower labor requirement for application and the possibility of mixing with irrigation water are some of the advantages of liquid fertilizers. Recently, some of the public sector fertilizer firms in India have introduced NP and NPK grades of liquid fertilizers. The efficacy of one such formulation containing NPK in the ratio 8:8:8 was compared with the conventional solid fertilizers for the nutrition of cassava (Nayar and Revindran, 1992). It was found that the liquid fertilizer was as effective as the solid fertilizers applied on an equal nutrient basis **(Table 12).**

Response of cassava to mycorrhizal inoculation

Cassava is known to be highly mycotrophic and its efficient uptake of phosphorus seems to be highly dependent on an effective mycorrhizal association. The effects of inoculation of vesicular-arbuscular mycorrhizal fungi (VAMF) on cassava were investigated under field conditions at CTCRI in partially sterilized and natural soils (Potty, 1990). Higher total dry matter production and root yield as well as the uptake of P, Zn and Cu were observed in VAMF treated cassava plants compared with uninoculated controls. This was most pronounced in the absence of applied P **(Figure 2).** Sivaprasad *et al.* (1990) also reported enhancement of biomass production and nutrient uptake in cassava inoculated with several VAMF species. Inoculation with *Glomus fasciculatum* was most effective.

Nursery technique for large scale field inoculation of VAMF

Being obligate in nature, it has been difficult to multiply mycorrhiza for large scale field inoculations. This has prevented the adoption of VAM inoculation in cassava fields. However, intensive work conducted at CTCRI resulted in the development of an effective nursery inoculation technique (Potty *et al.*, 1993).

It is well established that the peel of cassava roots contains a high concentration of

Table 11. Effect of four sources of nitrogen on yield parameters and quality attributes of cassava, cv Sree Visakham, grown at the College of Agric., Trivandrum, Kerala, India in 1985/86. Data are average values for five rates of N application.

Sources	No.of roots/ plant	Root weight/ plant (kg)	Average length of roots (cm)	Root yield (t/ha)	Top yield (t/ha)	Utili- zation index	HCN content (ppm)	Total dry matter (t/ha)
Sources								
Urea	5.08	2.03	25.25	19.95	8.57	2.53	47.40	10.52
Neem cake-coated urea	5.85	2.21	27.45	22.59	9.25	2.52	46.79	12.13
Urea super-granules	5.86	2.45	28.39	25.65	11.10	2.50	48.43	13.97
Rubber cake-coated urea	4.93	1.91	22.82	17.76	8.70	2.16	48.23	10.40
F-test	S	S	S	S	S	S	NS	S
SE	0.27	0.09	0.72	1.44	0.39	0.13	1.09	0.24
CD (5%)	0.55	0.19	1.47	2.96	0.82	0.27	-	0.49

1) Root:shoot ratio

Source: Vinod and Nair, 1992.

Table 12. Effect of liquid fertilizer on yield parameters of cassava, cv Sree Visakham, grown at CTCRI in Trivandrum, Kerala, India in 1987.

Treatments[1)]	Plant height (cm)	No.of roots/ plant	Mean wt. of roots (g/plant)	Root yield (t/ha)
T1 = Recommended NPK (control)	186	8	239	23.39
T2 = 50% NPK liquid as basal+ 50% NPK solid as top dressing	185	11	152	19.95
T3 = 100% NPK liquid as basal	182	10	213	26.46
T4 = 100% NPK solid as basal	190	9	176	18.74
T5 = 50% NPK liquid as basal+ 50% NPK liquid as top dressing	183	11	169	23.84
T6 = 50% NPK solid as basal+ 50% NPK liquid as top dressing	182	11	131	18.32

1) Recommended NPK application : 100 N, 100 P_2O_5, 100 kg K_2O/ha applied as urea, SSP and KCl

Basal application: at the time of planting

Top dressing : at 45 days after planting

Liquid fertilizer contains 8% each of N, P_2O_5 and K_2O

Source : Nayar and Ravidran, 1991.

VAMF propagules (105 units/cm). Since cassava is not very specific to particular VAMF species, almost any strain can be multiplied on cassava. The outer skin of cassava roots can be used as inoculum of efficient strains; these can be stored in inert materials like lignite or rice husk charcoal and preserved in this form for more than one month. The lignite culture thus produced is used as inoculum in nursery beds by mixing with the top soil. Cassava cuttings are planted closely as shown in **Figure 3.** Saw dust was found to be superior as nursery medium in giving higher establishment of the cuttings and higher colonization of VAMF. After 25 days in the nursery the rooted infected cuttings are then transplanted to the field. The technique of producing rooted infected cuttings can also be adopted to pot conditions. Apart from this, inoculation by placing a few grams of lignite culture in the hole before planting each cassava stake in the field is also possible. This technology was evaluated in farmers' fields under the Lab-to-Land program and the preliminary results were encouraging; these need to be confirmed.

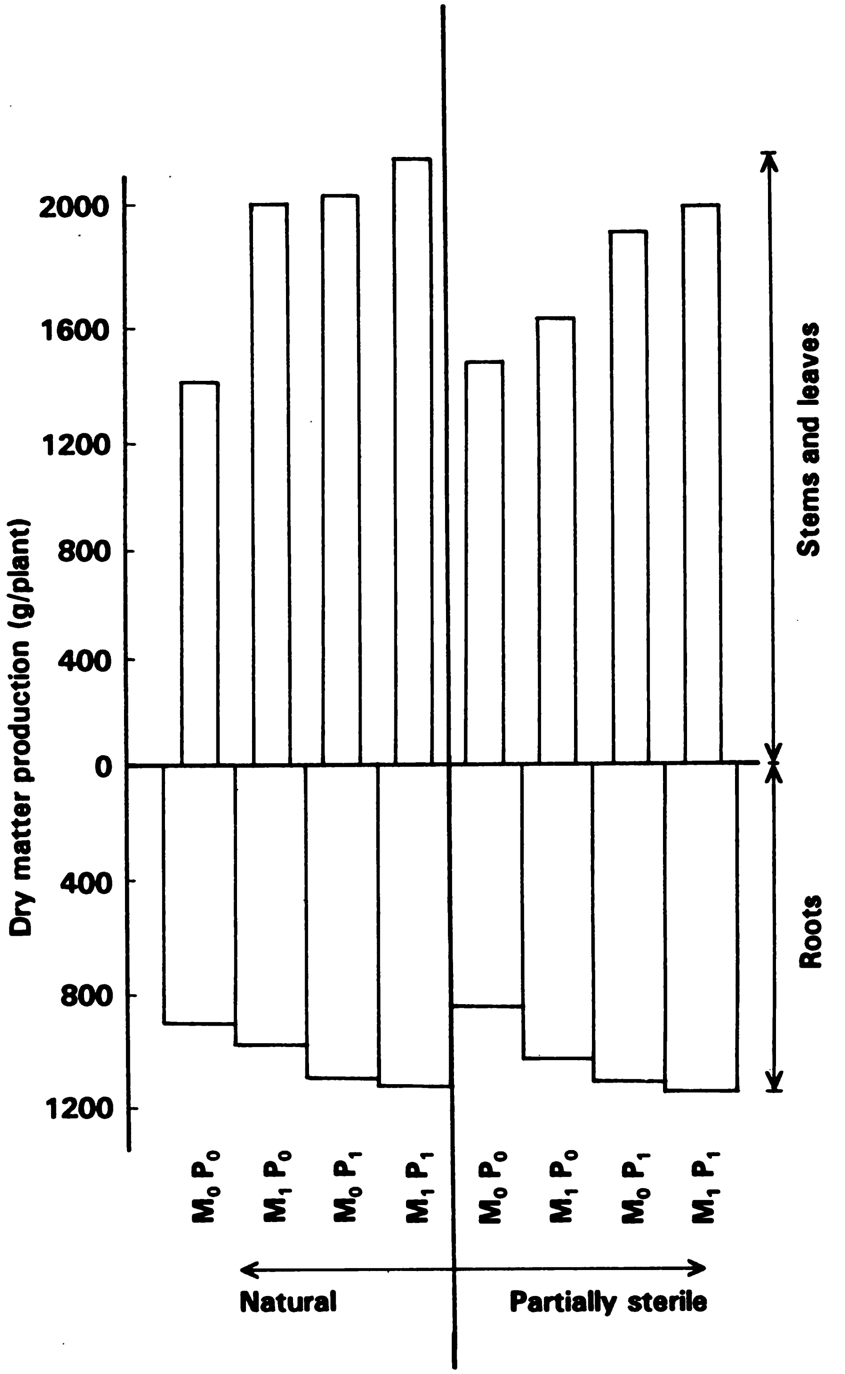

Figure 2 Effect of micorrhizal inoculation (M) and P application (P) on the dry root and top yields of cassava, cv H-1567, planted in natural and in partially sterilized soil at CTCRI, Trivandrum, India.

Source : *Potty, 1990*

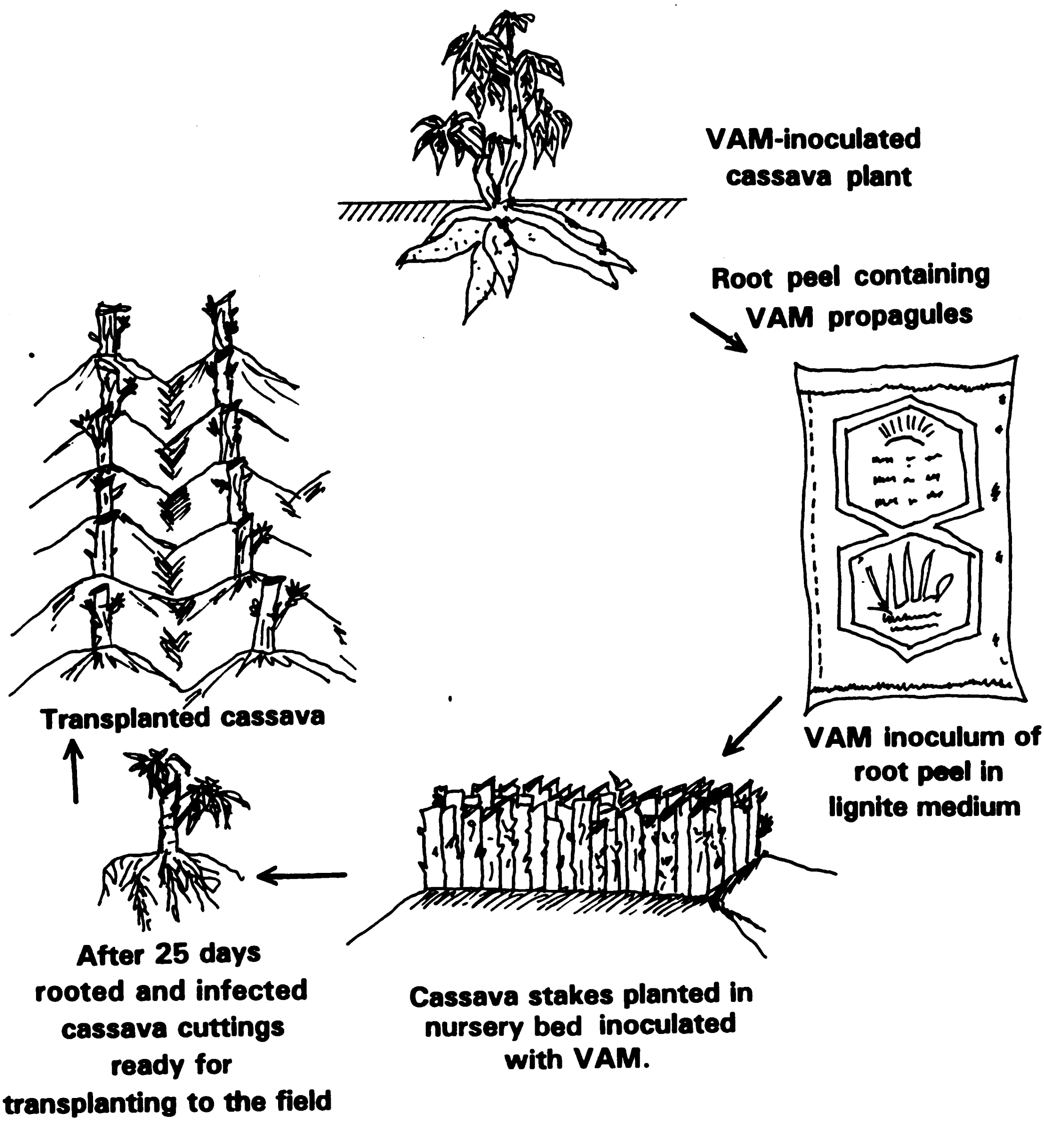

Figure 3. Multiplication and inoculation of VAM in cassava.

Cropping Systems Involving Cassava

Intercropping legumes with cassava

Groundnut and cowpea are the two leguminous intercrops that are recommended in cassava. Intercropping experiments conducted at Dapoli (Maharashtra) showed that the highest net profit of Rs. 10,043/ha was obtained from intercropping cassava with groundnut (AICRPTC, 1991).

To determine a common fertilizer schedule for the cassava-groundnut and cassava-cowpea intercropping systems, an experiment was conducted at the College of Agriculture in Trivandrum (Sheela and Mohamed Kunju, 1990). The experiment was laid out in split plot design with seven fertilizer rates in the main plot and two intercrops, groundnut and cowpea, in the subplots **(Table 13).** Half dose of N and full dose of P and K were applied at the time of simultaneous planting of cassava and the intercrops. The remaining N was applied at the time of incorporation of the residues of the intercrops. The results in **Table 13** indicate that the fertilizer level 50N, 62 P_2O_5 and 62 kg K_2O/ha produced the highest net return. Furthermore, groundnut was found to be significantly superior as an intercrop to cowpea, giving a mean net return of Rs.11,863/ha.

In another experiment with cowpea as intercrop in cassava, where the cowpea was harvested and removed as fodder, Anilkumar *et al.* (1991) found that to get maximum yield from the cowpea and cassava, they should be fertilized at 100% the recommended dosage for both crops.

Intercropping cassava in coconut gardens

When cassava is intercropped in coconut gardens the usual practice is to follow the fertilizer schedule for the sole crop in the absence of specific recommendations for the coconut-cassava intercropping system. However, the yield of cassava intercropped under coconuts is lower due to shading. Thus, application of fertilizers to the intercropped cassava at the full rate established for monocropping may not be necessary. A field experiment was conducted in 3^3x2 confounded factorial design to determine the NPK requirement for cassava intercropped in coconut gardens (Nayar and Sadanandan, 1992). The results indicate that N application at the higher levels significantly enhanced the plant height, number of leaves per plant and LAI. The effect of increased levels of P on the growth and yield of cassava was not very conspicuous, but K applied at the higher levels was beneficial in promoting the number of roots per plant, root size and root:shoot ratio, and significantly increased the root yield **(Table 14).** For maximum net returns from cassava intercropped in coconut gardens the application of 50 N, 50 P_2O_5 and 100 kg K_2O/ha was found to be sufficient.

Table 13. Effect of NPK fertilizer rates on the yield of cassava and cowpea or groundnut intercrops, as well as on the costs and net returns, College of Agriculture, Vellayani, Kerala, India.

Fertilizer levels $N:P_2O_5:K_2O$ (kg/ha)	Yield of cassava (t/ha)		Yield of intercrop (kg/ha)		Total cost of cultivation (Rs/ha)		Total net return (Rs/ha)	
	Cowpea	Groundnut	Cowpea	Groundnut	Cowpea	Groundnut	Cowpea	Groundnut
50 : 50 : 50	23.05	20.44	1,148	3,086	4,473	4,523	7,613	11,261
50 : 62.5 : 62.5	28.94	22.63	1,160	3,738	4,536	4,586	9,655	14,888
50 : 75 : 75	17.83	17.83	1,346	3,600	4,599	4,649	6,352	10,592
62.5 : 50 : 62.5	22.77	21.54	1,407	3,772	4,537	4,549	8,348	12,804
62.5 : 62.5 : 50	22.78	21.95	1,222	4,061	4,573	4,623	7,678	13,553
75 : 50 : 75	23.73	20.71	1,235	2,572	4,665	4,715	7,961	10,020
75 : 75 : 50	21.81	19.34	1,284	4,492	4,672	4,722	7,455	14,144
75 : 75 : 75	24.28	19.89	1,457	2,949	4,709	4,759	9,237	11,462
75 : 93.75 : 93.75	18.79	21.27	1,272	4,115	4,804	4,854	6,223	12,011
93.75 : 75 : 93.75	23.52	25.10	1,457	3,944	4,821	4,871	8,510	13,221
93.75 : 93.75 : 75	24.69	24.76	1,272	3,978	4,859	4,909	8,233	13,678
75 : 112.5 : 112.5	22.64	20.17	1,469	3,567	4,898	4,948	8,168	11,892
112.5 : 75 : 112.5	19.21	22.09	1,291	3,292	4,932	4,982	6,311	9,972
112.5 : 112.5 : 75	21.13	23.87	1,320	2,881	5,008	5,058	7,011	9,344
50 : 50 : 50 (Cassava alone)	35.95	35.95	-	-	3,473	3,473	9,109	9,109

Source : Sheela and Mohammed Kunju, 1991.

Table 14. Effect of three levels of potassium on yield parameters of cassava intercropped in coconut gardens at the Coconut Research Station Balaramapuram, Kerala, India in 1985 and 1986.

Level of K_2O (kg/ha)	No.of roots/ plant		Mean root weight (g/plant)		Root yield (t/ha)		
	1985	1986	1985	1986	1985	1986	Mean
50	3.75	3.46	170.12	173.19	6.19	5.74	5.96
100	4.50	4.43	220.94	204.87	9.55	8.70	9.12
150	4.63	4.46	226.40	213.44	10.17	9.05	9.16
CD	0.11	0.09	5.83	9.33	-		0.10

Source : Nayar, 1993.

Rice–cassava sequential cropping

From experiments conducted in a rice-based cropping system, it was found that the rate of P application to short-duration cassava that is grown after the harvest of rice, can be reduced to 25 kg P_2O_5/ha (CTCRI, 1992).

Water Management

Moisture stress at the time of cassava root bulking is one of the reasons for low yields, especially in years of poor rainfall distribution. For that reason, irrigation is practiced widely in Tamil Nadu. Hence, the effect of four levels of supplemental irrigation and four levels of fertilizers on the yield of cassava was evaluated for three consecutive seasons at CTCRI. From this study it was found that supplemental irrigation at IW/CPE ratio=1 increased the cassava yield by 90% over the rainfed crop. To realize the production potential of high yielding cassava cultivars, irrigation at IW/CPE ratio=1 and application of NPK at 150:100:150 kg/ha would be required **(Table 15).**

Prabhakar and Nair (1992) investigated the effect of supplementary irrigation on cassava-groundnut intercropping systems at CTCRI and reported that supplementary irrigation at 25 mm/week enhanced the yields of groundnut and cassava by 58% and 42%, respectively. The growth and yield components of both crops were also markedly improved by supplementary irrigation. The irrigated crop gave about 60% more income than the rainfed crop.

In another experiment the effect of three water table depths (40, 80 and 120 cm) on short-duration varieties of cassava were studied (Nayar, 1992). It was found that a shallow water table (at 40 cm) depressed the root yield of all varieties. The root yield of CI-590 was superior to those of other varieties; however, this variety has a higher HCN content **(Table 16).**

Table 15. Effect of various levels of supplemental irrigation and fertilizer application on root yield, starch and HCN contents of cassava planted at CTCRI, Trivandrum, Kerala, India.

Treatments	Fresh root yield (t/ha)	Starch (% on DW basis)	HCN (ppm on FW basis)
Levels of irrigation			
IW/CPE = 0 (Rainfed)	20.8	72.7	55
IW/CPE = 0.25	24.5	72.9	41
IW/CPE = 0.50	30.8	74.5	41
IW/CPE = 0.75	34.8	75.2	33
IW/CPE = 1.00	39.7	75.0	22
CD	4.8	-	-
Levels of NPK (kg/ha)			
50:100:50	23.3	75.9	37
100:100:100	28.9	75.2	37
150:100:150	33.4	71.1	39
200:100:200	34.9	74.0	46
CD	2.6	-	-

Note : Irrigation: during drought periods (more than 7 days without rain). Fertilizers were supplied 50% at planting and the rest at 45 days.

Source : Nayar T.V.R. and Kumar B. Unpublished.

Table 16. The effect of depth of water table on the root yield and HCN content of four cassava cultivars grown at CTCRI, Trivandrum, Kerala, India.

Cassava genotype	Root yield (t/ha)				HCN content (ppm on FW basis)			
	40 cm	80 cm	120 cm	Mean	40 cm	80 cm	120 cm	Mean
Sreeprakash	14.39	28.78	20.41	21.19	40	25	32	35.7
H-119	13.40	22.76	11.07	15.74	38	23	25	28.7
CI-590	14.64	40.83	34.80	30.09	69	42	48	53.0
Sree Visakham	14.15	25.09	29.02	22.75	46	28	21	31.7
Mean	14.15	29.36	23.87	-	48	32	31	-

Source: Nayar, 1992.

FUTURE DIRECTION AND PRIORITIES

The following research topics were considered of highest priority:

- Intensification of research on various cropping systems involving cassava
- Development of an effective and integrated nutrient management package
- Refinement of agronomic practices for non-traditional areas, with stress on moisture conservation and water management
- Identification of micronutrient problem areas, and the determination of critical levels and micronutrient requirements of cassava
- Development of low-input technology, in order to increase cassava's competitive ability in the production of animal feed and industrial products
- Development of management practices that reduce soil erosion when cassava is grown on slopes

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RECENT PROGRESS IN CASSAVA VARIETAL IMPROVEMENT IN INDIA

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ABSTRACT

In India cassava breeding is done mainly at the Central Tuber Crops Research Institute (CTCRI) in Trivandrum, as well as in the State Agricultural Universities through the All India Co-ordinating Centres.

CTCRI maintains 786 exotic and 848 indigenous accessions of cassava and 8 wild species in its germplasm bank. Coordinating Centres maintain about 280 indigenous accessions.

Seedling progenies of 158 and 19 CIAT cassava accessions were screened at the Regional Centre of CTCRI in Bhubaneswar during 1985 and 1990, respectively. High root yields of more than 4 kg/plant were recorded in seedling progenies of CM3426, CM4046 and CM4229.

Selection of promising germplasm and hybridization among selected accessions have been the principal strategies in cassava breeding. The most popular eating variety in Kerala, M-4, was introduced from Malaysia in the 1950s. Three high yielding hybrids, H-165, H-226 and H-97 were released in 1971 by CTCRI, of which H-165 and H-226 have become popular in Tamil Nadu for starch production. In 1983, 'Sree Sahya' and 'Sree Vishakam' were released at the national level. 'Sree Prakash' is a short duration cultivar released by CTCRI in 1987.

In 1993 the Tamil Nadu Agricultural University released a high yielding, short-duration cultivar, called 'Co-3', which is reported to be tolerant to CMD. Recently, the Kerala Agricultural University also released a short-duration cultivar, called 'Nidhi', which can be harvested in 5 1/2 - 6 months and has been recommended for paddy fallows of central Kerala. Two high yielding high quality short-duration cultivars, which can be harvested at six months, have been identified from the germplasm of CTCRI and are now being evaluated in advanced yield trials.

A study on hybrid vigor in cassava indicated the predominance of non-additive gene action for root yield and yield components, indicating the possibility of exploiting hybrid vigor. Seven elite top-cross selections have been identified with high root yield, starch and dry matter contents and with low HCN content.

By successive cycles of recurrent selection among germplasm accessions, the carotene content of roots could be raised significantly.

Induction of triploidy has been found to be very effective for the development of high yielding, high starch and high dry matter cassava cultivars. A promising triploid, 2/14, is

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being considered for release for starch processing.

Recently, successful induction of mutation has been reported in M-4. A few useful mutants, having higher root yields (20-25%) and high dry matter and starch contents, have been selected from single node cuttings of gamma-irradiated stakes.

Studies on the use of true seed revealed the possibility of enhancing the multiplication rate more than 15 fold compared to the traditional method of vegetative propagation. A few promising seedling families have been identified, which give seedling yields comparable to clonal yields. Cassava mosaic disease is considerably reduced in seedling families.

INTRODUCTION

Cassava is believed to have been introduced into India in the 17th century by Portuguese sailors. Though the original introduction of the crop comprised only a few clones, the large genetic diversity presently available in the indigenous collection is mainly due to the release of locked up genetic variability through natural cross pollination or from naturally occuring mutations. Earlier work on cassava breeding in India has been reviewed by Koshy (1947), Abraham (1956, 1957, 1970), Magoon (1967, 1968, 1970), and Nayar *et al.* (1988, 1990).

Though certain attempts to improve cassava varieties have been made earlier, a concerted effort was made only since the establishment in 1963 of the Central Tuber Crops Research Institute under the Indian Council of Agricultural Research. At present a few State Agricultural Universities are also involved in cassava breeding.

The National Commission on Agriculture reported that India should produce 40 million tonnes of cassava by 2000 AD. from an area of one million hectares. To attain this goal the breeding strategies are to be geared up to develop high yielding, high starch, short-duration and insect and disease tolerant varieties of cassava. Agronomic practices and processing techniques also need to be improved. This paper reports on the recent progress in cassava breeding research in India.

Germplasm Collection, Conservation and Evaluation

Genetic diversity is the essence of any crop improvement program. CTCRI maintains 786 exotic and 848 indigenous accessions of cassava and 8 wild species in its germplasm bank. Other research centers maintain about 280 indigenous accessions.

The most important sources of exotic genetic stocks at CTCRI are from Colombia, Madagascar, Nigeria, Thailand, Ghana, Uganda, Malaysia, Indonesia, Sri Lanka, Senegal and Gobon.

At CTCRI the genetic accessions of cassava have been evaluated based on morphological and biochemical descriptors and two catalogues were brought out.

Among this germplasm, most of the accessions have a medium stature. Dwarf plants reach a height of about 1.5 m, whereas tall plants are over 3.0 m. The internodal length varies from 0.7 to 1.0 cm among the dwarf clones in comparison to more than 3.0 cm in tall ones.

Most of the accessions have straight and cylindrical stems. However, in a few genotypes the main stem branches and assumes a zig-zag appearance.

The petiole length was found to be highly influenced by environment. A positive correlation was established between the petiole length and leaf area (Ramanujam, 1982).

Leaves generally have a green color. The light green color of leafblades of a few genotypes is considered a marker character. Altogether only five clones among the indigenous and nine among the exotics have light green leaves. Among the elite clones, M-4 possesses this trait.

Considerable genetic variation is observed for flowering and fruit setting among different genotypes. Profusely branching types tend to flower and fruit well. Flowering and seed set is generally more abundant among the exotics because of the wide prevalence of spreading types among them. Clones producing more than 75 g seed/plant at the 10 month stage have been identified in a recent study at CTCRI **(Table 1).** Out of twelve selections, five recorded root yields of more than 3 kg/plant. Six accessions have produced more than 1 t seed/ha. The accessions CE-397, CE-402, CE-457

Table 1. Root and seed yield of various accessions in the cassava germplasm collection at CTCRI in Trivandrum, India.

Clones	Root yield (kg/plant)	Harvest index	Seed yield (g/plant)
CE-374	0.6	0.30	83
CE-376	0.8	0.23	81
CE-386	5.6	0.42	97
CE-397	5.0	0.50	125
CE-401	2.0	0.50	150
CE-402	3.0	0.48	95
CE-405	1.0	0.33	129
CE-423	5.5	0.68	75
CE-425	0.5	0.20	162
CE-457	4.0	0.55	108
CE-567	1.6	0.40	93
CE-682	0.5	0.31	130

and CE-386 had both high root yield and seed production at 10 months. Cassava seeds contain about 47% lipids, which in turn are made up of triglycerides. About 20% oil could be extracted from cassava seed. Genotypes having high root yields (30-35 t/ha) and seed production of over 1 t/ha at 10 months are desirable for their potential dual purpose of both root and seed oil production. Cassava is generally female fertile but male sterility is widely present and more than 40 clones with this characteristic have been identified. Partial pollen sterility was primarily due to cryptic structural hybridity in the pachytene stage (Jos and Nair, 1979).

With respect to root yield, a wide variation from non-root bulking clones to very high yielding ones, like 'Ambakadan', which has given a yield of 51 kg/plant at 12 months, has been reported. Although the important yield components are mean root weight and root number per plant, the former is reported to be highly positively correlated to yield (Bala Shanmugham *et al.*, 1980).

Cassava produces the highest dry matter (DM) among root and tuber crops (Balagopal *et al.*, 1988) and in the germplasm collection the root DM content ranges from 20 to 52%. Dry matter is directly related to starch content (Ramanujam, 1985). The root starch content among germplasm accessions varied from 14 to 36%.

Though cassava root flesh is generally white, a few accessions have yellow pigmented flesh due to the presence of carotene. Among a total of 654 accessions screened for carotene, 21 clones had yellow flesh. The frequency of high carotene was more in the exotic collection. A few indigenous clones also registered high carotene content, ranging from 70 to 670 I.U./100g **(Table 2).** Recently, a common gene pool was developed through simple recurrent selection, wherein the carotene content was increased to 1500 I.U. in the first cycle, to 2000 I.U. in the second cycle and to 3217 I.U./ 100 g in the third cycle (Jos *et al.*, 1990).

The most important disease of cassava in India is cassava mosaic disease (CMD), which is caused by a gemini group of virus. A number of indigenous clones, like 'Kalikalan' and 'Aryan', are found to be 100% infected by the virus. A high degree of tolerance was noticed in M-4. Graft transmission studies have shown that germplasm accessions CE-9, CE-14, CE-92 and CE-101 possess a high degree of resistance as compared to the highly susceptible cultivar 'Kalikalan'.

Evaluation of Germplasm from CIAT

Cassava seeds received from CIAT were initially screened at the Regional Centre of CTCRI in Bhubaneswar. On the whole, the CIAT materials were found to be very susceptible to cassava mosaic disease. In 1987, 122 plants were selected from 158 seedling progenies on the basis of CMD tolerance, plant type, root yield, root dry matter content and bitterness of roots. When these were grown at CTCRI in Trivandrum

Table 2. Carotene content in cassava clones with yellow parenchyma in the CTCRI germplasm collection.

Exotics	Color of flesh	Carotene (I.U./100g FW basis)	Indi-genous	Color of flesh	Carotene (I.U./100g FW basis)
CE-373	yellow	670	CI-93	yellow	520
CE-314	"	660	CI-554	"	520
CE-303	light yellow	410	CI-499	"	475
CE-358	"	360	CI-562	light yellow	450
CE-352	"	260	CI-51	"	380
CE-356	"	260	CI-560	"	375
CE-350	"	180	CI-618	"	260
CE-4	"	110	CI-451	"	170
CE-117	"	110	CI-461	l.yellowish ring	65
CE-175	l.yellowish ring	85	CI-507	"	65
CE-169	"	70			

only 75 clones survived. Twenty four of these had narrow leaves. In the clonal generation, most lines did not conform to the plant type recorded in the seedling generation, and were predominantly spreading. The number of seedlings recorded as spreading that became erect types in the clonal stage was rather low. But, more than 61% of the erect seedlings had become predominantly spreading in the first clonal stage. The mean root yield ranged from 0.2 to 4.0 kg per plant. It was observed that high yielders were mostly among the spreading types. The roots were bitter or slightly bitter in 23 clones, while others had non-bitter or sweet roots. More than 50% of the clones showed variable intensity of yellow color in the flesh, indicating the presence of carotene. Bitter clones were also found among those with yellow flesh. Only 18 clones registered a yield of over 3 kg/plant. When plant type, yield, root shape and DM content were considered together, none of these accessions were very promising. However, 66 CIAT lines have been added to the germplasm collection. These accessions have medium yield potential, high carotene content and field tolerance to CMD.

Interspecific Hybridization

Manihot tristis sub-sps. *tristis* is reported to be drought resistant, while sub-sps. *saxicola* was found to have high protein content. Hybridization between cassava and these two sub-species resulted in a seed set of 22.5 and 17%, respectively. There was no discernable variation between the two sub-species when crossed with cassava, which indicates the close resemblence between the species. Meiosis of the interspecific hybrids was also normal. However, the pollen fertility ranged from 0 to 99%. Among the total of 57 male-fertile plants, 48 showed high pollen fertility, 4 had medium and 5 had only low fertility. About 30% of the seedlings were totally male-sterile. Detailed studies have shown that the type of male-sterility recorded in *M. esculenta, M. tristis* and the interspecific hybrids are basically the same. The seed set in relation to the capsules developed under open pollination was constantly above 80% in all the interspecific hybrids, indicating the prevalence of high female fertility. Further studies are in progress.

Cassava Breeding

Selection of promising germplasm and hybridization among selected accessions have been the principal strategy in cassava breeding. The most popular eating variety in Kerala, M-4, was introduced from Malaysia in the 1950s. Controlled pollinations among selected clones have resulted in the development of five high yielding clones in cassava (Magoon, 1970; Jos *et al.*, 1981). Among these, H-97, H-165, H-226 and 'Sree Visakham' (H-1687) resulted from single crosses, while 'Sree Sahya' (H-2304) was identified from a multiple cross involving five parents including M-4. While H-165 has been considered for early harvest at eight months, all the others have been recommended for harvest at 10-11 months. The yield potential reported for these clones ranges from 30-35 t/ha under the recommended package of practices, compared to 20-25 t/ha for the check variety. Recently, H-165 and H-226 have become very popular varieties in cassava growing areas of Tamil Nadu where cassava is mainly grown for industrial purposes. 'Sree Prakash' (S-856) is yet another variety released by CTCRI in 1987. It is a selection from the germplasm collection and has been found to be early bulking with a yield potential of 35 t/ha at 6 1/2 - 7 months. The plant type is quite ideal with very high leaf retention. The variety is also found suitable in paddy fallows as a rotation crop (Nair *et al.*, 1987).

The Tamil Nadu Agricultural University has released Co-1 and Co-2 as high yielding cultivars. Co-1 is a selection from a local collection, while Co-2 is a clonal selection from the seedling progeny of a local type. The yield of the varieties is 30-35 t/ha under the recommended package of practices. In 1993, the University released another cassava cultivar, Co-3, which is high yielding, early harvestable and reported to be tolerant to CMD.

Recently, the Kerala Agricultural University has released a short-duration cultivar called 'Nidhi', which can be harvested in 5 1/2 - 6 months, and which has been recommended for paddy fallows of central Kerala. At CTCRI, two early maturing clones, CI-649 and CI-665, were identified from the indigenous germplasm. These clones had a mean root yield of 25 t/ha at six months. The culinary quality is as good as that of M-4. These two clones are now being evaluated in multilocation trials.

Exploitation of Hybrid Vigor in Cassava

A recent study utilizing six fourth generation inbred lines of cassava crossed in a diallel system generated interesting information on hybrid vigor in cassava. This study revealed the predominance of non-additive gene action in the control of yield and yield attributing characters indicating the possibility of exploiting hybrid vigor in cassava.

The magnitude of hybrid vigor for different characters showed great variation **(Table 3).** Highly significant heterotic cross combinations were obtained for root yield, dry matter and starch content, low HCN content and compactness of foliage. Root yield hybrid vigor over mid parent ranged from 13.2 to 136.4%, while it was 6.3 to 100% over better parental values. The maximum standard heterosis (economic heterosis) was 36.8, 26.8 and 13.0% higher than that of Sree Sahya, Sree Visakham and Sree Prakash, respectively.

Table 3. Magnitude of heterosis observed in cassava at CTCRI, Trivandrum, India.

Character	Hybrid vigor range (%)		No. of highly significant heterotic combinations	
	MP[1]	BP	MP	BP
Height at first branching	1.7 - 78.4	4.3 - 75.3	18	12
Plant height	2.1 - 50.2	1.4 - 41.1	15	10
Petiole length	1.8 - 67.3	2.1 - 64.2	21	15
Length of middle leaflet	1.4 - 29.0	0.3 - 17.1	19	8
Breadth of middle leaflet	1.3 - 32.4	1.3 - 23.9	22	14
Spread of foliage	-18.0 - 45.8	-23.0 - 34.2	9	4
Root yield	13.2 - 136.4	6.3 - 100.0	29	28
Number of roots	6.1 - 100.0	3.5 - 94.7	28	27
Length of roots	4.3 - 57.0	2.2 - 52.0	29	21
Girth of roots	0.8 - 28.8	1.0 - 20.7	20	15
Mean weight of roots	2.9 - 82.2	0.5 - 67.7	3	-
Total biomass	7.0 - 95.1	9.6 - 72.9	30	25
Harvest index	0.9 - 70.8	1.5 - 69.3	19	11
Dry matter content	6.5 - 47.0	4.3 - 37.0	30	30
HCN content	-57.1 - 27.8	-61.9 - 6.4	15	27

[1] MP = mid parent
BP = best parent

Evaluation of the top-cross hybrids raised by first and second generation inbred lines with Sree Visakham revealed that top-crossing is effective in bringing about population improvement of inbred lines for plant type, root yield and root qualities, such as dry matter and starch content and cooking qualities **(Table 4).** Seven elite top-cross selections, i.e. TCH-1, TCH-2, TCH-3, TCH-4, TCH-5, TCH-6 and TCH-8, having high yield (37-44 t/ha), high harvest index (61.6 to 74.9%), high starch content (26.7 to 34.3%), low levels of HCN (53 to 89 ppm on fresh weight basis) and excellent cooking qualities, are under evaluation in multilocation trials in Kerala.

Table 4. Yield parameters of several promising top-cross selections at CTCRI, Trivandrum, India.

Genotype	Root yield (t/ha)	Harvest index (%)	Dry matter (%)	Starch (%)	HCN (ppm on FW basis)
TCH-1	44.4	69.7	36.5	29.7	73.9
TCH-2	41.9	70.7	36.3	26.7	79.6
TCH-3	41.9	74.9	39.5	27.8	64.0
TCH-4	40.7	65.7	39.6	29.7	89.2
TCH-5	39.9	61.6	37.6	29.1	79.8
TCH-6	37.0	66.6	42.0	34.3	53.1
TCH-8	37.0	64.2	38.2	32.8	83.9
R5-OP-5xM-4-43	39.5	71.5	38.0	33.2	73.8
Sree Visakham	40.7	67.2	35.6	25.8	50.7
M-4	28.4	70.0	39.0	30.1	56.6

Use of Triploidy in Cassava Improvement

Polyploidy breeding has unique advantages in cassava, because the economically useful product is a vegetative part, commercial cultivation is through clonal propagation, while the crop is amenable to hybridization. The somatic chromosome number is also relatively low (2n = 36), so that it can tolerate higher ploidy.

At CTCRI production and isolation of triploids in cassava have been achieved by crossing diploids with induced tetraploids. Tetraploids were induced in ten different selections by colchicine treatment. The adoption of the diploid clone as female parent was found to be more successful than the reciprocal, indicating that male gametes are more tolerant to higher ploidy. The high recovery of triploid plants in particular cross combinations, suggests that the meiosis during microsporogenesis in the tetraploid plants may be controlled in some way to produce a large number of diploid pollen grains. The leaf thickness was found to be a reliable parameter for the preliminary screening of the population for triploids. Most of the triploids were equal or better than the better parent in terms of root yield and root dry matter content, and they had invariably compact plant types. The compact plant type and high harvest index prevalent in a number of triploids indicate the possibility of accommodating more plants per hectare, thereby facilitating higher yields.

The dry matter and starch content of triploids from specific cross combinations were found to be higher than that of the diploids. An array of such clones have been identified, of which two best selections, 76/9 and 2/14, were found to have particularly high yields and DM contents **(Table 5)**. The clone 76/9 is a selection from the cross OP.4 (2x) x S.300 (4x), while 2/14 is selected from the cross OP.4 (2x) x H-2304 (4x). These clones are ideal for the starch industry. The selection 2/14 has been proposed to the State Variety Release Committee for use in industrial areas.

Table 5. Yield parameters of cassava triploids evaluated in multilocation trials.

Clones	Root yield (t/ha)[1]					Root DM content (%)	Root starch content (%)
	Trivandrum	Anchal	Kozha	Chokkad	Cuddalore		
76/9	33.9	32.1	34.9	37.3	23.4	44.3	36.5
2/14	35.7	29.5	32.3	33.4	58.3	46.9	36.8
H-1687	34.4	24.5	19.8	33.7	32.1	37.4	31.4
H-2304	26.5	22.3	30.1	26.5	23.2	41.0	33.2
Local	20.0	16.6	11.4	17.3	16.3	38.5	31.0
CD (5%)	7.20	10.06	8.94	11.83	12.29		

[1] Mean of two years, 1989/90 and 1990/91.

Mutation Breeding

Mutation breeding has played only a minor role in the improvement of cassava, probably due to unsatisfactory *in-vivo* methods of induction and detection of mutations. Stem cuttings of cassava cultivar M-4 were irradiated with 1-5 kR gamma rays. The irradiated stem cuttings were propagated as single node cuttings and the MV1 plants were pruned after 6 months. Planting of single node cuttings and secondary sprouts from the base of the MV1 plants led to the recovery of upto 30% more mutants than from stake planting. As reported by Domini (1976), the mutated tissue is mainly concentrated at the basal buds of the primary shoot (MV1). Many potential mutants are generally lost, because in plants with apical dominance such as cassava, these buds often do not sprout. Hence, cutting back increases mutation frequency and more solid mutants (Nakajima, 1973).

Screening of the 50 morphologically stable mutants in their MV4 and MV5 generations showed an increase in yield (20-30%), high photosynthetic rate and greater frequency of amphistomatal conditions than control plants **(Table 6).** A reduction in HCN content, both in roots and leaves, was also observed in some mutants. Among the mutants, one showed somatic pairing and early starch deposition (Vasudevan and Jos, 1991; Vasudevan *et al.*, 1993).

Table 6. Root and leaf characteristics of various cassava mutants grown at CTCRI, Trivandrum, India.

Variety/ mutants	Root yield (kg/plant)	RDMC (%)	HCN (ppm)[1] Root	HCN (ppm)[1] Leaf	Photo-synthetic rate[2]	Proline (ppm)	Stomatal ratio Upper:Lower
M-4	1,300	38.7	57	720	28.0	35	10 : 280
CAM 8	1,100	42.3	34	600	30.9	60	10 : 360
CAM 22	1,125	42.4	44	540	42.5	90	10 : 200
CAM 26	1,800	41.5	34	600	48.9	90	10 : 150
CAM 27	1,175	38.5	46	620	36.6	90	10 : 100
CAM 28	1,575	39.8	15	300	48.3	40	10 : 60
CAM 29	1,325	39.2	18	640	21.8	45	10 : 240
CAM 31	1,750	40.2	84	820	50.8	35	10 : 200
CAM 33	1,250	36.6	66	300	26.5	65	10 : 450
CAM 34	1,125	42.2	81	720	27.6	90	10 : 250

[1] on FW basis

[2] CO_2 uptake/m^2/sec

Cassava True Seed Program

The main advantage of propagation through true seed is that the multiplication rate could be increased to more than 1:150 compared with 1:10 in the conventional vegetative method. Under normal field conditions cassava seeds do not germinate satisfactorily. In a field nursery, however, in which more favorable conditions could be maintained, good germination of 80-90% was achieved. Almost 90% germination was obtained at 20 days after sowing. True seeds of male sterile lines have shown very high seed germination, whereas that of inbreds was very low. Cassava seeds lose viability in long-term storage. Four to six months storage is found ideal for good germination. However, seed viability is reduced drastically beyond 8 months of seed storage.

When seeds were sown *in-situ* the seedling germination and establishment was very low (33.5-53.7%) mainly due to weed competition. Sowing in a seedling nursery and transplanting 40-50 day-old seedlings to the main field was effective in obtaining more than 75% seedling establishment in the field. At the time of transplanting, the tap root is cut, which simulates clonal root formation at the seedling stage. The incidence of cassava mosaic disease was negligible in seedling progenies.

In two field experiments conducted in 1989/90 and 1990/91 it was observed that seedling progenies of promising parents had root yields and dry matter and starch contents similar to those of a clonal population of M-4. However, clonal propagation of the high yielding hybrid 'Sree Visakham' resulted in the highest root yield, dry matter and starch contents in both experiments **(Table 7).**

These studies indicate that cassava true seed propagation has potential in industrial areas due to the high multiplication rate, ease in covering extensive areas at lower costs and low transmission of cassava mosaic disease (Rajendran and Ravindran, 1993).

Table 7. Mean agronomic performance of 11 seedling families as compared to the clone Sree Visakham in CTCRI, Trivandrum, India in 1989/90 and 1990/91.

Entries	Stem girth (cm)	Plant height (m)	No.of roots/ plant	Root yield (t/ha)	Root dry matter (%)	Root starch (%)	Dry root yield (t/ha)	Starch yield (t/ha)
Seedling progenies[1)]								
CE-595-MF	10.2	2.9	5.3	24.3	25.0	18.0	6.08	4.4
CE-630-MF	12.4	3.0	6.3	30.5	32.9	25.5	10.03	7.8
CE-639-MF	10.6	2.6	5.1	21.4	21.9	16.8	4.69	3.6
CE-647-MF	10.1	2.4	4.6	20.2	26.8	21.9	5.41	4.4
CE-2-MS	10.3	2.9	5.2	25.1	29.4	22.9	7.38	5.7
CE-299-MS	10.6	2.4	4.7	23.0	27.8	23.1	6.39	5.3
CI-453-MS	9.9	2.6	5.6	28.4	31.2	23.9	8.86	6.8
Inbred 2	9.3	2.2	6.1	30.5	23.2	15.7	7.08	4.8
Inbred 3	10.9	3.0	5.0	20.2	33.5	25.8	6.77	5.2
Inbred 6	11.3	3.1	6.3	22.2	29.5	22.2	6.55	4.9
Inbred 10	10.2	2.7	5.1	21.4	27.3	22.1	5.84	4.7
Clone								
Sree Visakham	8.6	2.6	6.9	40.7	28.1	21.4	11.44	8.7
CD (5%)	1.61	0.41	NS	10.57	4.19	3.57		
SE	0.55	0.14	0.57	3.60	1.43	1.22		

1) CE = Exotic cassava

CI = Indigenous cassava

MF = Male fertile

MS = Male sterile

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CASSAVA TECHNOLOGY TRANSFER AND UTILIZATION IN INDIA

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ABSTRACT

The average cassava yield of 21 t/ha in India compares favorably with a world average of 10 t/ha. On-farm trials have revealed that it is possible to increase yields to more than 30 t/ha through more intensive management. The Cassava Technology Transfer Programme (CTTP) in India has passed through various phases, concentrating mainly on production technologies and of late on processing technologies.

CTTP started in the early 1970s with the release of high-yielding varieties of cassava (HYVC) and by conducting National Demonstrations in farmers' fields. These indicated that HYVC with intensive management could produce yields of more than 35 t/ha. During 1976, CTCRI (with financial assistance from IDRC) implemented an Operational Research Project in a village near Trivandrum with the main objective of identifying operational constraints faced by small farmers adopting cassava production technologies. In 1979 CTCRI implemented the Lab-to-Land Programme (LLP) of ICAR, with the main aim of creating a direct linkage between technology generators and small and marginal farmers. This program has directly benefitted more than 1000 farmers in 14 villages of three states. The LLP initially gave emphasis to production technologies, but is now also concentrating on transferring processing technologies by a series of demonstrations and training programs. All these CTTP attempts have proved effective in terms of increasing the adoption level of cassava technology by more than 40% of the farmers.

The transfer of technologies to a larger mass was also attempted through a functional linkage with development departments through systematic training programs in order to equip the extension personnel with the latest technologies in cassava production. Besides the efforts made by CTCRI, the State Departments of Agriculture through their extension network are engaged in the transfer of technology through demonstrations and farmers' training programs.

The socio-economic impact of CTTP is very encouraging considering that a) cassava yields in the country have increased at an annual rate of about 1% since 1970; b) the HYVC have diffused to more than three fourth of the cassava area in Tamil Nadu and Andhra Pradesh and to some pockets of Kerala; c) the majority of farmers have accepted most of the recommended practices.

The transfer of technology in the case of processing and utilization of cassava could not be done in an effective manner for want of an organized extension system for processing

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technologies. However, attempts are being made to diffuse the developed products and processing technologies through the Lab-to-Land Programmes, public exhibitions, food festivals, farmers' meetings etc.

INTRODUCTION

The term transfer of technology (TOT) has been widely used in agriculture to denote a process by which the viable technologies developed and perfected at research institutes are transmitted to the farming community and other end users through strategic programs and appropriate methods. Cassava, popularly known as tapioca in India, is predominantly grown in Kerala and Tamil Nadu, but is gaining importance also in adjoining states like Andhra Pradesh, Karnataka as well as in Northeastern hill states of the country. While cassava is traditionally an important food crop for people practicing subsistence agriculture, it has recently emerged as a raw material in starch, sago and animal feed industries. Though the area under cassava shows a declining trend in India, due to competition from commercial crops like rubber and coconut, it continues to occupy a niche in the agricultural economy because of the increasing demand for food and feed, and the crop's ability to tolerate low soil fertility, to suffer from few pests and diseases and to withstand drought better than most other crops.

The average yield of cassava of 21 t/ha in India compares favorably with the world average of 10 t/ha (FAO, 1993; Directorate of Economics and Statistics, 1992). However, on-farm trials have shown that the crop has an even higher yield potential of more than 30 t/ha through more intensive crop management. If this potentiality were to be translated into the field, the present declining trend in production could be expected to be reversed. Diversification into alternate uses of cassava will be an important incentive to farmers to retain the crop within the cropping system when an adequate remunerative price for the produce can be assured. In order to realize this production potential, a sustained and sound cassava transfer of technology program has to be implemented.

OVERVIEW OF NATIONAL TECHNOLOGY TRANSFER STRATEGY, STRUCTURE AND ORGANIZATION

The Cassava Technology Transfer Programme (CTTP) has passed through various stages, adjusting at every stage to changes in dynamic socio-economic factors. The CTTP in India may be broadly categorized into:

1. First Line Transfer of Technology Programme (FLTTP)
2. Transfer of Technology (TOT) by State Departments of Agriculture (SDA)

The FLTTP refers to technology transfer projects handled by the Indian Council of

Agricultural Research (ICAR) System, comprising research institutes and agricultural universities. Agricultural scientists of these institutions play a first line extension role by organizing demonstrations and training on a limited scale, but enough to have a catalytic influence on other extension systems or sub-systems.

The major components of FLTTP are: 1. National demonstration projects, 2. Operational research projects, 3. Lab-to-Land Programmes, 4. Krishi Vignana Kendras and Trainers Training Centres (Prasad *et al.*, 1987).

The TOT of SDA refers to the TOT programs and activities handled by the Extension Service of State Departments of Agriculture through the Training-and-Visit system and Crop Package programs.

Cassava Transfer of Technology under First Line Technology Transfer Programmes

CTCRI is the nodal agency for operating CTTP and FLTTP. The transfer of cassava technology began in an organized way in 1971 when CTCRI released three high yielding varieties of cassava (HYVC) as well as a package of recommended agronomic practices. Thus, the main emphasis was on production technologies.

Transfer of Production Technologies through National Demonstrations (ND)

The rational behind national demonstrations was that unless the scientists could demonstrate the technology, their advice may not be adopted by farmers. The conceptual framework of national demonstrations under the Cassava Transfer of Technology Programme differs from other demonstrations in four aspects:

1. There is a specific yield target and there is no control plot near the demonstration. The idea behind this principle is that the entire living memory of the farmers about the yield potential of the crop as well as the entire block in which the demonstration has been laid out should serve as the control.
2. The area of demonstration plot should be sufficiently large so that the feasibility of raising a good crop can be strikingly and unquestionably demonstrated.
3. The farmers in whose plots the demonstrations are laid out are the actual small-holding cultivators, so that the high yields obtained are not attributed to the effects of affluence.
4. The agricultural scientists conduct these demonstrations in association with local extension agencies/workers.

Keeping this conceptual framework in mind, CTCRI conducted the National Demonstration trials on high yielding varieties of cassava for a period of four years starting in 1970. A total of 27 demonstrations were laid out in farmers' fields. Out of these, twenty three were in Kerala, two were in Tamil Nadu and one each in Andhra Pradesh and Karnataka. In these trials the variety H-97 produced an average yield of 35 t/ha, H-165 40 t/ha and H-226 34 t/ha (CTCRI, 1974). These demonstrations proved beyond suspicion of the farmers the yield potential of high yielding cassava varieties. In collaboration with the then National Extension Service block authorities, farmers' days were organized in Kerala and Tamil Nadu for large-scale exchange of information regarding the demonstrated high yielding varieties of cassava. As a result of the proven potentialities of the HYVC, there was a large demand for planting materials, both by individual farmers and by State Departments of Agriculture. This was also a testimony to the rapid diffusion of HYVC technology. Thus, a beginning had been made in the transfer of improved cassava technologies.

OPERATIONAL RESEARCH PROJECT (O.R.P.)

The ORP aims at disseminating the proven technology in a discipline/area among the farmers on a watershed basis (covering the whole village or a cluster of villages) and concurrently studying constraints (technological, extension or sociological) as barriers to the rapid spread of improved technical know-how.

The ORP implemented by CTCRI, with assistance from IDRC, Canada, had the objective of creating a close link between CTCRI and small cassava growers through a field-oriented program for bringing about a radical increase in cassava yield in the operational area and to identify bottlenecks under field conditions. The program was operated in Vattiyoorkavu Village of Trivandrum District, Kerala State for five years starting in 1976.

The major technologies promoted in ORP were:

1. High-yielding cassava varieties H-2304 and H-1687 and improved methods of cultivation.
2. Cassava mosaic disease eradication.

Field demonstrations were conducted to popularize the technologies. Altogether 268 farmers directly participated in the demonstration programs **(Table 1)**. The performance of the HYVC was impressive with an average yield of 30 t/ha, as compared to about 15 t/ha for local varieties.

Under ORP a series of communication campaigns were organized through group discussions of farmers.

A preliminary survey indicated that intensity of CMD in local varieties ranged from 20-100%. Eradication of this disease was, therefore, included under ORP in an area of 200 ha. Farmers were recommended to mark the disease-infected plants and not to use the stems as planting materials.

Table 1. Root yield of high-yielding cassava varieties under field demonstrations in Vattiyoorkavu village, Trivandrum, Kerala, India.

Year	No.of demonstrations	Variety	Average yield (t/ha)
1977-78	52	H-2304	42
1978-79	135	H-2304	29
		H-1687	20
1979-80	81	H-2304	27
		H-1687	27

The following bottle-necks were identified to the adoption of recommended technologies:

1. Farming in this particular village is only a secondary occupation for the majority of the people with their primary occupation being either in service or business. Hence, the program could not create sufficient enthusiasm among farmers for complete participation.
2. The root quality of the introduced cultivars is not comparable to that of the local cultivars according to farmers' perception.
3. Poor market demand for HYVC as compared to the local cultivars.
4. Farmers' reluctance to incur additional expenditures required for the recommended practices. The implementation of ORP has thrown light on the varietal characters desired by farmers and lessons were learnt about appropriate selection of villages for TOT.

LAB-TO-LAND PROGRAMME (LLP)

The LLP was initiated by ICAR to commemorate the Golden Jubilee celebrations in 1979. It is a massive technology transfer program targetting socio-economic benefits for the small and marginal farmers. The salient features of the program are:

1. Direct participation of scientists as an interdisciplinary team.
2. Regular visits to the farm families and the holding of meetings.
3. Identification of problems encountered by weaker sectors of the community and providing solutions.
4. Application of a multi-mix extension approach as the TOT methodology.
5. Assessment of impact of the technologies transferred.
6. Serves as a feed-back mechanism for the agricultural scientists and extension func tionaries.

CTCRI took the responsibility of implementing LLP among cassava farming communities. The LLP determined the treatments of a package program starting from a base-level survey to final impact analysis. The CTCRI-LLP has passed through seven phases during the course of about thirteen years.

Selection of Villages and Farm Families

Utmost care was given to the selection of appropriate villages and farm families. The program was implemented in 15 villages belonging to three states benefitting 1050 cassava farmers **(Table 2).** While selecting the villages special attention was paid to the intensity of cassava area, coupled with a high concentration of small and marginal farmers. Farm families were selected following a cluster approach for mass impact and easy operations.

Socio–economic Profile of Cassava Farmers

For meaningful implementation of the program and assessment, information on the socio-economic conditions of participating farm families were collected.

Nearly 90% of the families might be considered as marginal farmers, owning up to one hectare of land. Rainfed agriculture was practiced except for the village in Salem district in Tamil Nadu. Cassava was grown in about one-third of the total cultivated area. The average land holding was only 0.30 ha and in general local varieties of cassava were cultivated and the yield was around 13-20 t/ha. It was observed that 60% of the families were quite large, indicating vast labor availability. Only very few farmers obtained agricultural information from the mass media (Anantharaman and Ramanathan, 1986b).

Adoption Level and Barriers

The overall adoption level was found to be low. Unavailability of sufficient planting material and the belief that HYVC are not adapted to local field conditions acted as barriers for adoption. Lack of conviction and knowledge as well as cost factors were some of the barriers to adoption of improved methods of cultivation (Anantharaman and Ramanathan, 1986a).

Technologies Transferred

1. High-yielding cassava varieties H-226, H-1687 and H-2304
2. Improved methods of cultivation
3. Intercropping cassava with groundnut, French bean and cowpea

TOT Approaches

With the farm family as the basic production unit, individual farm plans were

Table 2. Sites of Lab-to-Land Program implementation and the yield of introduced HYVC and recommended intercrops.

Phase	Village	State	No.of families	HYVC	Average yield (t/ha)				
					HYVC	Local cassava cultivar	Groudnut intercrop	French bean intercrop	Cowpea intercrop
I 1979-1982	Karippur	Kerala	50	H 1687 H 2304	28	15	0.60	-	-
	Manapuram	Kerala	60	H 1687 H 2304	29	15	0.44	-	-
	Munchirai	Tamil Nadu	60	H 1687 H 2304	24	14	0.60	-	-
	Gajjalnaicken Patti	Tamil Nadu	30	H 2304 H 1687 H 226	30	19	0.83	-	-
II 1982-1984	Anducode	Tamil Nadu	45	H 1687 H 2304	35	14	0.29	-	-
	Pacode	Tamil Nadu	30	H 2304	34	14	0.29	-	-
	Ayiroorpara	Kerala	125	H 2304	36	15	0.25	-	-
III 1984-1986	Sreekariyam	Kerala	100	H 1687	26	15	0.50	0.47	
	Perinad	Kerala	75	H 226	38	18	-	-	
	Phulbani	Orissa	25	H 1687	-	-	-	-	
IV 1986-1988	Perumpazhuthor	Kerala	100	H 1687	27	20	0.46	-	1.40
V 1988-1990	Kulathoor	Kerala	100	H 1687	29	18	0.59	-	1.30
VI 1990-1991	Poovachal	Kerala	100	H 1687	23	14	0.30	-	-
VII 1991-1993	Cherucode	Kerala	75	H 1687	27	13	0.30	-	-
	Anocode	Kerala	75	H 1687	27	16	0.35	-	-

developed and these were implemented with the active cooperation of the allied department and credit institutions functioning at various levels.

Demonstrations was the most effective method in proving the appropriateness of the technologies and giving working experience to farmers. The exposure training program at CTCRI was the first step in introducing the new cassava technologies. The cassava stems supplied to the farmers helped very much in overcoming the constraint of unavailability of planting materials. The critical inputs supplied free of cost acted as a motivation in the adoption of technologies. The interdisciplinary team of scientists gave the necessary guidance to farmers in conducting demonstrations through frequent farm visits. This efficient system of technology transfer also helped the technology generators to witness the operational constraints in the adoption of technology. The field days, exhibitions, seminars, group meetings, press coverage, radio programs etc. all played a role in the TOT process.

Impact of the Program

a. Economic impact

The average root yield of HYVC in the various villages ranged from 23 to 28 t/ha, while the yield of local cultivars ranged only from 14 to 20 t/ha **(Table 2)**. Thus, by adopting the HYVC with improved practices, farmers could double their cassava yields. This difference in yield was reflected in the net income, with HYVC giving an average net income of Rs. 11,000/ha, while the local cultivars gave only Rs. 8,000/ha, thus obtaining an additional net income of Rs. 3,000/ha.

In addition to the profit accrued through adoption of HYVC, intercropping in cassava fields was found to be economically viable. The performance of intercrops was satisfactory with average yields of 400, 470 and 1350 kg/ha for groundnut, French bean and cowpea, respectively. The yield of the intercrops obtained within a short span of 3-4 months benefitted the farmers with an additional income of Rs. 2,500-3,000/ha.

b. Adoption impact

Adoption of the technologies, besides many other factors, is governed by the soundness of the technology and the mental preparedness of the farmers. **Table 3** indicates that a fairly large proportion (66-77%) of farmers had already adopted certain practices like stake length, number of stakes/hill, and planting method even before the implementation of the program. Correct spacing, the retention of only two shoots per plant, mosaic control and fertilizer application was practiced by a smaller proportion of farmers (5-15%) and the planting of HYVC was practiced by none. The LLP has induced significant positive changes in the adoption behaviour of farmers as indicated by the proportion of farmers continuing to use the practices after termination of the program.

While non-monetary practices, such as stake length, number of stakes/hill and planting method, were adopted by 100% of the farmers, a sufficiently large proportion of the farmers were found adopting the other practices as well. The LLP was instrumental in farmers accepting and adopting HYVC, as indicated by the high proportion of farmers that continued adoption **(Table 3).**

Table 3. Adoption of recommended practices by beneficiary farmers of Kanyakuman and Trivandrum districts of south India before and after the program.

Recommended Practices	Farmers adopting recommended practices (%)	
	Before (1981/82)	After (1985/86)
HYVC	0	85 (17)
No. of stakes/hill	77 (77)[1]	100 (100)
Stake length	73 (73)	100 (99)
Planting method	66 (65)	100 (100)
Spacing	19 (15)	86 (80)
Fertilizer application	58 (5)	82 (11)
Mosaic control	8 (8)	41 (34)
No. of shoots retained	13 (13)	65 (61)

[1] Figures in parenthesis indicates percentage of farmers adopting the recommended practices in their entire cassava area.

Problems Encountered in Massive Spread of Technologies

a. Lack of sufficient planting materials: There is no institution dedicated to large-scale multiplication of planting materials of HYVC, while the crop is characterized by a slow multiplication rate compared to that of cereals and pulses.

b. Poor resource base of farmers: The resource base of most cassava farmers is limited and hence they are less likely to adopt HYVC with recommended practices because of the financial risks involved.

c. Limited diversification in cassava utilization: Presently, cassava is used mostly as a secondary staple food and only to a limited extent as a raw material in starch/sago industries. With the adoption of HYVC, cassava production in the community increases and in the absence of a diversified cassava market, this obviously results in an excess supply and thus low prices.

TRANSFER OF PROCESSING TECHNOLOGIES

Realizing the fact that transferring production technologies will be a futile exercise unless the production technologies are suitably linked with that of processing technologies in the villages, the transfer of processing technologies was also included in CTTP. In selecting the processing technologies most suitable for transfer, due consideration was given to low-cost technologies appropriate for adoption by small farmers at the individual farm level or on a small co-operative basis. The technologies identified are:

1. Storage of cassava roots
2. Preparation of cassava dry chips, and
3. Production of cassava rava

The processing technologies were transferred by organizing:
1. Training for voluntary organizations, 2. Training for farm women, and 3. Exhibitions and food festivals. Until now five training programs have been conducted on processing technologies, benefitting nearly 250 trainees.

A post-training survey conducted with a group of trainees indicated that one group of trainees had prepared on a co-operative basis cassava papad and chips in packaging materials.

Large quantities of cassava rava and porridge were sold through CTCRI exhibition stalls. A survey was conducted among the consumers of rava about their acceptance of the product **(Table 4).** The results indicate that the majority of the consumers expressed a high level of acceptance for characteristics like color, taste, consistency and easiness in cooking, while other characters like smell and fuel consumption had a somewhat lower level of acceptance. The overall acceptance of the product was quite good and some consumers indicated interest in the commercialization of cassava rava.

Table 4. Consumer acceptance of rava in terms of specific quality characteristics.

Product characterization	Level of acceptance (%)		
	Low	Medium	High
Color	3	9	88
Taste	12	14	74
Smell	11	43	46
Consistency	9	2	89
Easiness in cooking	6	6	88
Fuel consumption	9	77	14
Overall acceptance	23	9	68

TRAINING PROGRAMS FOR EXTENSION PERSONNEL

Apart from the front line transfer programs on cassava as detailed above, CTCRI conducts periodic intensive training programs for extension personnel of various State departments. The training program has benefitted more than 500 extension agents since 1980.

TRANSFER OF TECHNOLOGY BY STATE DEPARTMENTS OF AGRICULTURE

Besides CTTP undertaken by CTCRI in a modest way, the SDA of Kerala and Tamil Nadu are also involved in this process, mainly through the training and visit system (T&V). Basic information on improved cassava cultivation was supplied to agricultural officers during fortnightly training sessions and they in turn passed this information on to farmers.

Apart from SDA, Kerala had a special program called "Tapioca package programme" which was started in 1977. During the course of this program (1977-1981) altogether 1959 single crop demonstrations and 1401 intercrop demonstrations were laid out in farmers' fields to popularize improved cultural practices and intercropping amongst the cultivators.

In Tamil Nadu, using T&V, demonstrations were conducted in Salem district on high-yielding varieties, basal and top dressing of fertilizers, intercropping, phosphate slurry treatment of setts, use of herbicides and control of lime-induced iron chlorosis (Nanjayan, 1986). In Kanyakumari district too, adaptive research trials and demonstrations were conducted on variety H-1687, use of chemical fertilizers and intercropping with groundnut (Ramaiah, 1979). The Department of Horticulture in Tamil Nadu implemented a special program to popularize HYVC in the hilly regions of Salem district (Gurusamy and Kalikamoorthy, 1986).

GENERAL IMPACT OF CTTP

As a direct result of CTTP carried out by CTCRI and SDAs, the two high yielding varieties H-165 and H-226 now occupy more than 75% of the cassava area in Salem, South Arcot and Dharmapuri districts of Tamil Nadu. In Kanyakumari district of Tamil Nadu 14% of cassava area is under H-1687 and around 5% under H-165 (Ramanathan *et al.,* 1990). The variety H-226 is also popular in southern districts of Kerala occupying 33% and 15% of the cassava area in Pathanamthitta and Quilon, respectively (Ramanathan *et al.,* 1989). The impact of CTTP is also indicated by the annual rate of increase of about 1.25% in cassava yield since 1970.

Lessons from CTTP for Research Personnel

The lack of HYVC planting materials and the high cost of transport pose great problems in rapid dissemination of these varieties. This calls for the development of a methodology for faster multiplication and easier distribution. Until now, breeding of new varieties was done with specific selection criteria (high-starch or tasty varieties) to cater to the need of specific end users. The CTTP experience indicate that over the years the marketing of the cassava roots has undergone a change from specific sales for human consumption only to sales for diversified end uses. This situation demands varieties which can satisfy the cooking quality requirements as well as having high starch content.

It is an established fact that the resource base of cassava farmers is poor and hence it can not be expected that farmers will adopt the full recommended fertilizer rates. This points to the fact that researchers should either develop varieties tolerant to low fertilizer inputs or develop low cost fertility management practices.

CMD has become a serious disease in many local varieties as well as in HYVC. The recommendiation of avoiding the planting of CMD infected stakes will not suffice considering the magnitude of current infection. This warrants a suitable solution from researchers, either by replacing the current cultivars with CMD-resistant ones or through distribution of an abundant supply of disease-free planting material.

Cassava price and market demands are highly unstable due to storage problems and lack of more diversified end-uses. This situation requires processing technologists to develop more suitable storage methods and a wider range of cassava products.

Another fact learnt from CTTP is that one should not expect a complete adoption of all components of the recommended practices. Farmers tend to choose the recommended practices according to available resources, which indicates the importance of low-input research recommendations.

Lessons from CTTP for Extension Personnel

Many small cassava growers are quite receptive to new technologies once the information and required inputs are given. This means that there is a need for continuous updating of the information and for the provision of planting materials, both vital factors in enabling extension personnel to spread new technologies to more farmers.

Farmers generally accept those components which do not require expensive inputs. Consequently, among the various recommended practices, the adoption of the recommended dose of fertilizer was only partial due its cost factor. Extension agencies need to work out ways to effectively link farmers with credit institutions to obtain the required capital.

Sometimes adoption of certain non-monetary inputs can become constraint due to physical limitations. The best example of this is the case of CMD prevention by using disease-free stems. The shortage of sufficient stems to plant large areas forced farmers to use infected stems. To avoid long-term damage due to this disease, extension agencies need to change their strategies to educate the farmers about the ill effects of the disease, coupled with an effective system for the distribution of disease-free planting material free of charge.

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RECENT PROGRESS IN CASSAVA AGRONOMY RESEARCH IN THAILAND

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ABSTRACT

The paper reviews the available data and current research activities on agronomic aspects of cassava in Thailand. These activities were carried out by various national research programs in collaboration with CIAT during 1990-1993. The review shows that the inherent fertility of cassava soils has been depleted due to long-term cassava monocropping without sufficient replacement of plant nutrients, and from degradative processes of soil erosion, nutrient run-off and organic matter depletion. Consequently, there has been a reduction in root yields due to nutrient stress, water stress and top soil loss by erosion . Variability in production and income is a major characteristic of cassava cropping in Thailand. The challenge remains for research to take an integrated approach, involving all aspects of soil water, fertility and crop management in the program. Topics discussed include: (a) erosion control; (b) cropping practices; (c) integrated plant nutrition systems; (d) soil fertility evaluation; and (e) efficient use of fertilizers.

INTRODUCTION

Thailand is presently among the world's major producers of cassava roots and is the biggest exporter of cassava products. In 1992 the country exported 8.8 million tons of dry cassava products. About 90% of the total cassava production is exported, mainly as pellets and chips (92%) and a small quantity as starch (8%). The most important market is the European Economic Community (EEC). Since 1983 Thailand has encountered a root surplus problem, due to the import quota in the EEC, which limits the import of cassava pellets from Thailand to 5.25 million tons annually. Such a restriction has caused severe economic losses to those working in the cassava industry, especially to small farmers. As a measure to alleviate this problem the Thai government has formulated a "Cassava Action Plan". The plan calls for optimization of the cassava cultivation area, diversification of agricultural production at the farm level, a search for new domestic and foreign markets for cassava products, and the development of new

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processes for greater industrial use of cassava.

According to the recent Common Agricultural Policy (CAP) of the EEC, domestic cereal prices will be reduced gradually by about 29% over the period from July 1993 to June 1996. In order to remain competitive in the formulation of animal feed rations the Thai cassava pellet price will need to decrease, which in turn will decrease the farm gate price of cassava roots in Thailand by about 30%; this is lower than the present production cost. The government has dealt with this problem by a policy to reduce the supply through a reduction in area planted or allotment and by inducements to plant other crops. This program was initiated by the Ministry of Agriculture in 1993. Under this program, cassava research will need to focus mainly on increasing the level and stability of production using present land resources by improving the technology, the distribution of planting material and the understanding of the production process.

This paper reviews the agronomic research carried out by various national research programs in collaboration with CIAT during 1990-1993.

Cassava Production, Soils and Climate

Production: The trends in planted area, production and average yield of cassava since 1982 are shown in **Table 1.** Cassava production in Thailand reached its peak at over 24 million tons in 1989 and has declined to a level of about 20 million tons during the past few years. About 60% of cassava is produced in the Northeast, 29% in the Central Plain

Table 1. Area, production and yield of cassava in Thailand from 1981 to 1993.

Year of harvest	Planted area ('000 ha)	Production ('000 t)	Yield (t/ha)
1981	1,270	17,744	13.97
1982	1,236	17,788	14.39
1983	1,368	18,989	13.88
1984	1,405	19,985	14.22
1985	1,477	19,263	13.04
1986	1,240	15,256	12.30
1987	1,411	19,554	13.86
1988	1,581	22,307	14.11
1989	1,622	24,264	14.96
1990	1,530	20,701	13.53
1991	1,492	19,705	13.21
1992	1,492	20,356	13.64
1993 [1)]	1,473	19,767	13.42
Rate of increase (%)	1.867	1.655	-0.209

[1)] Estimated values.

Source: Office of Agric. Economics, 1994.

and 11% in the North. The yield has been fluctuating between 13 and 15 t/ha during the past ten years.

Soils: The majority of cassava soils in Thailand are classified at the great group level as loamy Paleustults and Quartzipsamments. The Paleustults occupy about 75% of the total cassava area in Thailand and are widerspread both in the Northeast and the East, whereas the Quartzipsamments are relatively more dominant in the Eastern region. Characteristically, most of the cassava soils are poor in terms of their indigenous soil fertility, as shown in **Table 2.** They have rather unfavorable physical and chemical properties, such as a very light texture in the surface soil, low levels of organic matter, low nutrient and water retention capacity, and also very low contents of available P and K. Moreover, due to their rather poor aggregate stability and their frequent occurence in areas of undulating or rolling topography, soil loss due to erosion can be very severe, particularly in the Northeast. This is one of the main causes of an apparent soil fertility decline in most of the cassava growing areas of the country.

Table 2. General characteristics of the major cassava soils in Thailand.

Great group	Quartzipsamment	Paleustult
1. Texture	sand or sandy clay loam	sandy loam
2. Drainage	good	moderate
3. Permeability	moderate	moderate
4. Surface run-off	rapid	rapid
5. Organic matter (%)	0.8-1.8	0.5-1.3
6. Base saturation (%)	35-75	35-75
7. CEC (me/100g)	2-4	3-5
8. Available P (ppm) (Bray-II)	4-7	2-6
9. Available K (ppm)	20-60	20-80
10. pH	5.0-6.5	4.5-6.0

Source: Duangpatra, 1988.

Climate: According to the air temperature, the cassava growing regions are classified as isohyperthermic with an annual mean temperature of 26-28°C. The mean annual relative humidity ranges from 70-75% in most areas. The mean potential evapotranspiration in the Northeast and East vary from about 1400 to 2000 mm annually. With respect to soil moisture, most soils in the cassava region are classified under the Ustic moisture regime.

The rainy season extends from May to October with a mean annual rainfall of about 1200 to 1600 mm. The rainfall pattern is bimodal with the first peak generally occuring in May to June and the second in Sept to Oct. The first rainfall peak from May to June is dominated to a large extent by the southwest monsoon and by tropical cyclones originating in the Indian Ocean, and the second peak from Sept to Oct by the northeast monsoon originating in the South China Sea.

Fertilizer Use

Decreasing cassava yield has been cited as a major problem by many farmers who have grown cassava on the same piece of land for several years. Many farmers have now started to use fertilizers on cassava, but the rates used are still very low.

Current fertilizer recommendations for cassava are still very general and not sufficiently specific to allow farmers to optimize fertilizer use. The rate of 100 kg N, 50 P_2O_5, and 100 K_2O/ha is recommended in general. However, it is essential that fertilizer recommendations be based on soil tests whenever possible.

Despite its demonstrated potential to increase yield, fertilization is not yet a widely accepted cultural practice, mainly because of the high risk of crop failure in rainfed areas. A survey conducted by the Department of Agricultural Extension in 1991 of 32 provinces in the cassava growing areas indicated that only 45% of farmers had ever used fertilizers (DOAE, 1992a). However, a more recent survey of cassava farmers in Rayong province showed that about 90% of farmers in that province now apply some chemical fertilizers (DOAE, 1992b).

RESEARCH RESULTS

Erosion Control

Erosion can be a serious problem in cassava fields since the crop is planted in rows 0.8-1.0 meter apart, and it takes 3 to 4 months for the canopy to close. Surface movement of soil carried by rainfall run-off is the dominant erosion process.

Ideally, a high-residue crop should be grown before cassava to provide some surface protection and to increase soil organic matter. However, under the existing soil and climatic conditions, different crops vary in the effectiveness of the residues to provide sufficient cover. Generally the greatest problem a farmer encounters is in preserving adequate residue to protect the soil from erosion, while still controlling weeds. The method also loses effectiveness when drought limits the quantities of available crop residues.

Little research on soil erosion in the cassava growing areas has been conducted that measured both run-off and soil loss. Since 1987, many simple trials that measured only soil loss were established on different slopes in the eastern region (Jantavat *et al.*, 1991; Tongglum *et al.*, 1992). The effect of many cultural practices on yield and erosion were measured. From all these experiments it was concluded that contour ridging and no-tillage were very effective practices because they produced high yields and low soil loss due to erosion, as shown in **Table 3**; lack of fertilization, on the other hand, resulted in high soil losses and low yields.

Table 3 Effect of the use of various cultural practices on average dry soil loss due to erosion and the yield of cassava planted on 5–8% slope in two provinces of the Eastern region of Thailand.

Cultural practice	Dry soil loss (t/ha)		Cassava yield (t/ha)	
	Chonburi (1987-1988)	Rayong (1989-1990)	Chonburi (1987-1988)	Rayong (1989-1990)
No-tillage, with fertilizers	49.7	10.7	28.4	16.9
Coventional (plowing and discing), with fert.	20.8	17.5	28.5	14.4
Conventional with contour ridging, with fert.	8.1	13.2	32.6	15.6
Conventional with up-and-down ridging, with fert.	23.6	19.7	29.4	16.0
Conventional, no fertilizers	35.8	25.7	21.4	12.2

Source: Jantawat *et al.*, 1992.

Although zero or minimum tillage reduced erosion in many (but not all) situations, this practice has not been widely adopted because the cultural practices developed for clean-tilled soils are not always applicable to conservation-tilled soils. Therefore, additional research is needed to develop more practical and economically attractive practices.

Agronomic Practices

Planting time: Cassava in Thailand can be planted year round since there is usually sufficient soil moisture. However, there are commonly two planting periods. In the first period cassava is planted right after the first rains of sufficient size (>15 mm), usually from the end of Febr to the middle of June. The second planting period is directly after the main rainy season, between early Oct and early Dec, the duration depending on the availability of soil moisture. The crop can be harvested any time at 8-12 months after planting, but preferably in the dry season when root starch content is high. Research results on the best time of planting vary, but usually indicate highest yields when the crop is planted in May or in November (Phornphrompprathaan *et al.*, 1993).

Weed control: Control of weeds is as important as most other management practices, such as choice of varieties, stand establishment, and water/fertilizer application. In fact, other improved cultural practices without adequate weed control will generally lead to disappointing yields. Effective weed control is the first step towards reducing water loss and thereby improving yields in the uplands. Weeds need to be controlled mainly in the early stage of cassava growth. Numerous studies have indicated that the more limited the water supply, the more critical becomes adequate weed control.

Weed control is traditionally done by hand with a hoe. The number of weedings necessary for cassava varies considerably depending on soil fertility, climatic factors and varieties. Tongglum *et al.* (1992) studied the effect of frequency of weedings on the yield of two recommended varieties (Rayong 3 and Rayong 60). They reported that two times of hand weeding at 1 and 2 months after planting gave the best results for both varieties **(Table 4).** Results indicate that the weeding cost varies according to the planting season, the cost being much higher when cassava is planted in the early rainy season than when planted in the early dry season.

The use of herbicides in cassava is quite new, but in recent years some research has been conducted in this area. Tirawatsakul *et al.* (1988) reported that the pre-emergent herbicide Metolachlor, applied at the rate of 1.56 kg a.i./ha, could control 90% of weeds during the first three months after planting, and resulted in a significantly higher yield of 26.8 t/ha and lower production costs **(Table 5).**

Table 4. Cassava fresh root yields and weeding costs as effected by the frequency of hand weeding when cassava, Rayong 3 and Rayong 60, were planted at Rayong Field Crops Research Center in the beginning of the rainy and dry seasons of 1991.

Treatment	Rainy season		Dry season	
	Root yield (t/ha)	Weeding cost (US $/ha)	Root yield (t/ha)	Weeding cost (US $/ha)
Varieties				
Rayong 3	21.44 b	111	22.88 b	57
Rayong 60	28.00 a	94	30.81 a	53
F-test	*		*	
Weeding times				
No weeding	4.81 b	0	23.63	0
1 & 2 months	26.69 a	77	24.88	9
1, 2 & 3 months	29.00 a	85	25.38	14
1, 2, 3 & 6 months	27.94 a	127	26.06	57
1, 2, 3, 6 & 9 months	31.44 a	118	29.56	104
As necessary	28.81 a	106	31.56	90
F-test	**		NS	

Source: Tongglum *et al.*, 1992.

Intercropping: Cassava is extensively grown as a monocrop in areas of low soil fertility, but in more fertile soils it is grown in complex cropping systems, often as an intercrop. In traditional systems where no fertilizer is applied, the yields of cassava and the intercrops are generally low. When cassava and grain legumes are planted simultaneously, 2-3 rows of grain legumes between widely-spaced cassava rows, and fertilizers are applied, good yields of both crops can be obtained. Although, the yields of both cassava and the intercrop are normally reduced, the land equivalent ratio is consistently greater than one. The average yields of cassava and the intercrops in an intercropping system at the Rayong Research Center are shown in **Table 6.**

The potential for obtaining a rapid cash return from grain legumes with little reduction in cassava yield is particulary attractive to the resource-poor small farmers.

Integrated Plant Nutrition

The basic principle of integrated plant nutrition is the maintenance of soil fertility, sustaining increased agricultural productivity and improving farmers income through

Table 5. Effect of chemical weed control in cassava (Rayong 1) on yield and economic benefits in Rayong Field Crops Research Center, Rayong, Thailand in 1987/88.

Treatment	Root yield (t/ha)	Gross benefit[2] (US$/ha)	Weeding cost (US$/ha)	Net benefit (US$/ha)
1. Metolachlor (1.56 kg/ha);PE[1]	26.82 a	955	230	725
2. Oxyfluorfen (1.56 kg/ha);PE	21.26 b	757	234	523
3. Metolachlor (1.56 kg/ha);PE-B + Paraquat (0.5 kg/ha);ST	25.76 ab	917	234	683
4. Metolachlor (1.56 kg/ha);PE once bullock cultivation +Fluazifop-butyl (0.38 kg/ha);PE	25.66 ab	914	268	646
5. Metolachlor (1.56 kg/ha);PE + Fluazifop (0.38 kg/ha);ST	27.00 a	961	258	703
6. Twice bullock cultivation +Paraquat (0.5 kg/ha);ST	26.84 a	956	237	719
F-test	**			

[1] PE - Pre-emergent

PE-B = Pre-emergent, band spraying

ST = Spot-treatment

Herbicide application rates are in kg active ingredient/ha.

[2] Root price = US$ 35.6/ton.

Source : Tirawatsakul, 1988.

Table 6. Average yield of cassava and intercrops in various intercropping systems planted in Rayong Field Crops Research Center, Rayong, Thailand, 1988–1991.

Cropping system	Yield of cassava (t/ha)	Yield of intercrops (kg/ha)
Cassava monocrop	13.80	-
Cassava+sweet corn	13.54	12,556[1]
Cassava+mungbean	13.39	306
Cassava+peanut	11.42	744
Cassava+soybean	10.18	450

[1] Number of ears/ha.

Source: Tongglum *et al.,* 1992.

the judicious and efficient use of mineral fertilizers, organic manures and biofertilizers.

When cassava is grown continuously on the same land, the nutrient supplying capacity of the soil may become limited, due to nutrient losses through crop removal, leaching, erosion and run-off. Therefore, the judicious use of mineral fertilizers to replenish the nutrient supply is a key factor in maintaining soil productivity. The application of organic materials to soils and their effect on improving the physical properties are well known, but what is needed is the development of rational and realistic practices that will optimize economic returns while preserving the soil's productivity.

Paisarncharoen *et al.* (1990) reported on the long-term effects of different leguminous green manures on the physical and chemical soil properties of Yasothon soil (oxic Paleustult) at the Khon Kaen Field Crops Research Center in the Northeastern region. The green manures were planted annually during the early rainy season and were incorporated into the soil at 60 days after planting; after that, cassava (Rayong 3) was planted and harvested at about 10 months. The results show that cowpea (Vita-3) residues increased cassava root yields significantly when compared with *Crotalaria* and pigeon pea **(Table 7).**

Table 7. Cassava root yield (t/ha) as affected by the incorporation of different green manures before planting cassava at the Agric. Developm. Research Center (ADRC) in Khon Kaen, Thailand.

Green manure	Crop year					Means
	1	2	3	4	.5	
Cowpea	10.23	17.58	16.24	19.14	14.64	15.57
Pigeon pea	5.44	12.91	14.16	13.25	14.18	11.99
Crotalaria juncea	5.88	13.43	14.94	17.21	15.20	13.33
No green manure	4.43	13.99	14.13	12.07	13.97	11.72
F-test	**	NS	NS	NS	NS	**
CV (%)	23.6	29.7	23.9	11.5	32.7	10.7

Source: Paisarnchareon *et al.,* 1990.

Tongglum *et al.* (1992) also studied the maintenance of soil fertility through the use of green manures in cassava grown on Mapbon soil series (Typic Paleustult) in Pluak Daeng, Rayong. They found that *Crotalaria juncea* produced much more above-ground dry matter (7306 kg/ha) but contained slightly less N than did either *Mucuna* or *Canavalia* **(Table 8).** The results also indicate that the root yield response of cassava corresponded to the quantities of N added to the soil in the green manures.

Table 8 Dry matter production and the amount of N in the above-ground part of various green manuring crops as well as their effect on the yield of the subsequent cassava planted in Pluak Daeng, Rayong, Thailand in 1991/92.

Green manure	Dry matter (kg/ha)	Total N (kg/ha)	Cassava yield (t/ha)
No green manure	-	-	3.61 c
Sesbania rostrata	1387 d	23.4 e	4.77 bc
Mucuna fospeada	4831 b	157.5 a	7.04 ab
Crotalaria juncea	7306 a	122.8 a	7.73 a
Pigeon pea	5181 b	106.3 c	7.61 a
Cowpea (local)	2825 c	73.7 d	6.00 abc
Canavalia ensiformis	5168 b	136.4 ab	6.00 abc
CV (%)	14.6	14.4	26.9

Source: Tongglum *et al.,* 1992.

Soil Fertility Maintenance

Research on soil fertility maintenance and fertilization of cassava has been conducted for many years in Thailand. The objective is to provide information on the nutrient status of the soil and predict the relative response to added nutrients. Sittibusaya *et al.* (1988) and Hagens and Sittibusaya (1990) reviewed the nutrient availability in cassava soils and the response to fertilizers in Thailand. Results of experimental trials have been variable, but in general it was evident that N was the most limiting nutrient. Yield increases from N fertilizers were reported in most locations, while cassava responded to P and K in only some locations. However, cassava is known to absorp large quantities of K for starch accumulation. The need for K application is well-understood. From several long-term fertilizer trials with continuous cropping it is evident that K soon became the most limiting nutrient. Soil test summaries showed that most cassava soils are inherently low in available N and P and moderately low in available K (Duangpatra, 1988).

Fertilizer Recommendations Based on Soil Analyses

The determination of optimum fertilization rates is one of the important functions of agronomic research. It is difficult to arrive at fertilizer recommendations for specific producing conditions as crop response to fertilization depends on the nature of the crop itself, the characteristics of soils and climate at the location where it is grown, and the management practices employed in growing the crop. Soil analysis is a valuable source of information for use in soil management; however, the analyses results must be correctly interpreted to be useful.

A model was developed to predict the necessary P and K rates of application to obtain maximum economic returns based on field trial data. Sittibusaya (1993) reported a rough estimation of the soil-P and soil-K levels that will seperate responding and non-responding soils. Using cassava yield data obtained from the FAO fertilizer trials conducting on farmers' fields at about 100 locations in Thailand during 1980-1987, critical soil test levels were identified using a simple statistical procedure for partitioning the soil test correlation data, as proposed by Cate and Nelson (1971). This allows the grouping of cassava soils into four responding and non-responding categories. The soil tests for available P (Bray-2) and exchangeable K, can thus be very useful in deciding whether or not to apply those nutrients to a given soil.

The splitting of the soil test correlation data into two groups by the above-mentioned statistical procedure resulted in critical levels of 4 ppm of soil-P (Bray-2) and 22 ppm of soil-K for cassava grown on the Korat soil series (typic Paleustults) in the Northeast region. For the Sattahip soil series (Quartzipsamments) in the eastern region, the critical levels were found to be 6 ppm of soil-P and 22 ppm of soil-K. Based on these critical soil test levels, the sites were grouped into four different soil categories. The pooled data for each group are shown in **Table 9.**

From the data in Table 9 regression constants were calculated by fitting the quadratic equation $Y=a+bX+cX^2$ to the response curves for each nutrient. The calculated equation constants are shown in **Table 10.**

The final step, before a recommendation can be made, is to apply economic criteria to determine the optimum profitable rate of NPK fertilizers for the farmer. An analysis of Marginal Rate of Return (MRR) on investment was executed using the quadratic response curves for each nutrient shown in **Table 10,** as well as prices of nutrients and cassava roots at the farm gate. To account for cost of capital and a variety of risks, the MRR on investment of the last additional fertilizer application was assumed to be 100%. The calculated optimum rates of N, P_2O_5 and K_2O for each fertility category are shown in **Table 11.** It should be pointed out that the predicted rates varied according to the particular soil/crop conditions. However, the average amount of fertilizers are comparable to the general recommendation of 100 kg N, 50 P_2O_5 and 100 K_2O/ha.

FUTURE RESEARCH DIRECTION

Conservation-tillage and other soil conservation practices offer a major potential for improving cassava yields while reducing soil erosion. There is also a need to establish a more satisfactory fertilizer program and to conduct more research on efficient weed control methods. Crop residue management also requires further work. A major requirement is the establishment of site-specific, environment-specific recommendations for the agronomic practices used in cassava cultivation.

Table 9. Average effect of various fertilizer treatments on the root yields (t/ha) of cassava in the FAO on-farm trials conducted in the Northeast of Thailand from 1981 to 1987 when these trials were grouped into four soil fertility categories.

Treatment $N-P_2O_5-K_2O$ (kg/ha)	Soil fertility category Low P-Low K (n=14)	Low P-High K (n=7)	High P-Low K (n=16)	High P-High K (n=16)
0-0-0	13.4	22.9	16.7	18.1
0-50-50	16.1	22.6	22.6	20.5
50-50-50	25.1	28.9	27.7	28.1
100-50-50	28.3	28.4	33.3	30.6
50-0-50	21.6	26.4	27.0	27.3
50-100-50	27.1	25.8	27.2	26.7
50-50-0	18.9	27.8	25.1	27.4
50-50-100	25.3	29.2	28.4	28.8
LSD (0.05)	3.8	4.1	3.9	4.1
CV (%)	21.4	13.6	21.1	22.2

Source : Sittibusaya, 1993.

Table 10. Coefficients calculated by fitting the average response of cassava to N, P and K application in four soil categories to a quadratic equation.

Soil fertility category	No. of trials	Response curve coefficients a	b	c
Low P, Low K	14	N: 16.1	1.0	-0.02
		P: 21.6	0.7	-0.02
		K: 18.9	1.2	-0.05
Low P, High K	7	N: 22.5	0.8	-0.03
		P: 26.4	0.9	-0.08
		K: 27.8	0.2	-0.01
High P, Low K	16	N: 22.6	0.4	-0.02
		P: 27.0	0.2	-0.02
		K: 25.1	0.4	-0.01
High P, High K	16	N: 20.5	0.8	-0.02
		P: 27.3	0.3	-0.03
		K: 27.4	0.1	-0.01

Source: Sittibusaya, 1993.

Table 11. Optimum levels of application of N, P and K to cassava in four soil fertility categories based on an analysis of Marginal Rate of Return (MRR) using current cassava and fertilizer prices.

Soil fertility category	Optimum application (kg/ha)[1]		
	N	P_2O_5	K_2O
Low P, Low K	126	72	69
Low P, High K	84	28	35
High P, Low K	-	-	70
High P, High K	119	11	-

[1] Price (US $) of fresh roots = $ 36/ton; N = $ 0.50/kg; P_2O_5 = $ 0.60/kg and K_2O= $ 0.35/kg.

Source: Sittibusaya, 1993.

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RECENT PROGRESS IN CASSAVA VARIETAL IMPROVEMENT IN THAILAND

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ABSTRACT

Five cassava cultivars for industrial purposes, Rayong 3, Rayong 60, Sriracha 1, Rayong 90 and Kasetsart 50, were released during 1984-1992. New cultivars were simultaneously evaluated in research stations and farmers' fields in 53 locations during 1991 and 1992. Yields of each cultivar were regressed on mean yield of all cultivars in each location to detect the response of cultivars to 53 different yielding environments. New cultivars had higher HI and root DM content than the most important local cultivar, Rayong 1.

Rayong 3, which had higher HI but lower total biological yield (TBY) than Rayong 1, yielded higher than Rayong 1 only in very high yielding environments. Rayong 60 and Rayong 90, which had higher HI and similar TBY to Rayong 1, yielded higher in high yielding environments, but in low yielding environments Rayong 60 yielded lower, while Rayong 90 yielded higher than Rayong 1. Kasetsart 50 and a promising clone, CMR25-105-112, which had higher HI and TBY, yielded higher than Rayong 1 in all environments.

Results of effects of harvesting time (at 9 and 12 MAP) from nine experiments revealed that Rayong 60 yielded the highest at 9 MAP. In a different experiment it was found that Sriracha 1 was a good cultivar for late harvest (two years after planting). In contrast, late harvest resulted in high occurence of root rot in Rayong 60. Detailed studies on optimum season-of-planting and harvesting and on harvesting time of each cultivar is suggested for the future. Data on population means over 11 years of selection indicate that yield improvement in cassava is possible and could be achieved through selection for higher TBY and root DM content while maintaining high HI.

INTRODUCTION

In Thailand cassava is the second most important crop after rice in terms of planting area, generating farmers' income, rural employment and export earnings. In the past five years, the average cassava planted area was 1.54 million ha and the average

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production of fresh roots was 21.47 million tonnes, corresponding to an average yield of 13.94 t/ha. About 75% of cassava roots are processed into chips and pellets for exports, mainly to European Economic Community (EEC) countries to be used as animal feed. The remaining 25% of cassava is processed into starch.

As the major part of cassava exports is destined to EEC countries, it is inevitable that any change in agricultural policy in the EEC will have a significant impact on Thailand's cassava policy. Recently, the EEC agreed to lower its support price of cereals as much as 30% within the next three years, beginning in late 1993. This will undoubtedly reduce the price of Thai cassava significantly.

In order to safeguard the Thai cassava farmers and industry, the Ministry of Agriculture and Cooperatives (MOAC) has established a policy to try to reduce the cassava planted area by about 160,000 ha. To achieve this goal, the MOAC plans to replace cassava with fast growing trees, fruit trees and pastures. Additionally, to increase cassava yields, the traditional cultivar Rayong 1 should be replaced by new higher yielding cultivars in about 300,000 ha, within the next five years (1994-1998). Currently, the large-scale multiplication, promotion and distribution of new cassava cultivars is being planned by both the government and the private sector.

CASSAVA VARIETAL IMPROVEMENT

Historical Background

Before the Second World War, cassava was cultivated mainly in the southern part of Thailand, especially in Songkhla province, for use in starch and sago production. In those days, an attempt was made to introduce new cassava clones for selection. Komkrid (1937) reported that three clones from the Philippines and 17 clones from Malaysia were introduced for selection at the Southern Field Crops Station in Songkhla (presently, the Songkhla Rubber Research Center). During that period, two cassava cultivars, Local 1 and Local 2, were used for industrial purposes. No further information, however, was reported about those introductions.

As time progressed, the cassava growing area gradually moved to the eastern part of the country, especially to Chon Buri and Rayong provinces. In 1949, 16,000 ha of cassava were planted in Chon Buri, according to reports in Agricultural Statistics of Thailand. Since then, cassava research has been conducted mainly by the Rayong Field Crops Research Center (RAY-FCRC) of the Department of Agriculture (DOA), which was established in 1954.

Early work at RAY-FCRC, from 1956 to 1961, was concerned mainly with local cultivar collections and clonal selection. One of the best local clones was officialy named "Rayong 1" in 1975 (Sinthuprama, 1983). Rayong 1 is by far the most successful cultivar in Thailand, with presently more than 90% of the cassava area planted to this cultivar.

From 1962 to 1984 about 81 clones were introduced from Indonesia, Virgin Islands and from CIAT/Colombia and were evaluated at RAY-FCRC; however, none of those clones was found to be superior to Rayong 1.

F_1 hybrid seeds have been introduced continuously from CIAT/Colombia since 1970. Local hybridization and selection started at RAY-FCRC in 1975 and at Sriracha Research Center of Kasetsart University (KU) in 1983. In a major breeding program by RAY-FCRC, 15,000-20,000 F_1 seeds from RAY-FCRC and 1,000-3,000 F_1 seeds from KU, were produced and evaluated annually. Regional yield trials and on-farm trials were conducted jointly by RAY-FCRC and KU and promising cross parents were mutually exchanged. In 1983, CIAT established its Asian Regional Program in Thailand and its role has been mainly to supply cassava germplasm from Latin America and to help train cassava researchers.

Since 1984, several new cassava cultivars suitable for industrial purposes, such as Rayong 3, Rayong 60 and Rayong 90 (formerly called (CMC 76 x V43) 21-1), were released by RAY-FCRC, and Sriracha 1 by KU, while Kasetsart 50 (formerly called MKUC 28-77-3) were jointly released by KU and RAY-FCRC. Cross parents and the main features of these cultivars are summarized in **Table 1.**

Table 1. Recommended cassava cultivars in Thailand.

Cultivars	Year released	Parents	Main features
Rayong 1	-	Selected among local cultivars	high yield, good plant type
Rayong 3	1984	MMex 55 x MVen 307	high root DM
Rayong 60	1987	MCol 1684 x Rayong 1	early harvest, high yield
Sriracha 1	1991	(MCol 113 x MCol 22) x Rayong 1	high root DM, good plant type
Rayong 90	1991	CMC 76 x V 43	high root DM, high yield
Kasetsart 50	1992	Rayong 1 x Rayong 90	high root DM, high yield, good plant type

Improvement in Varietal Performance

Rayong 1 is a selection from a local land race; it has excellent agronomic traits, such as good germination, vigorous vegetative growth, favorable plant type, moderate harvest index (HI), tolerance to mites and the capacity to give relatively high yields under average farmers' conditions. More than 1 million hectares are planted annually to Rayong 1. So it can be stated that Rayong 1 is the most successful cassava cultivar in the world and the success of the Thai cassava industry is largely due to the excellent characteristics of Rayong 1 (Limsila *et al.*, 1992).

Promising cultivars, namely Rayong 1, Rayong 3, Rayong 60, Rayong 90 and Kasetsart 50, as well as a promising new clone, CMR 25-105-112, were simultaneously tested in regional yield trials, on-farm trials and on-farm tests (0.16 ha plots without replication) in both 1991 and 1992, giving data from a total of 53 trials. Yield parameters and agronomic traits are summarized in **Table 2.**

Table 2. Average yield data of five cassava cultivars and a promising clone obtained in 53 on-farm trials and tests conducted in 1991 and 1992 in Thailand.

Cultivar	Root yield (t/ha) fresh	Root yield (t/ha) dry	Root DM content (%)	Root starch content (%)	Leaf & stem weight (t/ha)	Total plant weight (t/ha)	HI
Rayong 1	22.39	6.87	30.68	16.72	16.21	38.60	0.58
Rayong 3	19.03	6.51	34.19	21.73	11.11	30.14	0.63
Rayong 60	23.58	7.43	31.52	17.67	13.85	37.43	0.63
Rayong 90	23.49	8.15	34.71	22.17	13.79	37.28	0.63
Kasetsart 50	24.83	8.44	33.98	21.22	14.58	39.41	0.63
CMR25-105-112*	25.50	8.60	33.71	20.85	14.33	39.83	0.64

* a promising clone selected from cross 27-77-3 x Rayong 3.

All new cultivars except Rayong 3 produced higher average fresh and dry root yields than Rayong 1. A progressive improvement in root yield of the new cultivars has been made, since all new cultivars have higher root dry matter (DM) content and HI than Rayong 1; however, the root DM content of Rayong 60 is only slightly higher than that of Rayong 1.

In terms of canopy strength (leaf and stem weight), Rayong 1 ranked highest and Rayong 3 lowest. Further improvements in leaf and stem weight were evident in Rayong 60, Rayong 90, Kasetsart 50 and the promising clone CMR 25-105-112. However, none of the new cultivars had leaf and stem weights comparable to Rayong 1. With respect to total biological yield (TBY, or total plant weight), only Kasetsart 50 and CMR 25-105-112 were higher than Rayong 1.

Early vs Late Harvest

Five cultivars, Rayong 1, Rayong 60, Rayong 90, Sriracha 1 and Kasetsart 50 were tested to determine their most suitable harvesting time, i.e. at 9 or at 12 months after planting (MAP). Experiments were planted in the early rainy season of 1992 in nine locations. At the early harvest at 9 MAP, Rayong 60, which was released as an early-harvestable cultivar, had the highest fresh root yield **(Figure 1A)**, but at the late harvest at 12 MAP its root yield was lower than that of Kasetsart 50. The fresh root yield of all cultivars had a similar rate of increase when the harvest was delayed, except for Rayong 60, which had the lowest rate of increase.

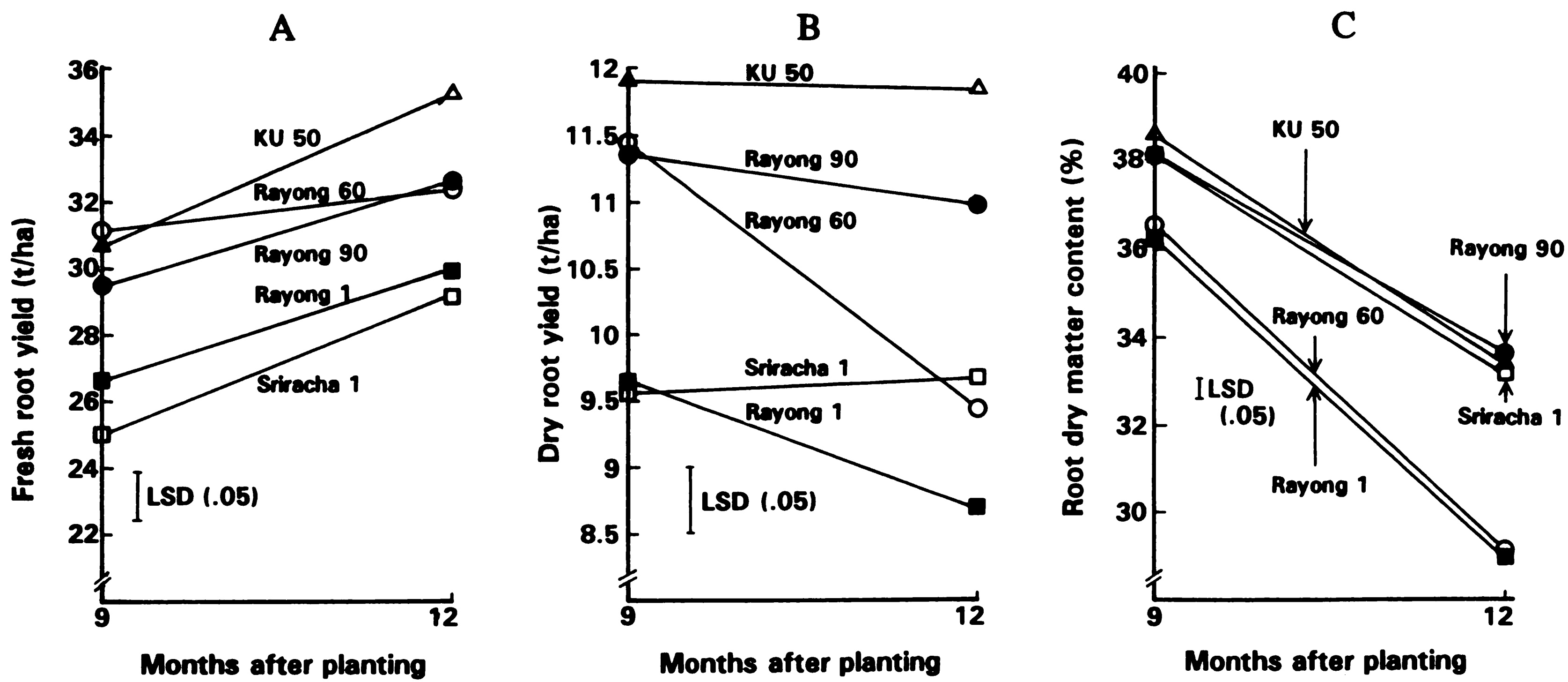

Figure 1 A-C. Fresh root yield, dry root yield, and root DM content of five recommended cassava cultivars harvested at 9 and 12 months after planting. Data are the average from trials planted in 1992 amd 1993 in nine locations.

All cultivars except Sriracha 1 showed a tendency of decreasing dry root yield when the harvest was delayed **(Figure 1B).** The rate of decrease was greatest in Rayong 60 and Rayong 1. In both the early- and late-harvested experiments, cassava encountered a dry period (between November-April) during the growing season. When cassava was harvested at 12 MAP, the crop had just passed through 4-5 months of drought after which it had received rains in early May. Thus, the plants had renewed their top growth at the expense of root growth, resulting in a reduction of root DM content in cassava harvested at 12 MAP **(Figure 1C).** The rates of decrease in root DM content were different among cultivars. Rayong 60 and Rayong 1 (low root DM content cultivars) had a higher rate of decrease in root DM content, whereas Rayong 90, Sriracha 1 and Kasetsart 50 (high root DM content cultivars) had a lower rate of decrease in root DM content. To get high root yield, farmers, who have experience with Rayong 60, usually harvest the crop in the dry season.

Nonetheless, this interaction between cultivars and harvesting time has not been observed in some sets of cultivars when they were planted in the early- to mid-dry season. This phenomenon could be attributed to the crop's growth response to wet and dry seasons since in this case there was no "regrowth" prior to the late harvest.

When harvest time was extended to two years after planting, Rayong 60 yielded less than Rayong 1 and Sriracha 1 **(Table 3).** These results reflect the fact that root rot was a more serious problem in Rayong 60 than in Rayong 1 and Sriracha 1. Consequently, Rayong 60 is not suitable for delayed harvest, whereas Sriracha 1 is relatively more suitable in areas where a delay in harvest is expected.

Table 3. Yield and agronomic traits of Rayong 1, Rayong 60 and Sriracha 1 harvested at 2 years after planting.

Cultivars	Yield (t/ha)		Root DM content (%)	Leaf & stem weight (t/ha)	HI
	fresh	dry			
Rayong 60	35.57	9.54	27.25	19.21	0.65
Rayong 1	48.53	11.72	24.44	25.23	0.66
Sriracha 1	46.75	13.96	29.86	28.50	0.65
LSD (0.5)	5.75	1.51	0.83	3.73	0.03
CV (%)	15.70	15.30	11.30	18.20	4.47

Response of New Cultivars to Different Yielding Environments

To analyze the yield response of each cultivar to different yielding environments, the data of six cultivars that were tested in 53 locations, as summarized in **Table 2,** were recalculated with Rayong 1 representing a baseline of 100% in all parameters. Using this data, presented in **Table 4,** the four cultivars (Rayong 3, Rayong 60, Rayong 90, Kasetsart 50) and one promising clone (CMR 25-105-112) were classified into three groups: group 1 includes those cultivars having a high HI but low TBY, as for example Rayong 3; group 2 includes those cultivars having high HI and similar TBY as Rayong 1, such as Rayong 60 and Rayong 90; and group 3 includes those cultivars having both high HI and TBY, such as Kasetsart 50 and CMR 25-105-112 **(Table 4).** Kawano (1988) indicated that cassava clones that have high HI but low TBY were adapted only to high-yielding environments, but not to low-yielding environments, due to their deficient

Table 4. Yield data of five cassava cultivars and a promising clone relative to those of Rayong 1. Data are the average from 53 trials conducted in 1991 and 1992 in Thailand.

Cultivars	Root yield fresh	Root yield dry	Root DM content	Leaf & stem weight	Total plant weight	HI
	(%)					
Rayong 1	100	100	100	100	100	100
Rayong 3	85	91	111	69	78	109
Rayong 60	105	107	103	85	97	109
Rayong 90	105	121	113	85	96	109
Kasetsart 50	111	123	111	90	102	109
CMR25-105-112	114	126	110	88	102	110

canopy strength. Cassava clones having both high HI and TBY, produced higher yields in both low- and high-yielding environments. The clones having a high HI and a TBY similar to that of the traditional cultivar, Rayong 1, would produce yields higher than Rayong 1 under high-yielding environments, but similar or lower yields under low-yielding conditions. To test this hypothesis, the response of each cultivar to various environments was analyzed. The fresh root yields of each cultivar at each location were regressed on the mean yield of all cultivars at each location. By this method the productivity of each environment is represented by the mean yield of all cultivars at that environment. Data of 53 yield trials conducted in both research stations and in farmers' fields in 1991 and 1992 were used in the computation and the regression lines of all cultivars are shown in **Figure 2.** These experiments covered a very wide range of environments with mean yields of all cultivars varying from 10 to 45 t/ha. It was not surprising that Rayong 1, which has the highest leaf and stem weight (canopy strength) but lowest HI, responded less to high-yielding conditions than the other cultivars. This is indicated by the relatively low linear regression coefficient or slope of 0.84 for Rayong 1 **(Figure 2 A–E).** In contrast, the high HI cultivars, Rayong 3, Rayong 60, Rayong 90, Kasetsart 50 and CMR 25-105-112, were more responsive to high-yielding environments, as indicated by their higher linear regression coefficients of 1.02, 1.07, 0.98, 0.96 and 1.05, respectively. Cultivars having a high HI but low TBY, such as Rayong 3, had

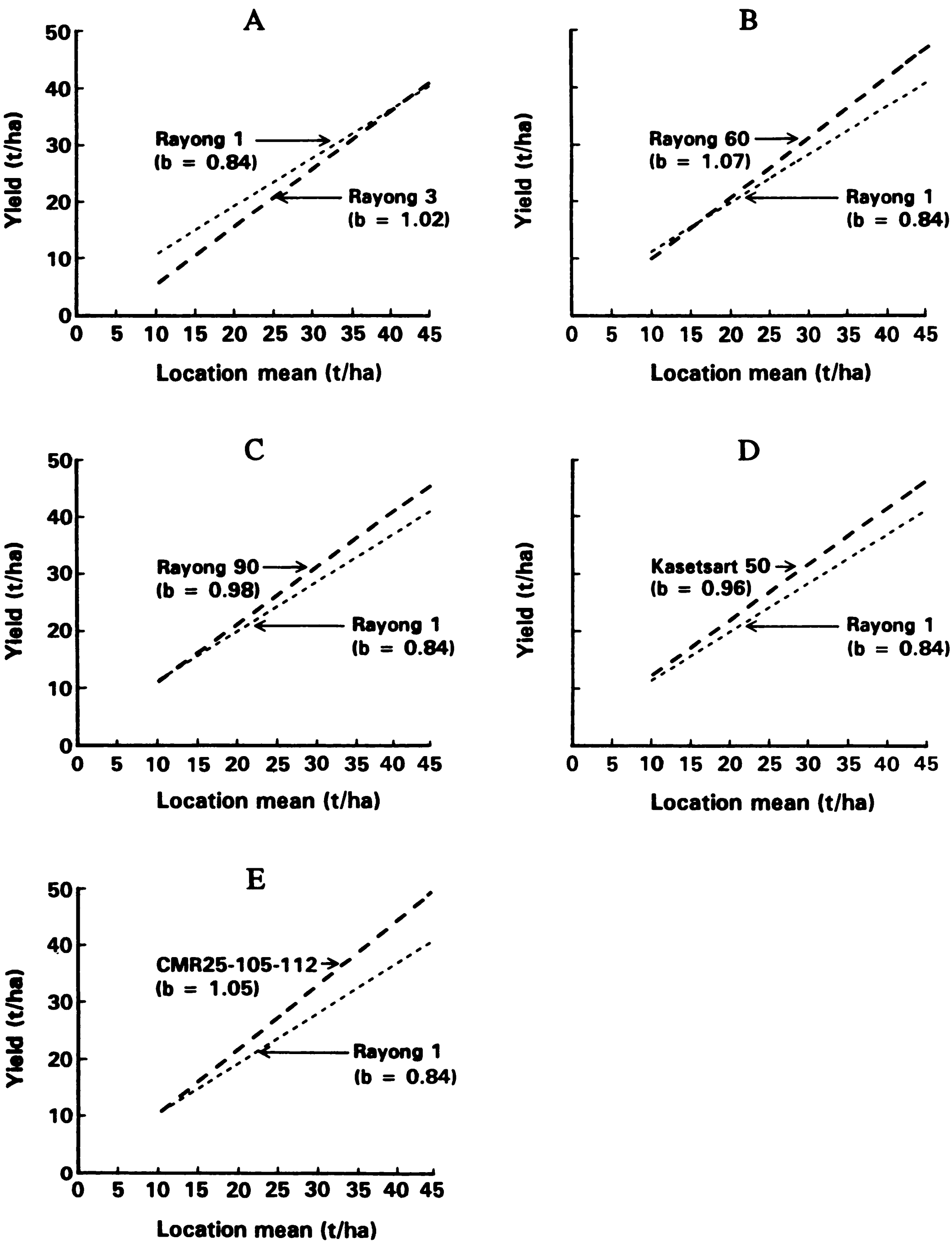

Figure 2 A.-E. Regression of fresh root yields of six cassava cultivars on the location mean (average fresh root yield of all cultivars at each location) of 53 different yielding environments.

higher yields than Rayong 1 only in very high-yielding environments. The linear regression equation predicts that Rayong 3 produces higher yields than Rayong 1 only in those environments having a mean yield higher than 39 t/ha.

Rayong 60 and Rayong 90, which have a higher HI but a TBY similar to that of Rayong 1, yielded more than Rayong 1 in most of the environments. Under low-yielding environments, this type of cultivars is expected to give either higher or lower yields than Rayong 1. In case of Rayong 60, the yield was lower than Rayong 1 when the environmental mean yield was lower than 15 t/ha **(Figure 2B)**; however, Rayong 90, while being in the same group as Rayong 60, had higher yields than Rayong 1 in all environments **(Figure 2C).**

The last group of cultivars, Kasetsart 50 and CMR 25-105-112, which have a HI and TBY higher than those of Rayong 1, gave higher yields than Rayong 1 in all environments (Figure 2D, E). Hence, future cultivars, in order to produce high mean yields, should have high HI for more productivity in high-yielding environments, but should also have high TBY to ensure high yields in both high- and low-yielding environments.

Varietal Adoption

Several attempts have been made to replace Rayong 1 with Rayong 3 and Rayong 60 from 1985 to 1990, but with limited success. The Department of Agricultural Extension (DOAE) reported that in 1991/92 only 50,000 ha were planted to new cultivars. In fact, the chipping and starch industry prefer to use Rayong 3 because of its high root DM content, and the price paid for Rayong 3 roots is usually higher than that of Rayong 1. Rayong 3 has very low TBY, but has high HI and high root DM content. This cultivar has a very small canopy, and it has already been shown that it yielded higher than Rayong 1 only in very high-yielding environments. Furthermore, the small canopy causes more weed problems, especially in unfertile soils commonly used for cassava production. The low rate of adoption of Rayong 60 was due to its low root DM content, and the light yellow color of the root parenchyma, which made it less acceptable to the industry.

The more recently released cultivars, Rayong 90, Kasetsart 50 and the promising clone CMR25-105-112, which have given high yields in both high- and low-yielding environments, as well as having high root DM content, should be more acceptable to farmers. At present, the DOAE and DOA have established a 5-year plan (1993-1997) with a budget of about US$ 11 million to actively multiply, promote and distribute these newly-released cultivars.

FUTURE DIRECTION

The future direction for cassava breeding in Thailand is to concentrate on yield improvement to ensure the competitiveness of Thai cassava in the world market.

Tan (1987) suggested that the goal in cassava yield improvement was to improve HI while maintaining the same canopy strength of traditional cultivars. Furthermore, Kawano (1988) has shown that a simultaneous improvement in HI and TBY in these genotypes would result in higher yields than those of presently available cultivars, both in high- and low-yielding environments. Lately, Kawano *et al.* (1990) showed that further improvements in HI and TBY were possible. This paper has already shown that the newly-released cultivar, Kasetsart 50, and the promising clone CMR 25-105-112, having both higher HI and TBY than Rayong 1, gave higher yields than Rayong 1 in both low- and high-yielding environments.

The selection for still higher yielding cassava clones continues. Newly-released cultivars have shown a further improvement in yield parameters **(Table 2).** All new cultivars have higher HI and root DM content than Rayong 1, and the TBY has been increasing. However, all new cultivars had a similar HI of 0.63-0.64, as compared to 0.58 for Rayong 1.

To assess the progress made in selection for higher productivity, as indicated by average yield parameters of the breeding population (all entry mean in yield trials), the mean fresh root yield, root DM content, HI and TBY from 11 cropping years from 1982 to 1992 were compared with those of Rayong 1 **(Figures 3 and 4).** The fresh root yield, root DM content and biomass improved steadily. Some improvement in HI was achieved during 1982-1985, but thereafter no further improvement took place **(Figure 4).**

In summary, further improvement of cassava yield is possible by selecting for higher TBY and root DM content, while maintaining a high HI.

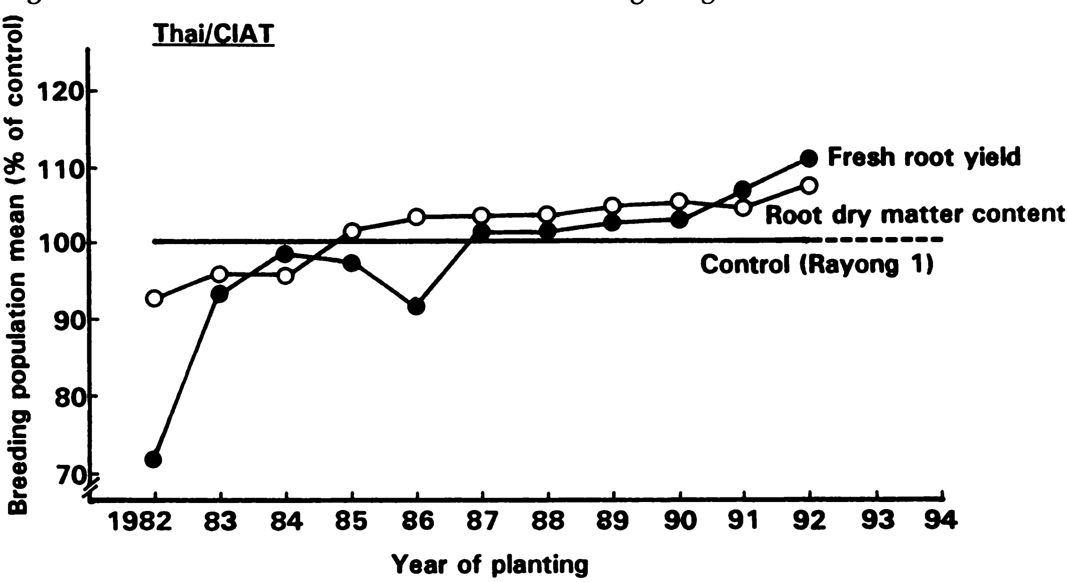

Figure 3. Change in the mean of breeding populations (all entry mean in yield trials) in fresh root yield and root dry matter content in Thailand.

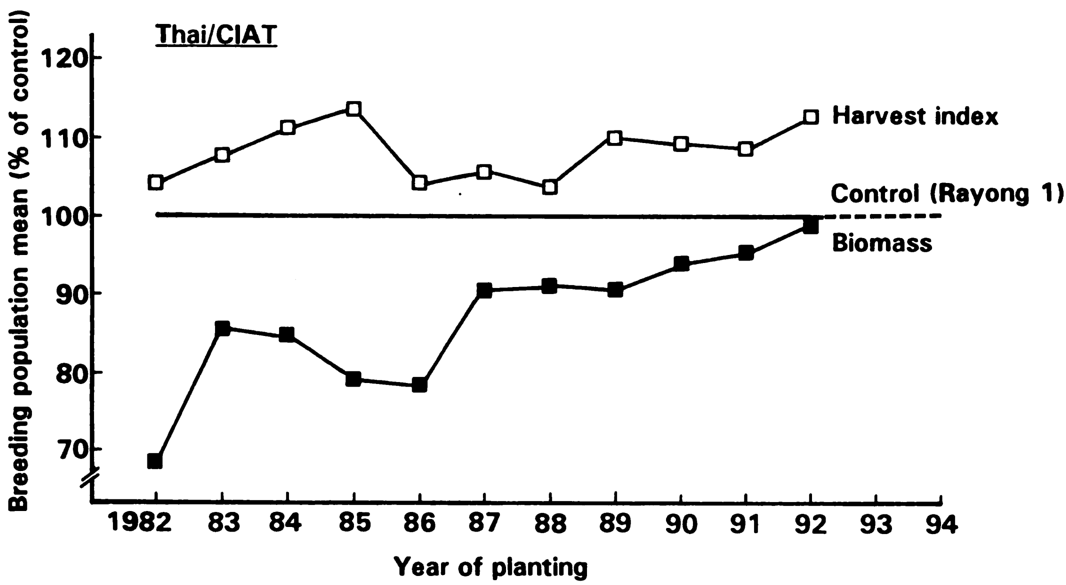

Figure 4. Change in the mean of breeding populations (all entry mean in yield trials) in biomass and harvest index in Thailand.

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CASSAVA EXTENSION ORGANIZATION AND ACTIVITIES IN THAILAND

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ABSTRACT

Being easy to grow and drought tolerant, cassava is a popular crop among Thai farmers, particularly in the Northeast and East. The area planted annually is 1.28-1.60 million hectares. Because of drought and infertile soils in these areas, cassava yields average only 13-14 t/ha with about 18% starch. The price of fresh roots is about US $ 28-30/tonne.

In the past only the local varieties were grown all over the country. In 1984, a better variety, Rayong 3, was introduced to the farmers. It is characterized not only by high yield but also by high starch content. Later, other new varieties have been released by the research institutes and universities. The government has therefore allocated a budget to multiply and promote new cassava varieties. This long-term program started in 1993 and will continue until 1998.

Due to changes in the Common Agricultural Policy of the European Economic Community, the government policy makers expect that the cassava price in the EEC will decline. The government is therefore making an effort to reduce the cassava area by promoting the production of other perennial crops. Also, a large government budget has been provided to survey the potential area for cassava crop substitution.

The future target of our program is for average cassava yields to increase to about 14.5 t/ha, while the recommended varieties will be cultivated in about 20% of the total cassava area by 1998.

INTRODUCTION

Cassava is one of the major economic crops in Thailand, occupying a total area of about 1.5 million ha and producing annually approximately 20-24 million tonnes of fresh roots. The main export products of cassava to the world market are pellets and starch. About 75% of the total amount of roots produced are exported in the form of hard pellets, mainly to the European Economic Community (EEC) and to a lesser extent to other Asian countries; about 25% of cassava is processed into starch for export as well as for local consumption. Based on the total export value of more than US$ 800 million cassava is counted among the top five foreign exchange earners for Thailand.

The Northeastern and Eastern region of Thailand account for more than 80% of the total area planted to cassava in the country **(Table 1).** The main production areas are: Nakhon Ratchasima, Chaiyaphum, Udon Thani, Kalasin, Khon Kaen, Rayong and

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Chonburi. The crop is popular with small farmers because of its relatively high cash return per unit area of land. The crop has many advantages over other economic crops, such as its ability to produce reasonable yields in poor soils and under droughty conditions, its flexibility in planting and harvesting time, and the near absence of pests and diseases.

Table 1. Area, production and yield of cassava in Thailand in 1992.

Region	Planted area ('000 ha)	Harvested area ('000 ha)	Production ('000 t)	Yield (t/ha)
Northeast	932	901	12,231	13.58
North	158	152	2,229	14.68
Central Plain	27	27	396	14.63
West	72	70	1,066	15.12
East	302	301	4,433	14.75
Total	1,491	1,451	20,355	14.03

Source: Office of Agricultural Economics, 1992.

Almost all of the cassava area is planted with only one local cultivar, Rayong 1. This variety is very well adapted to the soil and climatic conditions in Thailand, producing a rather stable but relatively low yield of 13 to 14 t/ha. However, Rayong 1 has a relatively low starch content and as such, production costs at the farm level are relatively high.

The overall objective of the cassava breeding program of the Department of Agriculture (DOA) is to increase the crop's productivity and improve the profitability for the small farmer through the development of improved varieties. The DOA has released Rayong 3, a cultivar with high starch content, but which is adapted mainly to relatively fertile soils. The variety was selected locally from a cross made at CIAT in 1974, and was released to the Thai farmers in 1984. Since then the Department of Agricultural Extension (DOAE) has tried to encourage and convince cassava farmers to realize the benefits of growing Rayong 3 instead of the local variety.

EXTENSION PROGRAM ON VARIETAL DISTRIBUTION

The process of varietal distribution is shown in **Figure 1.** After the new variety has been registered, the DOA distributes planting material in three ways: to small farmers, to cassava chip and starch factory owners, and to the DOAE for establishing demonstration plots. Small farmers as well as chip and starch factory owners received planting material for planting of approximately 0.25 ha in the first year. They then increased the

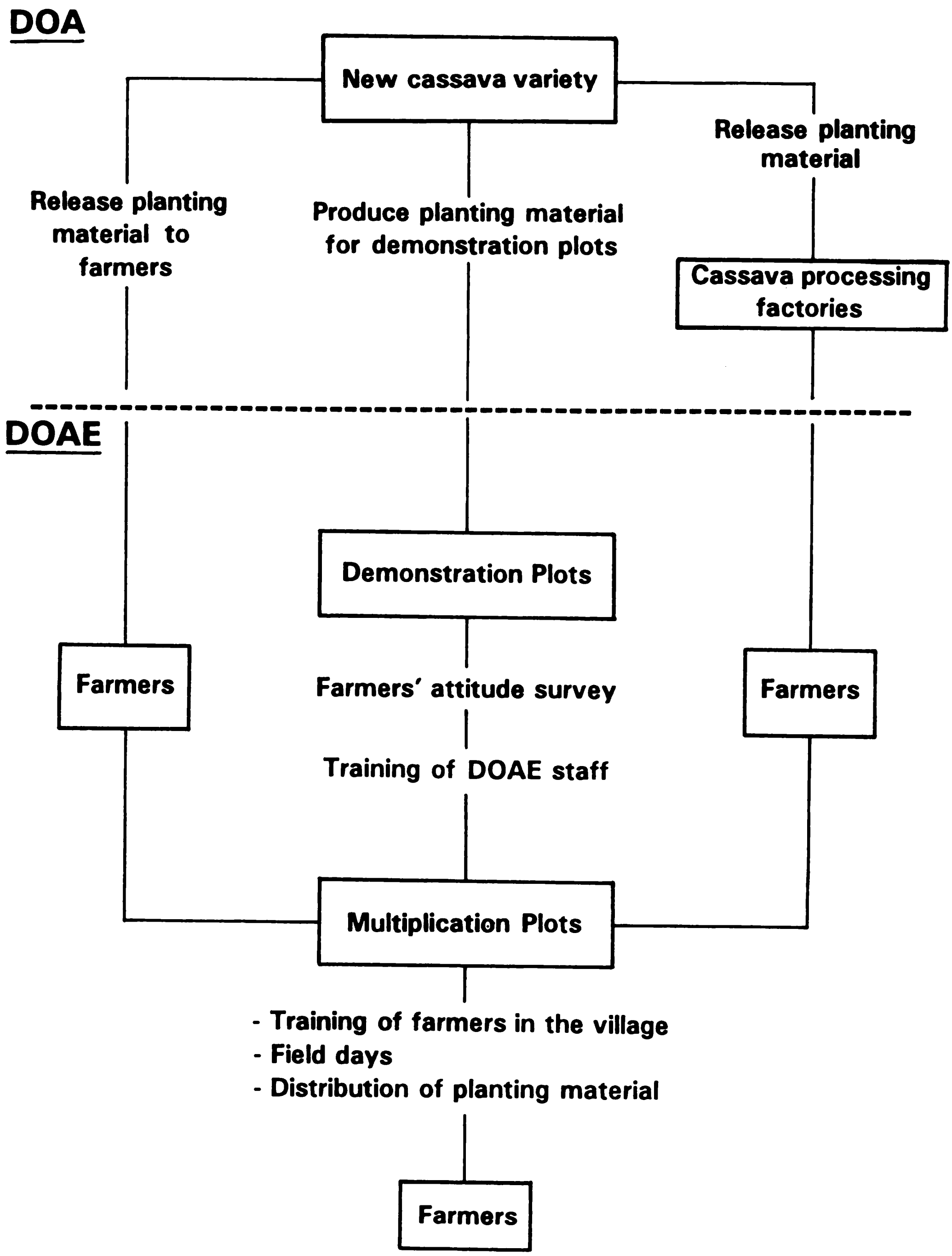

Figure 1. Cassava varietal distribution scheme in Thailand.

planting material in their own areas. In the same way, the DOAE's demonstration plots were established and managed in collaboration with DOA under recommended real-farm conditions.

After the release of a new cultivar, the DOAE plant demonstration plots for 2-3 years. In case of Rayong 3, the DOAE conducted demonstration plots in 1985 and 1986. DOAE distributed only planting material of the new variety to the farmers and factory owners, but farmers used the same cultural practices as with the old variety. After that, the DOAE conducted a survey on the farmers' attitude to the new variety.

In 1987, a survey on farmers' attitude towards Rayong 3 showed that the area planted to Rayong 3 tended to increase. Also, 89% of the farmers liked Rayong 3 because it gave higher yields and had a higher starch content than Rayong 1. In the same year, the DOAE initiated the distribution of Rayong 3 to the farmers. The activities of this project were as follows:

1. **Establishment of multiplication plots:** DOAE staff established multiplication plots as follows:

   a. Multiplication plots were 4-8 ha in each village.
   b. The multiplication plots were established in suitable areas, such as those having good soil fertility, transportation, etc.
   c. The farmers who planted multiplication plots were under the direct supervision of DOAE staff.
   d. At harvest time, the farmers had to return planting material to the DOAE in amounts equivalent to 3-5 times the orginally received quantity.

The project on distribution of Rayong 3 began in 1987 with financial support from the Cassava Foundation (an initiative by the private sector of cassava exporters) and 64 ha of multiplication plots were established in 8 villages; subsequently, the area increased the following year. In 1989, with financial support from the Cassava Foundation as well as the government, the area was increased to 1,600 ha and 320 ha, respectively.

2. **Training:** The DOAE coordinated with the DOA, which provided training courses for the local DOAE staff to increase their knowledge about the new variety. Thereafter, farmers in multiplication plot villages were also trained.

3. **Field days:** These were organized to encourage and convince cassava farmers to realize the benefits of growing Rayong 3 instead of the old variety, Rayong 1.

VARIETAL ADOPTION

The DOAE indicated in its Annual Reports for 1989 and 1991 that the area planted to Rayong 3 had increased to 17,158 and 50,283 ha, respectively. The annual rate of increase of the area planted to Rayong 3 was 71.2%. The popularity of Rayong 3 increased as indicated by the distinct increase in the number of cassava farmers planting this variety. The annual rate of increase in the number of farmers adopting Rayong 3 was 151% (**Figure 2**). However, this rate will not continue. Currently, the 1993 estimates show that the area under Rayong 3 is leveling off with an expected adoption ceiling of about 108,000 ha or 7.3% of the total cassava area in Thailand (**Figure 3**).

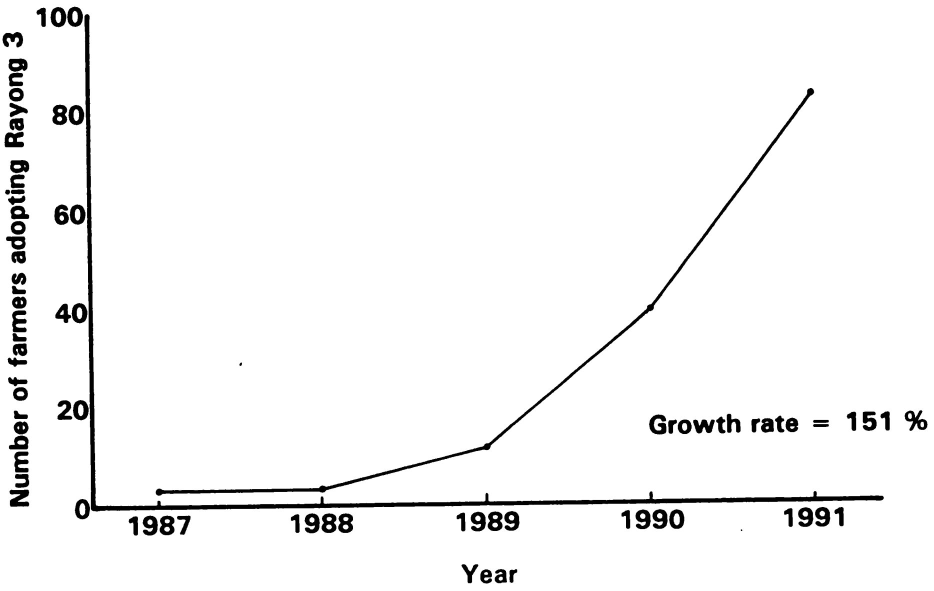

Figure 2. Number of farmers who planted Rayong 3 from 1987 to 1991, as indicated from a survey of 778 farmers in nine provinces of Thailand.

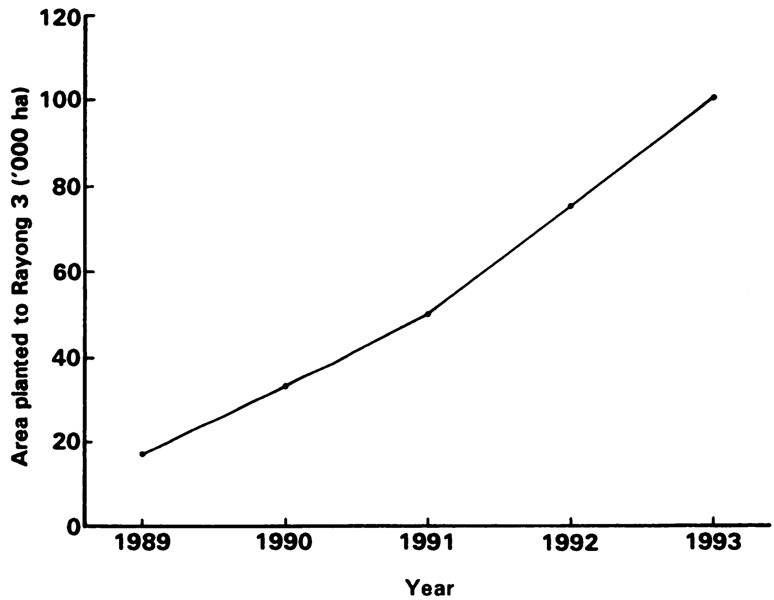

Figure 3. Area planted to Rayong 3 from 1989 to 1993, as estimated from a survey of 778 farmers in nine provinces of Thailand.

The change from Rayong 1 to Rayong 3 was stimulated by the efforts of government officers and by the success of Rayong 3, which was very convincing to neighbors. Planting material was mainly provided by the government sector, while some farmers also purchased stakes from the private sector. An important aspect in convincing farmers to try Rayong 3 is that the cultural practices for Rayong 3 and Rayong 1 are basically the same; therefore it was relatively easy for farmers to experiment with Rayong 3. In addition, Rayong 3 usually produces higher yields than Rayong 1. Farmers indicated that the sales price as well as the fresh root yield of Rayong 3 were higher than those of Rayong 1. The yield advantage of Rayong 3 was most pronounced in fertile soils **(Figure 4).** Thus, the shift from Rayong 1 to Rayong 3 was more common among farmers growing cassava in fertile soils and among those having larger farms **(Table 2).**

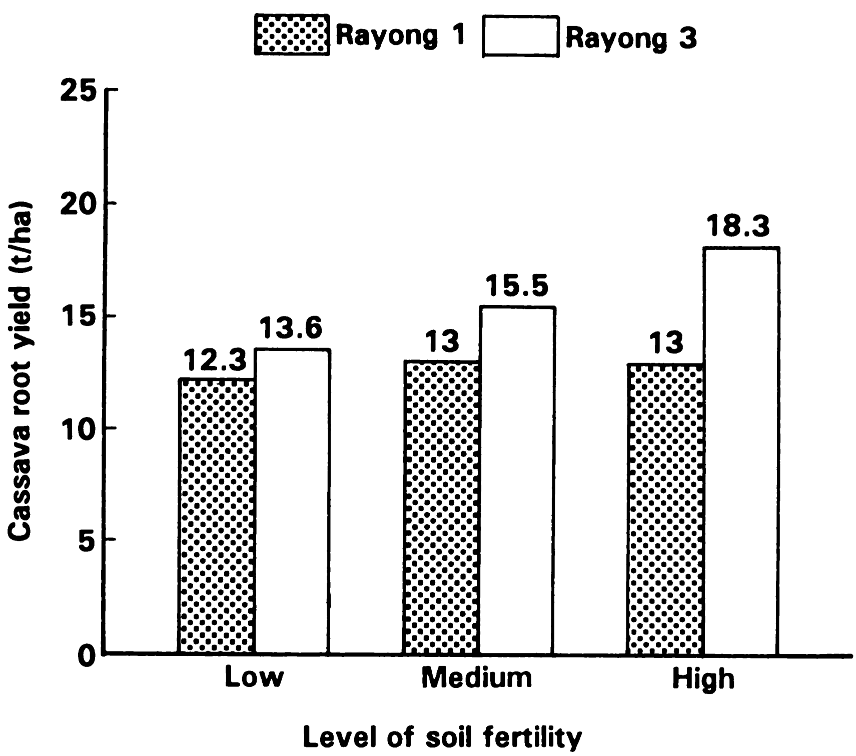

Figure 4. Yield of Rayong 1 and Rayong 3 cassava varieties grown at three levels of soil fertility, as indicated from a survey of 778 farmers in nine provinces in Thailand.

Table 2. Number of cassava growers of various farm size and soil fertility, who plant Rayong 1 or Rayong 3 as indicated from a survey of 778 cassava farmers in nine provinces of Thailand.

Variety planted	Farm size [1]			Soil fertility		
	small	medium	large	high	medium	low
Rayong 1	107	475	73	241	320	94
	(87.7%)	(83.8%)	(82.0%)	(82.5%)	(85.3%)	(84.7%)
Rayong 3	15	92	16	51	55	17
	(12.3%)	(16.2%)	(18.0%)	(17.5%)	(14.6%)	(15.3%)
Total	122	567	89	292	375	111

1) small = less than 1.76 ha
medium = 1.76-8.0 ha
large = more than 8.0 ha

In 1991, with the help of CIAT, the DOAE initiated a study on the adoption of Rayong 3, in order to generate feedback for extension workers and researchers on the adoption characteristics of Rayong 3. The survey was conducted in nine provinces and a total of 778 questionnaires were analyzed.

According to survey results the majority of the farmers indicated that there were no differences in requirements for land preparation, fertilizer application and weed control, as shown in **Table 3.** Some farmers indicated that growing Rayong 3 required different practices: 15.3, 22.5, and 25% pointed out that Rayong 3 required more land preparation, weeding and fertilizer application, respectively, than Rayong 1. The growth of Rayong 3 was slower than that of Rayong 1, but the yield was generally better (15.9 and 13.1 t/ha for Rayong 3 and Rayong 1, respectively). Adoption of Rayong 3 did not only give higher yields but had also other advantages. The production cost for Rayong 1 was US$263/ha (US$20.0/t), while that for Rayong 3 was US$340/ha (US$21.6/t) **(Table 4).** The difference in production costs between Rayong 1 and Rayong 3 was due to the higher costs of planting material, weeding, harvesting and transportation. However, planting Rayong 3 resulted in a gross income of US$590.5/ha, while that of Rayong 1 was US$440.2/ha **(Table 5).** The increased net income derived from Rayong 3 encouraged farmers to adopt this variety.

Having seen the benefits from growing Rayong 3, such as higher yield and higher starch content as compared to Rayong 1, 60% of non-adopting farmers indicated that they wanted to grow Rayong 3 in the future. Cassava chip and starch factories also prefer Rayong 3. Due to its higher starch content, the sales price of Rayong 3 in some chip factories was approximately 5-10% higher than that of Rayong 1.

Table 3. Opinion of farmers adopting Rayong 3 about the characteristics of Rayong 3 in comparison with Rayong 1.

Characteristics	R1>R3 (%)	R3=R1 (%)	R3<R1 (%)
Germination	49.2	31.1	19.7
Crop growth rate	54.3	22.6	23.3
Yield	84.9	6.5	8.6
Land preparation requirement	15.3	84.0	0.8
Fertilizer application requirement	25.0	72.3	2.6
Weeding requirement	22.5	69.8	7.8

R3 > R1: Rayong 3 is better than Rayong 1

R3 = R1: Rayong 3 is the same as Rayong 1

R3 < R1: Rayong 1 is better than Rayong 3

Table 4. Production costs of Rayong 3 and Rayong 1 in Thailand in 1991–1993.

Type of expenditure	Rayong 1 (US $/ha)	Rayong 3 (US $/ha)
Inputs	42.6	86.8
Planting matterial	14.9	54.9
Chemical fertilizers	19.7	27.8
Green manures	2.0	1.5
Pesticides	0.4	0.8
Herbicides	5.5	1.9
Labor costs	220.7	253.9
Land preparation	58.6	56.1
Cultural practices	64.2	75.2
Harvesting costs	50.5	67.4
Transportation costs	41.0	48.1
Others	6.5	7.1
Total production costs	263.2	340.6

Table 5. Costs, income and benefits of growing Rayong 1 and Rayong 3.

Item	Rayong 1	Rayong 3	Change (%)
Production cost (US $/ha)	263.2	340.6	29.4
Average yield (t/ha)	13.1	15.9	21.4
Production cost (US $/t)	20.0	21.6	8.0
Price of fresh roots (US $/t)	33.6	37.2	10.7
Gross imcome (US $/ha)	440.2	591.5	34.4
Profit (US $/ha)	177.0	250.9	41.2

CONSTRAINTS FOR THE GROWING OF RAYONG 3

In the previous section both positive and negative characteristics of Rayong 3 were discussed. As such, this was the opinion of Rayong 3 adopters. However, it may be even more important to know why other farmers did not adopt Rayong 3.

Even though Rayong 3 has a high starch content, and is thus preferred by chip and starch factories, its planted area is still small due to the following constraints:

1. **Traditional cultivation:** Thai farmers use traditional methods of cassava cultivation, adapted to the local variety, Rayong 1. During December to Febuary, after harvesting the fresh roots, cassava stems needed as planting material are cut and stored in bundles in the field or under trees until the next planting season in March to June. During this storage period the decrease in germination rate over time is faster for Rayong 3 than for Rayong 1. Planting material of Rayong 3 can not be stored for more than 3-4 weeks after cutting of the stems from the field. Thus, the use of this traditional method causes a loss of stand of Rayong 3 as well as a loss of planting material. To solve this problem, farmers should leave part of their mature cassava plants standing in the field to be used as planting material until they are ready to plant again. To change this practice is very hard for most farmers.

2. **Agronomic characters:** Rayong 3 has some undesirable agronomic characteristics, such as:

- Short stems, a branching plant type and low growth rate, which result in difficulty in weeding.
- Roots easily break during harvest, resulting in increased costs of digging out broken roots.
- Less drought tolerant than Rayong 1.
- Less production of good quality planting material per area.

In **Table 6** the reasons for non-adoption of Rayong 3 are summarized. It must be noted that in the questionnaire farmers were asked to rank the reasons for non-adoption. As such the results in **Table 6** show only the top two reasons given by each farmer. As mentioned before, this Table shows again that Rayong 3 is prefered mainly for the more fertile soils as the lack of suitable soils was the most important reason for non-adoption. Both harvesting and weeding problems show a high ranking as well. These problems are caused by the different plant architecture, i.e. the shorter height and branching plant type.

It is also important to note that the unavaibility of planting material was not mentioned often by the farmers as a major problem. The problems of Rayong 3 are mainly related to the plant's own characteristics.

Table 6. Ranking of the most important reasons for non-adoption of Rayong 3.

	Number of respondents	Rank
Soils not suitable	32	1
Difficulty in harvesting	24	2
Difficulty in weeding	16	3
Stake storage problem	12	4
Slow plant growth	8	5
No stakes available	6	6
High production costs	6	7

FUTURE PLANS

As a result of the recently adopted Common Agricultural Policy of the European Economic Community, Thai policy makers expect that the cassava price in the EEC will decline. The Thai government is therefore trying to reduce the cassava planted area while increasing the efficiency of production.

1. **Increasing production efficiency:** The government has formulated a program for increasing the efficiency of production and the quality of raw materials used in the starch industry as well as in other factories, such as those producing modified starch, fructose syrup, monosodium glutamate etc. The government has initiated a program for the distribution of new varieties to the farmers coordinated by the DOAE, DOA and Kasetsart University (KU). The five recommended varieties are Rayong 3, Rayong 60, Rayong 90, Sriracha 1 and KU 50. The target of the program is to increase cassava yields to about 14.5 t/ha. In 1998, these recommended varieties are expected to be grown in 20% of the total area, or in about 300,000 ha. We believe that Rayong 3 will be grown in not more than 150,000 ha by the year 2000, because the adoption of Rayong 3 is constrained by its need for high soil fertility and by the absence of a price premium for Rayong 3 in certain areas. Rayong 3 grows well only in high fertility soils, while most of cassava is grown in infertile soils. The other varieties, Rayong 60, Rayong 90

and KU 50, are expected to be adopted very rapidly.

In 1987, at the beginning of Rayong 3 distribution, the planting area of Rayong 3 expanded at a low rate because the DOA and DOAE received only a small budget. Through the financial support of the Cassava Foundation since 1989, the rate of Rayong 3 adoption increased rapidly. DOAE established multiplication plots in several areas of the country. However, the adoption of Rayong 3 has been limited by soil fertility constraints and the absence of a price premium. Therefore, in the future the varietal distribution should consider both soil fertility and markets, especially for Rayong 90, which has similar characteristics as Rayong 3.

Before 1993 the DOAE received only about US$40,000-80,000 for the transfer of cassava technology and relied mainly on the financial assistance from the Cassava Foundation. However, for the 1993-1998 period the government is emphasizing cassava research and the transfer of technology by allocating a total budget of US $ 11.24 million of which 60% is for the transfer of technology and 40% for research.

2. **Reducing the cassava area:** Considering domestic consumption and the expected decline in exports, policy makers have decided to try to reduce the cassava area by approximately 200,000 ha in the next three years, and to substitute cassava with other perennial crops. Also, a large government budget has been provided for our cassava staff working in the field to conduct a survey on potential crops that can substitute for cassava.

CONCLUSIONS AND RECOMMENDATIONS

From the previous discussion the following conclusions can be drawn:

- Cassava farmers in the more fertile areas were higher adopters of Rayong 3 than those in less-fertile areas. Also, farmers living near cassava processing factories were higher adopters than others, since factories were one of the major sources of planting material.
- Major constraints to the adoption of Rayong 3 are related to the different plant type or architecture. The shorter and more branchy plant causes difficulties in weeding and harvesting. In addition, the shorter storage time of stakes is a major constraint, given the predominant use of traditional cassava cultivation practices. Farmers can overcome these constraints, but they would have to break with traditional practices, which is difficult.
- The adoption of Rayong 3 has also been heavily influenced by the pricing methods of processing factories. In areas were factories did not pay a premium price for the higher starch content of Rayong 3, adoption of this variety was much lower.
- The technology transfer methodology used by DOAE has proven to be efficient and effective. Stake multiplication by the farmers and the subsequent distribution of these to neighbors has been effective. This DOAE methodology has also increased the inter-

action between researchers, extensionists and farmers, leading to the above discussion on Rayong 3 characteristics and those of the newly introduced superior varieties Rayong 60, Rayong 90, KU 50, etc. It is estimated that the adoption of Rayong 3 will reach a ceiling of at most 10% of the total Thai cassava area.

From this experience, some valuable lessons can be drawn that are useful to both researchers and extension people. It was found that, for a variety to be successfully adopted, its characteristics must be as similar to Rayong 1 as possible with regard to plant type and architecture as well as the requirements for cultural practices.

To increase the diffusion rate of new cassava varieties, the private sector (Cassava Foundation and cassava processing factories) need to be involved as much as possible, especially in the areas of stake multiplication and distribution. In order to improve the adoption rate, the Thai Tapioca Trade Association must convince the processing factory owners to pay the appropriate price premium for higher starch content varieties. This will function as a major incentive for adoption.

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RECENT PROGRESS IN CASSAVA AGRONOMY RESEARCH IN INDONESIA

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ABSTRACT

Cassava agronomy research, conducted by the Bogor and Malang Research Institutes for Food Crops and by Brawijaya University in Malang, as well as the status of cassava production in Indonesia are summarized. The annual growth of cassava production during the past seven years seems to keep pace with the increase in population, while the harvested area of cassava increased only 0.5% annually. Of the total cassava production, more than 70% is used for human food. Aside from being consumed as food, cassava is also used for industrial purposes. Therefore, the development of this crop should be in line with the development of other food crops and agro-industry.

Of the total cassava area planted in the country, more than 60% is harvested during June to October. Delaying the planting of both intercropped and monoculture cassava tends to give similar gross returns compared to that of planting in the early rainy season. In order to meet the year-round demand for cassava, the delayed planting time is promising. When cassava was planted in monoculture, the yield was positively correlated with rainfall during the first month, as well as with rainfall during the last 2-4 months before harvest.

Intercropping of cassava with other food crops or relay planting gave a higher gross return than that of monoculture cassava and therefore the intercropping system is more suitable for farmers with small land holdings, lack of capital and labor.

Under intercropping systems, plant height of cassava was positively correlated with the yield of cassava and was negatively correlated with the yield of interplanted crops. The total value of crops in these intercropping systems was affected by the kind of interplanted crops, their yield potential and the plant type of the cassava clones used, as well as by the rainfall distribution. Intercropping cassava with other food crops and the application of fertilizers reduced erosion by about 12% and 23% compared to that grown in monoculture or unfertilized, respectively. Erosion was also reduced about 20% by the planting of contour strips of elephant or setaria grass or hedgerows of *Gliricidia sepium* or *Leucaena leucocephala* on contour ridges.

NPK fertilization of both intercropped and monoculture cassava increased the total crop value significantly, while the return of plant residues improved the soil's condition. On-farm trials in Sulawesi showed that the use of improved varieties like W 1435-85 and Adira-4 with

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adequate fertilizers resulted in a benefit/cost ratio of 2.2-2.5 compared with only 0.8 for the traditional farmers' practice. The intercropping of cassava with upland rice, maize and/or grain legumes, each planted with optimum fertilization, is the most promising practice for sustainable cassava production.

INTRODUCTION

Indonesia has the fifth highest cassava production in the world. Annual production is quite variable, fluctuating from 17.1 million tons in 1989 to 15.8 million tons in 1990 and 16.3 million tons in 1992 **(Table 1).** This fluctuation is due to the fact that increased production always brings about a decrease in price. And these low prices discourage farmers from growing cassava in the next season. Therefore, these price fluctuations should be minimized through the development of more agro-industry, food processing and greater diversification of end markets.

Table 1. Cassava harvested area, production and yield in Indonesia from 1986 to 1992.

Year	Harvested area ('000 ha)	Production ('000 t)	Yield (t/ha)
1986	1,170	13,312	11.4
1987	1,222	14,356	11.7
1988	1,302	15,471	11.9
1989	1,402	17,191	12.2
1990	1,312	15,830	12.1
1991	1,319	15,954	12.1
1992	1,333	16,318	12.2

Source: CBS, 1992.

Crop productivity is one of the determining factors in the farmers' income. In Indonesia, the average cassava yield of about 12 t/ha is much below the potential yield obtained in experiments, which ranges from 20 to 40 t/ha. Therefore, there is still a potential to improve production technologies in order to increase yields and farmers' incomes.

The main cassava producing areas in Indonesia are located in relatively dry regions and on marginal soils where the crop is grown mainly by small-scale farmers. Consequently, the planting time tends to coincide with the beginning of the rainy season and the crop is harvested all at about the same time in the next dry season. As a consequence, cassava production is not evenly distributed through the year and is not well synchronized with consumer requirements.

Cassava may absorb large amounts of nutrients from the soil. Therefore, fertilization is often the only way to maintain soil fertility and land productivity. It should be noted that supplying organic matter is also very important considering that in Indonesia most cassava plant parts are utilized and thus removed from the field, leaving little organic matter to be returned to the soil. Thus, organic matter additions are also needed to maintain soil fertility in the long-term.

Intercropping cassava with upland rice and other food crops not only improves the land use efficiency, farmers' income and the distribution of this income through the year, but it also contributes more organic matter to the soil than planting cassava in monoculture. Therefore, this is a very suitable system for most production areas in Indonesia.

During the last ten years, the Bogor and Malang Research Institutes for Food Crops and the Agricultural Faculty of Brawijaya University in Malang have been working on cassava agronomy research with emphasis on solving the above-mentioned problems.

Production Areas and their Agro–ecological Characterization

Trends in cassava area, production and yield from 1986 to 1992 are presented in **Table 1.** Cassava production increased substantially from 13 million tons in 1986 to 16 million tons in 1992, while the planted area increased only from 1.17 to 1.33 million hectares. Thus the production increase was mostly achieved through intensification of cropping (more fertilizer use, higher plant populations, better weed control) resulting in an increase in yield from 11.4 to 12.2 t/ha.

Increasing the planting area can only be done outside of Java, but area expansion there is constraint by limited labor availability. In Java, the average land holding of farmers is relatively small and the land use for non-farming purposes is increasing. Therefore, it is very difficult to increase the cassava production area in Java. Increasing cassava production can only be achieved through crop intensification resulting in increased yields. Some factors which should be taken into account in trying to achieve this objective are: the distribution of cassava areas, the type of climate and soil, the prevalent cropping patterns and the adoption level of new technologies.

The cassava production areas are not evenly distributed in the country, since about 60% of the planted area is located in Java and the remaining 40% is mainly in Lampung province of Sumatra, in Nussa Tenggara and in Sulawesi **(Figures 1 and 2).** This is not in accord with the goverment policy of trying to obtain a more even agro-industrial distribution and greater food diversification.

Cassava planting in Indonesia is done mainly at the beginning of the rainy season and most of the crop is harvested between July and October **(Figure 3).** Thus, the production distribution is not in balance with the monthly demand. More information is, therefore, needed on the effect of time of planting in order to better synchronize supply and demand.

1. Aceh
2. North Sumatra
3. West Sumatra
4. Riau
5. Jambi
6. South Sumatra
7. Bengulu
8. Lampung
9. DKI Jakarta
10. West Java
11. Central Java
12. KI Yogyakarta
13. East Java
14. Bali
15. West Nusa Tenggara
16. East Nusa Tenggara
17. West Kalimantan
18. Central Kalimantan
19. South Kalimantan
20. East Kalimantan
21. North Sulawesi
22. Central Sulawesi
23. South Sulawesi
24. Southeast Sulawesi
25. Maluku
26. Irian Jaya

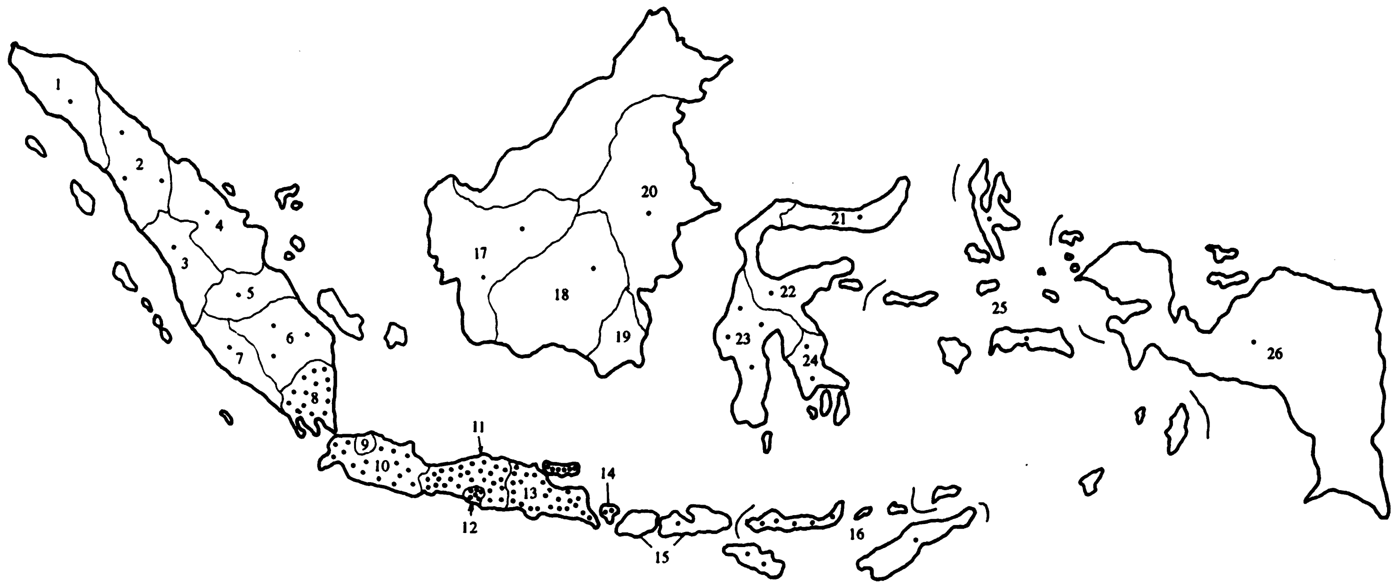

Figure 1. Distribution of cassava production zones in Indonesia in 1991. Each dot represents 10,000 ha of cassava.

Source : *Central Bureau of Statistics (CBS), Jakarta, Indonesia.*

1. Jakarta
WEST JAVA
2. Pandeglang
3. Lebak
4. Bogor
5. Sukabumi
6. Cianjuri
7. Bandung
8. Garut
9. Tasikmalaya
10. Ciamis
11. Kuningan
12. Cirebon
13. Majalengka
14. Sumedang
15. Indramayu
16. Subang
17. Purwakarta
18. Karawang
19. Bekasi
20. Tanggerang
21. Serang
CENTRAL JAVA
22. Cilacap
23. Banyumas
24. Purbalingga
25. Banjarnegara
26. Kebumen
27. Purworejo
28. Wonosobo
29. Magelang
30. Boyolali
31. Klaten
32. Sukoharjo
33. Wonogiri
34. Karanganyar
35. Sragen
36. Grobogan
37. Blora
38. Rembang
39. Pati
40. Kudus
41. Jepara
42. Demak
43. Semarang
44. Temanggung
45. Kendal
46. Batang
47. Pekalongan
48. Pemalang
49. Tegal
50. Brebes
YOGYAKARTA
51. Kulon Progo
52. Bantul
53. Gunung Kidul
54. Sleman
55. Kodya Yogyakarta
EAST JAVA
56. Pacitan
57. Ponorogo
58. Trenggalek
59. Tulungagung
60. Blitar
61. Kediri
62. Malang
63. Lumajang
64. Jember
65. Banyuwangi
66. Bondowoso
67. Situbondo
68. Probolinggo
69. Pasuruan
70. Sidoarjo
71. Mojokerto
72. Jombang
73. Nganjuk
74. Madiun
75. Magetan
76. Ngawi
77. Bojonegoro
78. Tuban
79. Lamongan
80. Gresik
81. Bangkalan
82. Sampang
83. Pamekasan
84. Sumenep
85. Surabaya
86. Panarugan

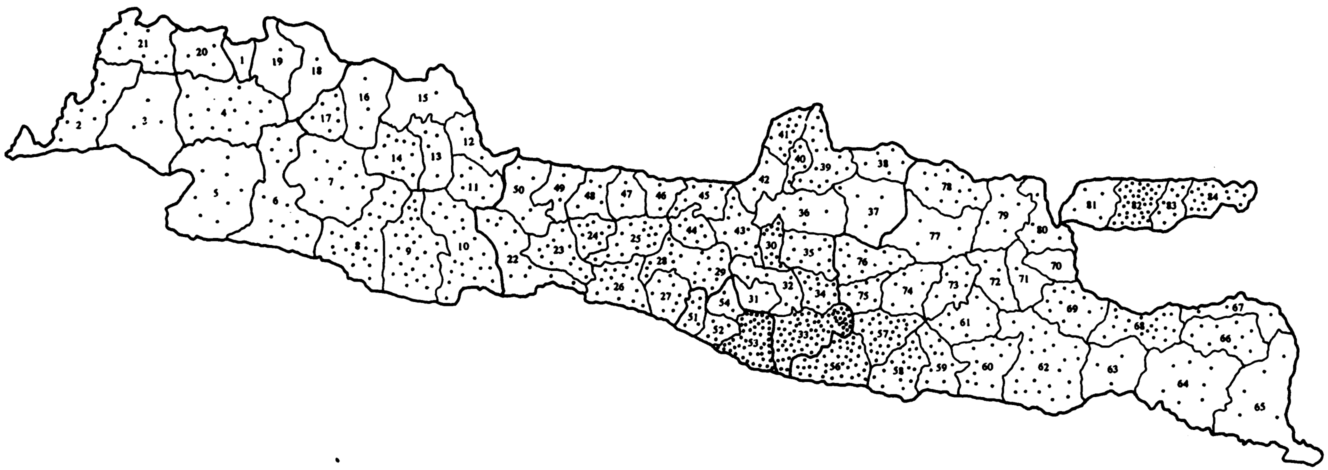

Figure 2. Distribution of cassava production zones in Java and Madura islands of Indonesia in 1991. Each dot represents 1,000 ha of cassava.

Source *: Central Bureau of Statistics (CBS), Jakarta, Indonesia.*

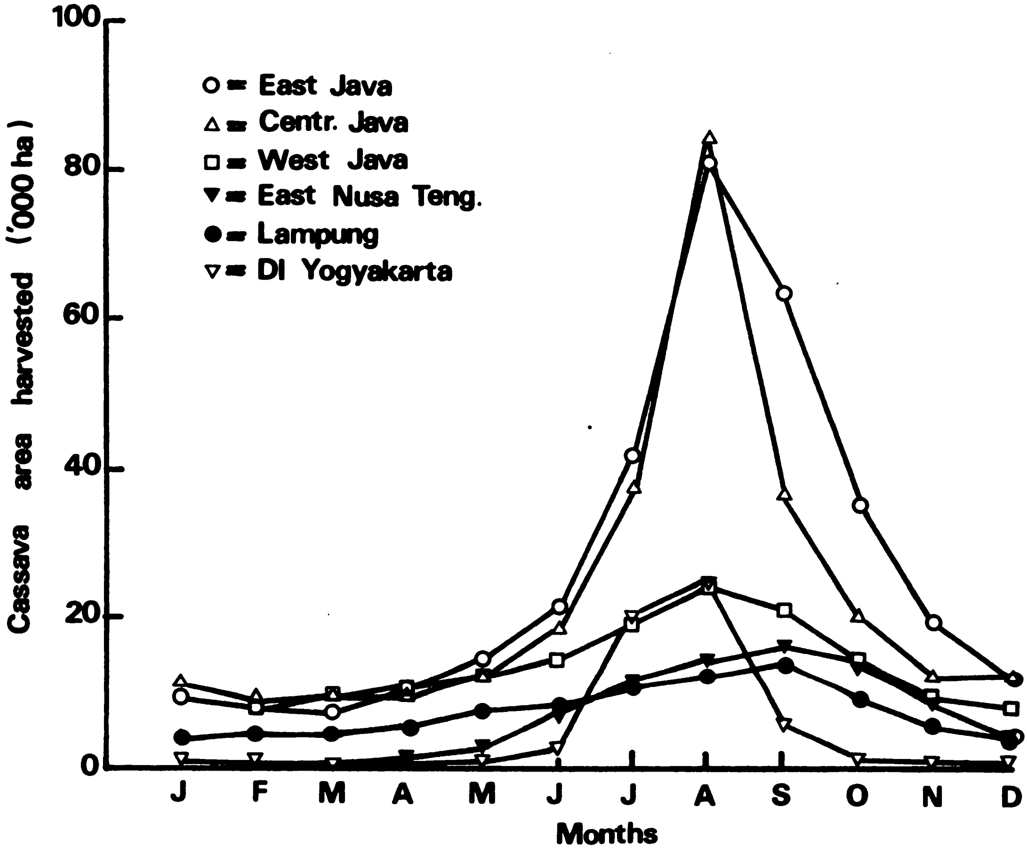

Figure 3 Average cassava area harvested during the year in six important cassava growing provinces in Indonesia.

***Source :** Bastari et al., 1990.*

Cassava in Indonesia is grown on a variety of soils, such as Mediterranean (Alfisols), Red-yellow Podzolic (Ultisols), Grumusol (Vertisols), Latosol and Andosol (Inceptisols) and various soil complexes (Wargiono, 1988). These soils are usually infertile and very often are susceptible to erosion. Therefore, better soil conservation technologies, which are able to maintain or improve land productivity and are acceptable to farmers, are urgently needed.

The limited availability of capital and labor, the relatively small size of land holdings, as well as an inefficient cassava marketing system, which has not been able to increase farmers income, are the main constraints in the adoption of new technologies and in the stabilization of cassava production.

RECENT CASSAVA AGRONOMY RESEARCH

Cassava agronomy research in Indonesia has as its main objective to increase cassava yields or farm income while maintaining or improving soil fertility and land productivity.

The agronomy research includes the study of the potential of some new cassava clones in different cropping patterns and agro-ecosystems, the effect of different planting times, the control of erosion, and improved cultural practices and fertilizer efficiency.

1. Cropping Systems

Cassava is planted in monoculture only around urban areas and in starch factory plantations as well as in non-productive land which cannot be planted with other food crops. Most farmers, however, plant cassava intercropped with other food crops, since this will enable them to increase their land use efficiency and income, improve the soil physical condition and reduce erosion, compared with planting in monoculture (Guritno, 1989; Moreno and Hart, 1978; Thung and Cock, 1978; and Wargiono, 1988).

Table 2 shows the effect of cassava varieties and cropping systems on cassava yields and gross income. Cassava yields were slightly decreased by intercropping, but the total gross income markedly increased. The decrease in cassava yield is due to the competition between cassava and the interplanted crops, either for nutrients, water or solar radiation. The decrease in yield of the first intercrops due to this competition ranged from 25 to 35% when the intercrop rows were planted 30 to 60 cm away from the cassava rows, and only 10% when the interplanted crops were planted 90 cm away from the cassava rows.

Table 3 shows that the canopy diameter of various cassava cultivars at 2 months after planting (MAP) was significantly different. However, the relative ranking of cultivars with respect to canopy diameter changed during the growth cycle. It is well

Table 2. Cassava yield and total crop value of mono–and intercropping systems involving three cassava varieties, peanut or upland rice as the first intercrop and mungbean as the second intercrop in Bogor in 1993.

Treatment	Cassava fresh root yield (t/ha)	Crop value[1] ('000 Rp/ha)			
		Cassava	First intercrop	Second intercrop	Total
Cropping pattern					
Cassava+peanut-mungbean	26.12 a	1,306 a	541.6 a	176.2 a	2,023
Cassava+rice-mungbean	26.40 a	1,320 a	269.8 b	189.1 a	1,788
Monoculture cassava	27.99 a	1,399 a	-	-	1,399
" rice or peanut followed by mungbean	-	-	605.9	326.1	932
Cassava clone					
Adira 1	24.79 b	1,239 b	496.3 a	134.4 a	1,870
Adira 4	27.77 a	1,388 a	501.8 a	127.4 a	2,017
No. 39-1-1	28.03 a	1,401 a	429.3 a	142.3 a	1,973

[1] Crop prices : cassava = Rp 50/kg fresh root
rice = 250/kg dry grain
peanut = 800/kg dry pods
mungbean = 1,000/kg dry grain

known that during the first growth phase cassava is relatively weak, and the growth rate is very slow (Hozyo *et al.*, 1984; Wargiono, 1991). The varietal differences in early growth result in different levels of competition between cassava and the intercrops. Thus, canopy diameter and harvesting time of the intercrop are the main factors which should be taken into account when trying to minimize intercrop competition.

Table 3. Canopy diameter of some cassava clones intercropped with peanuts and rice in Bogor, 1993.

Cassava clone	Canopy diameter of cassava (cm)			
	2 months	4 months	6 months	8 months
Adira 1	71 b	97 b	100 b	121 b
Adira 4	85 ab	111 ab	125 ab	157 ab
No. 46-8	85 ab	93 b	120 ab	151 ab
No. 39-1-1	90 a	105 b	119 ab	123 b
No. 40-3-3	86 ab	120 a	137 a	174 a

The results of on-farm research in southern Malang **(Table 4)** showed that adopting the recommended package of technologies for both cassava and the interplanted crops increased the yields of cassava roots and maize grain by 34 and 119%, respectively, compared to the farmers' practices.

Table 4. Effect of improved technology on cassva root and maize grain yields under various cassava–maize intercropping systems in farmers' fields in Malang, E. Java, in 1989.

Treatments [2]	Yield (t/ha) [1]	
	Cassava (fresh roots)	Maize (dry grain)
Technology package #1	37.00 a	5.72 a
Technology package #2	35.84 a	5.60 a
Farmers' practice	27.29 b	2.59 b

[1] Average from 7 farmer cooperators

[2] Technology package #1 = Cassava Faroka variety + Pioneer hybrid maize using recommended technologies

Technology package #2 = Cassava Faroka variety using farmer's practice + Pioneer hybrid maize using recommended technology

Source: Widodo *et al.,* 1993.

2. Cassava Response to Different Cropping Systems and Planting Times

Figure 3 shows the cassava area harvested during each month in various provinces of Indonesia. Most cassava is harvested in July to Oct as most cassava is planted in Oct-Nov at the beginning of the rainy season. Moreover, cropping systems and farmers' traditions also determine the time of planting and harvest.

Cassava growth depends greatly on water availability, especially during the first sixth months. Most farmers avoid stand failure by planting cassava at the beginning of the rainy season and harvesting in the dry season. This causes over-production from the middle until the end of the dry season, leading to a decrease in price of cassava and a corresponding decrease in farmers' income. Delaying the harvest is one alternative to reduce this temporary over-production. However, the farmers' flexibility is limited since the root starch content will decrease if the harvest is delayed to more than 10 months for early harvesting clones and to more than 12 months for late and medium-harvesting clones, especially if the harvest takes place at the start of the rainy season.

The best way to solve this problem is to move the harvest time by changing the planting time according to the rainfall distribution. **Figure 4** shows the effect of planting time of cassava, grown on a large plantation in monoculture, on yield. The yield of cassava was highly correlated ($r=0.711^{**}$) with the amount of rainfall during the first month after planting, as well as with rainfall during the last 2-4 months before harvest

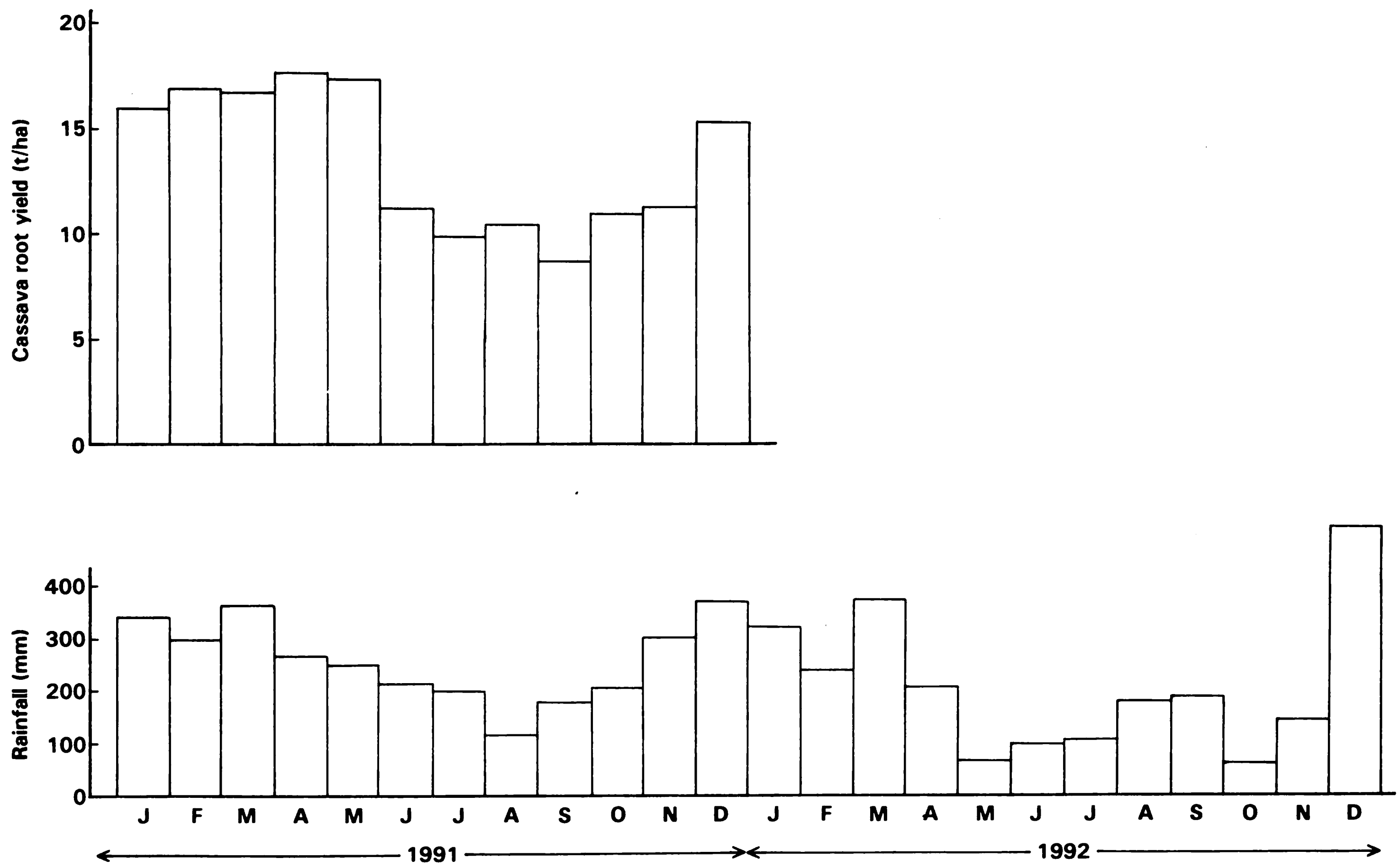

Figure 4. Effect of date of planting on the fresh root yield of cassava planted in the Lampung Peletizing Factory plantation in Gedongwani, Central Lampung in 1991 and harvested after 12 months. The rainfall distribution in 1991 and 1992 is shown below.

Source: *Wargiono, 1993.*

($r=0.819^{**}$ to $r=0.847^{**}$). Adequate rainfall during the first month is important for good germination, while rainfall at the end of the cycle is important to maintain adequate photosynthetic activity for root bulking. There was a negative (but non-significant) correlation between the yield and rainfall during the fourth month ($r=-0.392$), indicating that too much rain at that time may have resulted in excessive weed growth, while weeds are difficult to control at that stage of the growth cycle. This data is important to plantations in order to estimate the supply of raw material based on the rainfall distribution.

Table 5 shows that under intercropping systems the farmers' income is distributed

Table 5. The effect of cassava cropping system and planting arrangement on the total gross income and the relative contribution of each crop to total income in Tamanbogo, Lampung, Indonesia. Data are average values for three years (1987–1990).

Cassava plant spacing/ Cropping system [1]	Total gross income ('000 Rp/ha)	Relative contribution to income (%)			
		First intercrop (s)	Second intercrop	Third intercrop	Cassava
1.0 x 1.0 m					
Cassava monoculture	1,386	-	-	-	100
C+M+R-P-CP	1,466	37	14	2	47
C+M-P-CP	1,406	25	19	3	53
C+R-P-CP	1,581	32	15	3	50
C+P-MB-CP	1,577	35	6	3	56
2.0 x 0.5 m					
Cassava monoculture	1,242	-	-	-	100
C+M+R-P-CP	1,550	36	18	3	42
C+M-P-CP	1,378	23	23	3	51
C+R-P-CP	1,607	33	17	3	47
C+P-MB-CP	1,464	35	5	3	57
2.73 x 0.6 x 0.6 m					
Cassava monoculture	1,240	-	-	-	100
C+M+R-P-CP	1,486	39	13	3	45
C+M-P-CP	1,299	25	21	3	51
C+R-P-CP	1,477	27	17	2	53
C+P-MB-CP	1,666	32	6	4	58

C = cassava, M = maize, R = rice, P = peanut, MB = mungbean, CP = cowpea.

more evenly over the year compared with monoculture cassava. Between 23 and 39% of total income was obtained from the first intercrops at about four months, 5 to 21% from the second intercrop at about 8 months, while 45 to 62% was obtained from the final harvest of cassava and the third intercrop at 10-12 months. This continuous flow of income in farming can be achieved if the rainfall is well distributed and soil fertility is maintained.

As has been reported before, intercrop competition can be minimized if the plant type of each crop is suitable for intercropping, i.e. if the cassava canopy diameter is small, the stem is short and the intercrop has a short growth cycle. **Tables 6 and 7** show

Tabel 6. Cassava and intercrop yields in an intercropping system of cassava+peanut followed by mungbean using six different cassava clones in Bogor, Indonesia, 1993.

Treatment	Cassava[1] (fresh roots)	Peanut (dry grain)	Mungbean (dry grain)
	(t/ha)		
Adira 1	22.2 ab	0.42 a	0.13 bc
Adira 4	27.2 a	0.42 a	0.16 bc
No.46-8	18.3 b	0.46 a	0.20 b
No.50-2	22.9 ab	0.46 a	0.14 bc
No.39-1-1	26.6 ab	0.39 a	0.09 bc
No.40-3-3	23.9 ab	0.42 a	0.07 c
Monoculture (peanut followed by mungbean)	-	0.58 a	0.34 a

[1] Cassava yield in intercropping.

Table 7. Cassava and intercrop yields in an intercropping system of cassava+rice followed by mungbean using six different cassava clones in Bogor, Indonesia, 1993.

Treatment	Cassava (fresh roots)	Rice (dry grain)	Mungbean (dry grain)
	(t/ha)		
Adira 1	26.1 a[1]	1.08 ab	0.14 b
Adira 4	28.0 a	0.82 ab	0.11 b
No.46-8	25.4 a	0.76 c	0.17 b
No.50-2	24.9 a	0.88 ab	0.14 b
No.39-1-1	29.3 a	1.03 ab	0.10 b
No.40-3-3	29.5 a	0.87 ab	0.11 b
Monoculture (rice followed by mungbean)	28.8 a[2]	1.38 a	0.31 a

[1] Cassava yield in intercropping.

[2] Average of Adira 1, Adira 4 and No. 39-1-1 grown in monoculture.

that cassava and intercrop yields were both affected by the different plant types of various cassava clones.

Most farmers in Indonesia plant cassava in intercropping systems. Therefore, an important factor to consider before changing the cassava planting time is the distribution of rainfall and its effect on the competition between casava and the first intercrop. **Tables 8 and 9** show that delaying the planting of cassava to several months after that of the intercrops decreased the cassava yield significantly, especially in the dry season. The decrease in yield of cassava was sometimes associated with an increase in intercrop yield; however, it was different in each location and it was influenced by the distribution of rainfall. Also the growth rate of cassava during the first two months is lower than that of rice, maize and peanut, making it difficult for cassava to compete with those intercrops if cassava planting is delayed.

Table 8. The yield of cassava and intercrops [1] as affected by the time of planting cassava relative to that of the intercrops, using three different cassava clones in two different planting seasons in Bogor in 1992.

Treatment	Yield (t/ha)					
	Cassava		Maize		Peanut	Soybean
	wet season[2]	dry season[2]	wet season	dry season	wet season	dry season
Planting time of cassava (MAPI)[3]						
0	27.39 ab	27.33 a	2.51 a	1.17 a	0.41 a	0.54 a
1	33.04 b	20.58 ab	2.76 a	1.31 a	0.42 a	0.47 b
2	29.61 ab	21.39 ab	2.75 a	1.26 a	0.41 a	0.47 ab
3	25.09 a	16.53 b	2.75 a	1.26 a	0.38 a	0.40 b
4	25.11 a	14.78 b	2.69 a	1.22 a	0.41 a	0.43 ab
Cassava clone						
Adira 1	26.97 a	14.39 b	2.63 a	1.17 a	0.41 a	0.49 a
Adira 4	31.03 a	24.39 a	2.66 a	1.28 a	0.39 a	0.41 a
Local	26.36 a	20.75 ab	2.78 a	1.28 a	0.40 a	0.47 a

[1] Intercropping system : Cassava+Maize+Peanut in wet season.
Cassava+Maize+Soybean in dry season.
Cassava is planted at 1.25x0.8 m.

[2] Cassava planted from November to March for wet season,
May to September for dry season.
Intercrops planted in Nov. (wet season) or May (dry season)

[3] MAPI = months after planting intercrops.
0 = planting in November for wet season, in May for dry season.

Table 9. The yields of cassava and intercrops [1] as affected by the time of planting cassava relative to that of the first intercrops, using three different cassava clones in two locations. First intercrops were planted at the beginning of the wet season in November.

Treatment	Yield (t/ha)							
	Cassava		Maize		Rice		Mungbean	Soybean
	Y.karta	Lampung	Y.karta	Lampung	Y.karta	Lampung	Y.karta	Lampung
Planting time of cassava (MAPI)[2]								
0	18.46 a	39.79 a	1.03 a	2.51 a	1.98 a	1.68 b	0.25 c	0.28 b
1	11.07 b	38.95 a	1.12 a	2.76 a	2.17 a	2.11 a	0.42 b	0.34 a
2	8.03 bc	27.74 bc	1.12 a	2.75 a	2.37 a	2.17 a	0.47 ab	0.36 a
3	4.71 c	21.78 c	1.03 a	2.51 a	2.37 a	2.18 a	0.55 a	0.28 b
Cassava clone								
Adira 1	11.60 a	37.64 b	1.01 a	2.63 a	2.29 a	0.44 a	0.37 a	0.38 a
Adira 4	11.08 a	39.19 a	1.05 a	2.66 a	1.98 a	2.04 a	0.33 a	0.36 a
Local	9.03 a	24.77 c	1.17 a	2.78 a	2.28 a	1.99 a	0.49 a	0.36 a

1) Intercropping system : Cassava+Maize+Rice-Mungbean in Yogyakarta.
Cassava+Maize+Rice-Soybean in Lampung.

2) MAPI = months after planting of first intercrops.

Source : Wargiono, 1993.

3. Erosion Control by Cultural Practices

Soil erosion is the main cause of soil degradation and is affected by climate, topography, vegetation, type of soil, as well as by human activities (Suwardjo and Sinukaban, 1986).

Cassava production areas in Indonesia are mainly located in mountainous areas of Java where erosion can be quite severe. In this area farm size is very small and erosion can be reduced substantially by terracing; however, this is quite expensive. Therefore, another cheaper way which is practical and more advantageous should be found. Several years of erosion control trials in Malang, E.Java, have shown that one way of controlling erosion is the planting of contour barrier strips with grasses, such as elephant or napier grass (*Pennisetum purpureum,*) or the planting of contour hedgerows of *Leucaena leucocephala* or *Gliricidia sepium*. The elephant grass barrier reduced erosion to only 45% compared to that without the grass barriers in the second year (Wargiono *et al.*, 1992), while the *Leucaena* and *Gliricidia* hedgerows were most effective in reducing erosion and increasing cassava yields in the fourth year (Table 10). Another advantage of these practices is that elephant grass can be used for animal feeding, while the prunings of the hedgerows, when applied as a mulch, supply additional N to cassava and improve the soil OM and physical characteristics **(Table 10).**

Cassava is also extensively grown on Red-yellow Podzolic soils in southern Sumatra, a production area which is also quite susceptible to erosion, but which has a great potential for further development. Erosion can be reduced through minimum tillage or strip tillage or by the use of mulch. Minimum tillage is not often used by farmers because it makes weed control more difficult, while mulch to protect the soil from erosion is seldom available, since crop residues are usually consumed by animals. Therefore, other practical alternatives should be identified. **Figure 5** shows that in both monoculture and intercropping systems, erosion and total crop value were affected by cropping systems and planting patterns. Intercropping had no effect on erosion when cassava was planted in a square pattern, but markedly reduced erosion when cassava was planted in a wide-row or double-row system. Planting pattern did not significantly effect erosion nor total crop value when cassava was grown intercropped, but the square arrangement reduced erosion significantly and increased total crop value when cassava was grown in monoculture. Most erosion occured during the first four months of cassava establishment.

Fertilization usually increases both the height and the canopy diameter. The greater the canopy diameter the more soil is protected from the direct impact of falling raindrops and the lower the erosion. **Figure 6** shows that when cassava was grown in monoculture, fertilizer application reduced erosion by about 22%, while the effect of fertilization on erosion was minimal when cassava was intercropped. Erosion losses for

Table 10. Effect of various agronomic practices on cassava yield, soil losses due to erosion and soil physical and chemical characteristics in Jatikerto, Malang, Indonesia in 1990/91 (4th consecutive year).

Treatments	Cassava yield (t/ha)	Dry soil loss (t/ha)	OM (%)	Bulk density (t/m^3)	Infiltr. rate (cm/h)	Aggreg. stab. (MWD) (mm)
1. Contour ridges, no live barriers	17.77	18.6	1.16	1.24	0.40	0.18
2. Contour ridges, elephant grass barriers	18.66	12.9	1.41	1.24	2.00	0.24
3. Contour ridges, setaria grass barriers	16.66	12.6	1.39	1.27	1.80	0.24
4. Contour ridges, peanut barriers	16.10	16.5	1.56	1.31	1.20	0.21
5. Contour ridges, *Gliricidia sepium* barriers	25.55	7.5	2.12	1.16	3.00	0.39
6. Contour ridges, *Leucaena leucocephala* barriers	27.77	10.9	1.94	1.17	2.20	0.38
7. No ridges, peanut barriers	13.88	26.5	1.42	1.29	1.40	0.14
8. No ridges, setaria grass barriers	13.30	24.3	1.47	1.30	0.80	0.20

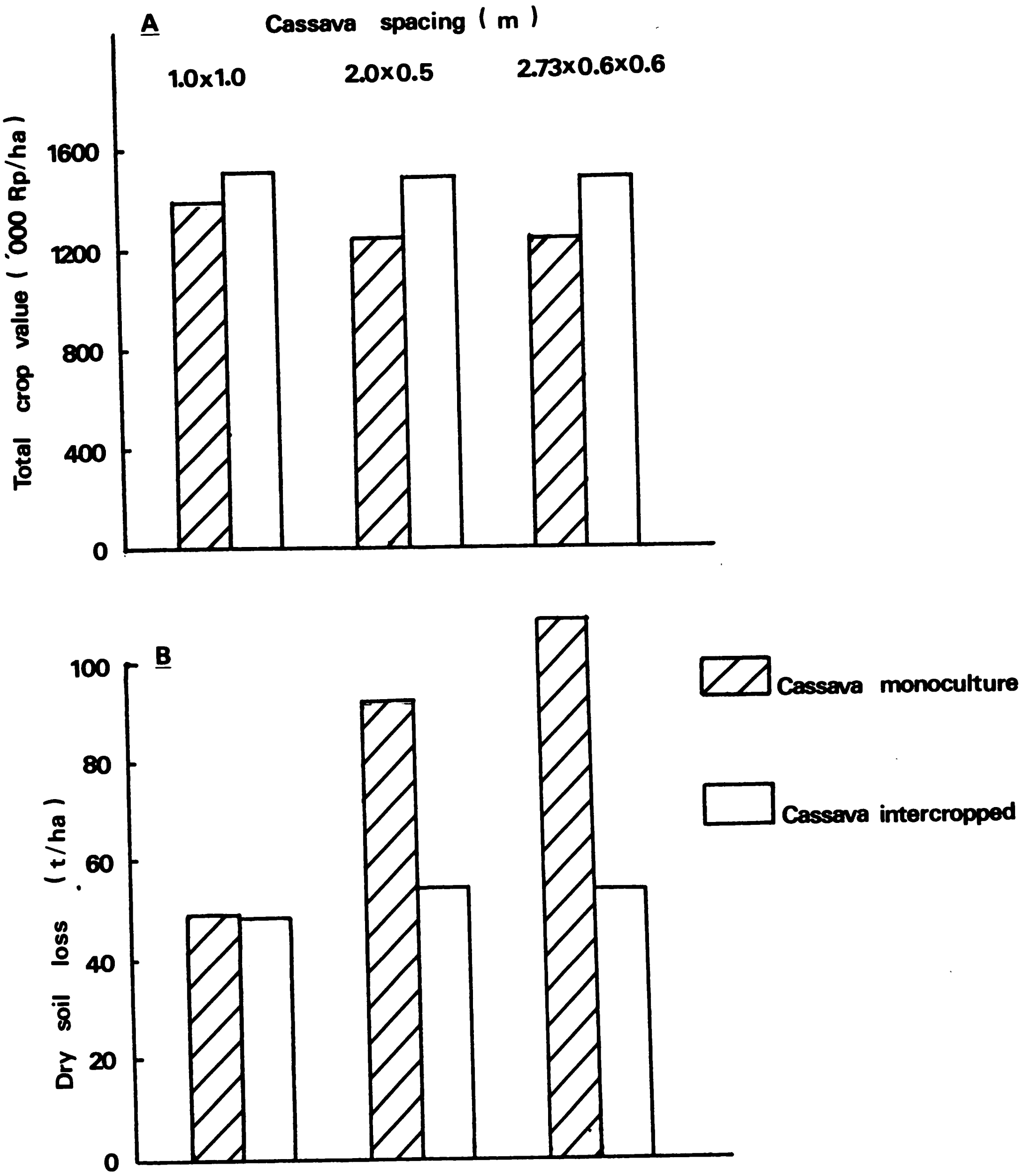

Figure 5. Effect of cassava planting arrangement on (A) total crop value and (B) soil losses due to erosion for either monocropped or intercropped cassava, grown in Tamanbogo, Lampung, Indonesia. Data are avg. of trials conducted in 1987-89. Intercropped cassava is avg. of four cropping systems (C+M+R-P; C+M-P; C+R-P; and C+P-Mu, where C=cassava, M=maize, R=upland rice and Mu=mungbean).

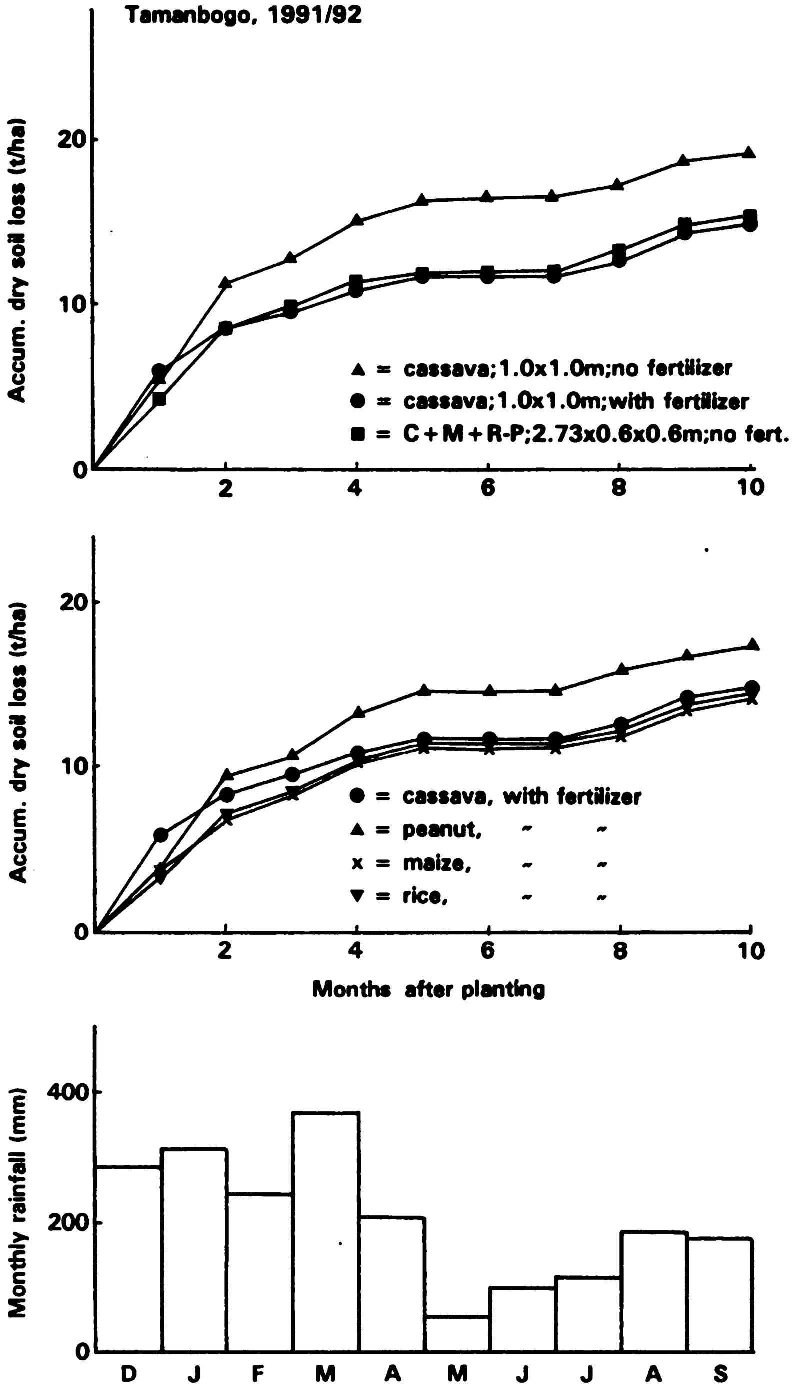

Figure 6. Effect of fertilizer application and cropping systems on accumulative dry soil loss due to erosion on 5% slope in Tamanbogo, Lampung. Indonesia in 1991/92.
C= cassava, M = maize, R = upland rice, P = peanut.

fertilized cassava grown in monoculture were similar to those of monoculture rice and maize, and were about 15-20% lower than those of peanut.

Intercropping tends to reduce erosion and increase farmers' income. Having increased their income, farmers have more money available to buy fertilizers. By applying fertilizers to cassava and the intercrops erosion losses will be further reduced, while soil fertility and land productivity will be increased.

4. Fertilization

Cassava growth is often inhibited and leaves show deficiency symtoms when the content of nutrients in the soil is below the critical level. This condition can be improved by adding nutrients to the soil. The efficiency of fertilizer application or the crop's ability to absorb nutrients is affected by the type of soil and fertilizer, the responsiveness of the variety, the crop's general condition, the cropping pattern, and the availability of other nutrients (Howeler, 1981; Wargiono, 1988, 1991; and Widjaya *et al.*, 1990).

Figure 7 shows the response of cassava to the application of various levels of N, P, and K during three consecutive cropping cycles in Jatikerto station in Malang, E. Java. High root yields of 30-35 t/ha could be maintained with a balanced fertilizer application of 100 kg N, 50 P_2O_5 and 100 K_2O/ha. Among the three nutrients applied, the effect of N application was most pronounced, and the response to N increased with each consecutive cropping cycle; during the third year yields increased from 6 t/ha to 33 t/ha by the application of 100 kg N/ha. Responses to application of P were less dramatic but were generally significant, while the response to K was only significant during the first year. The lack of a significant K response is to be expected in these volcanic ash-derived soils which have a high K content. Since cassava is generally grown continuously in the same field a balanced but not excessive fertilization is necessary to maintain high yields.

Fertilizer experiments conducted in Yogyakarta and Lampung have given different results. In Yogyakarta **(Figure 8)**, the levels of fertilization of N, P and K significantly affected the total crop value, but only the rice yield was significantly affected by the application of N, while the yields of other crops were not significantly affected. The highest total crop value and net income were obtained at the intermediate level of 90 N, 50 P_2O_5 and 90 kg K_2O/ha. However, in Lampung **(Figure 9)**, the application of N, P and K significantly affected the yields of cassava, rice, maize and peanuts (negative) as well as the total crop value and net income. The highest total crop value and income were obtained at the highest level of fertilization, corresponding to 180 N, 100 P_2O_5 and 180 kg K_2O/ha. The original soil fertility considerably affected the results of these experiments.

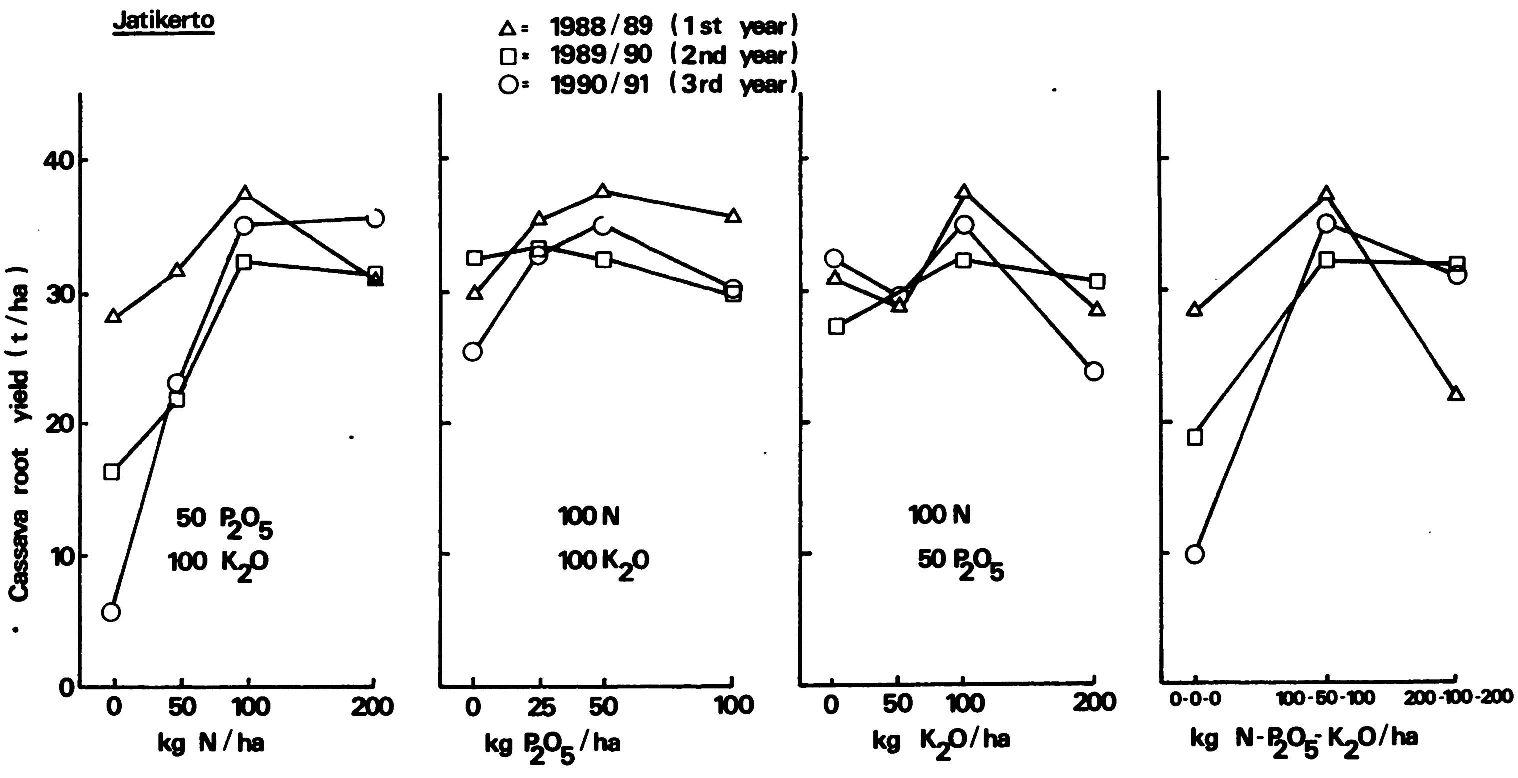

Figure 7. Response of cassava to application of N, P, and K during three consecutive years in Jatikerto, Malang, Indonesia.

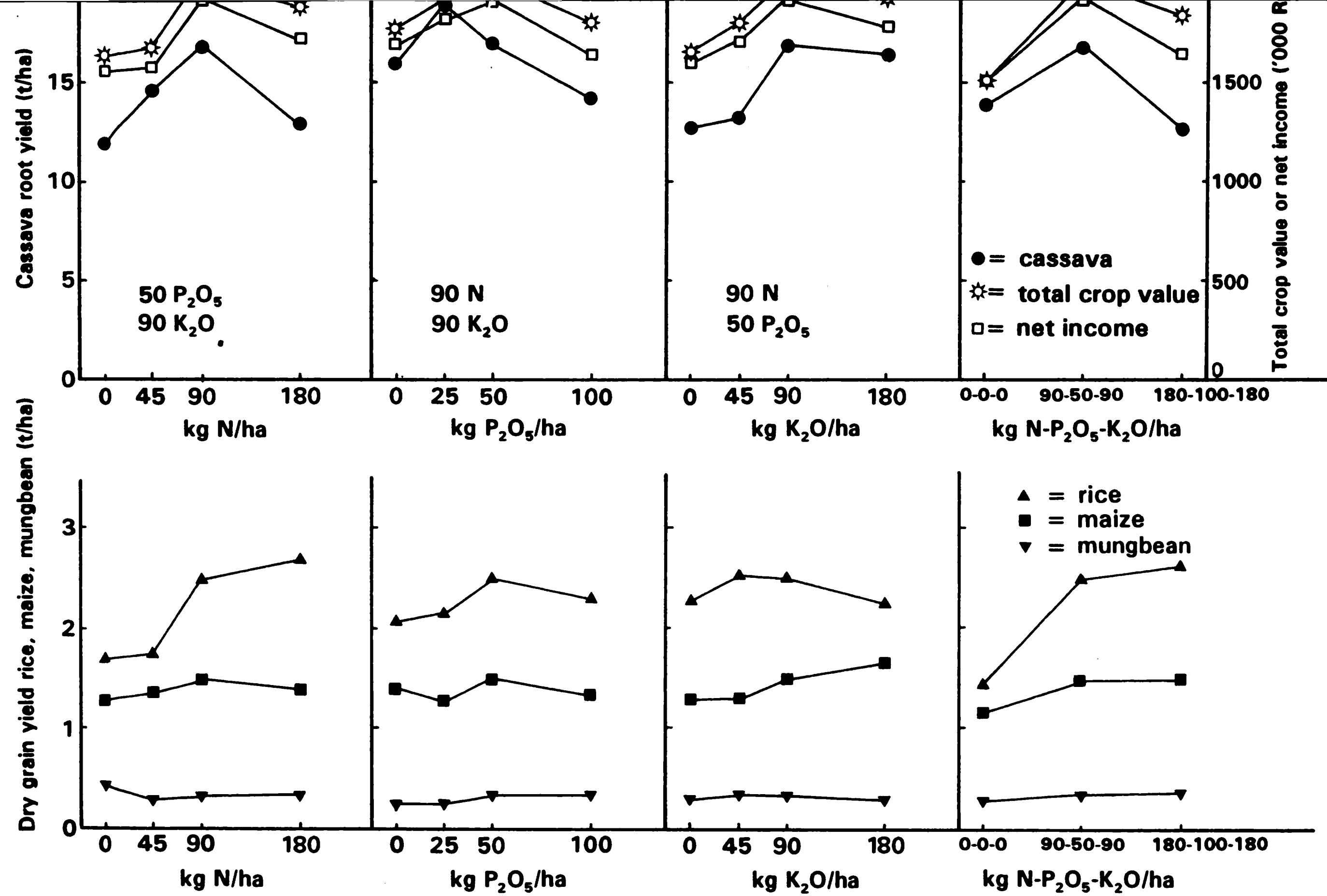

Figure 8. Effect of the application of various levels of N, P and K on the yield of cassava and intercrops as well as on total crop value and net income in a cassava + maize + rice - mungbean cropping system in Yogyakarta, Indonesia in 1991/92.

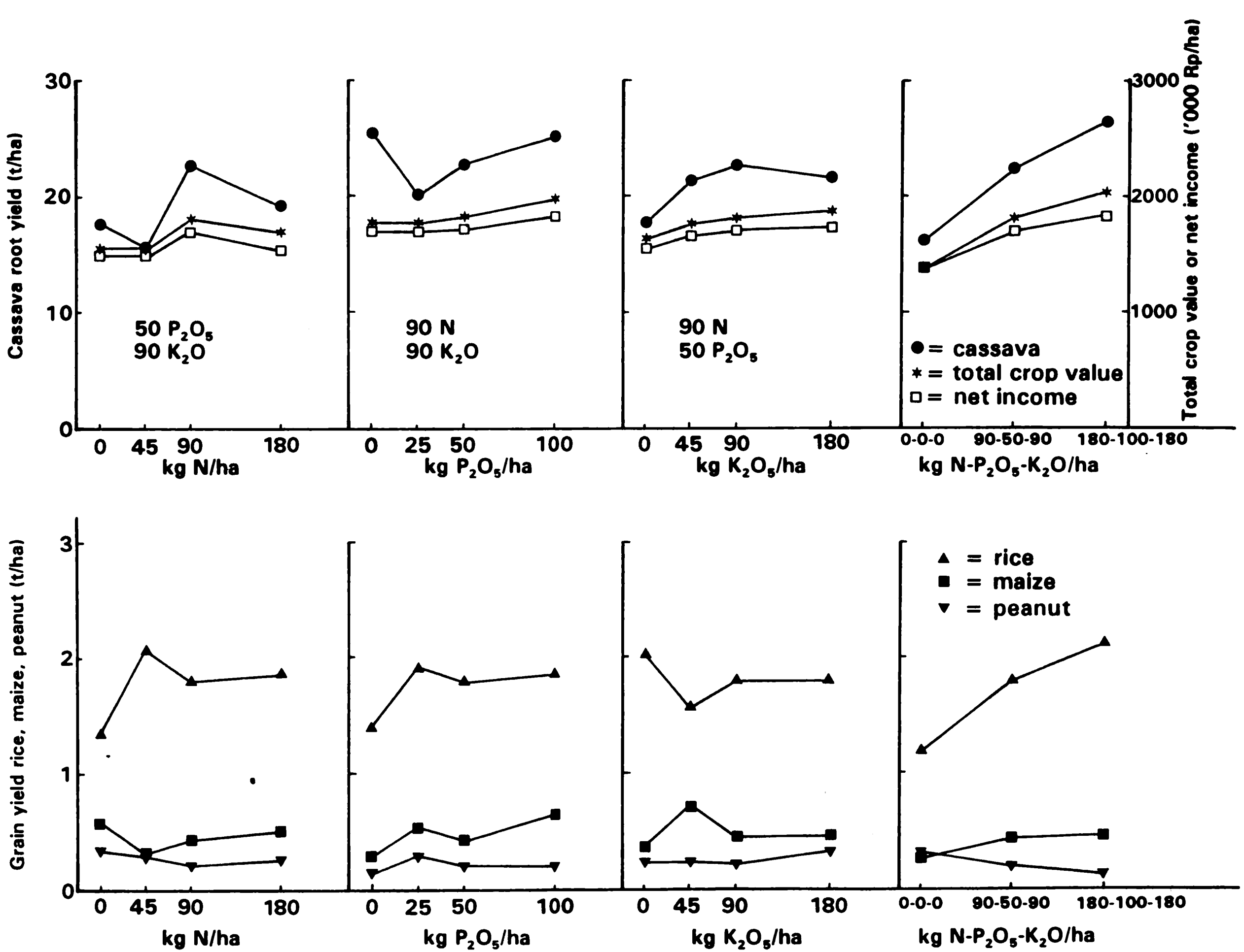

Figure 9. Effect of the application of various levels of N, P and K on the yield of cassava and intercrops as well as on total crop value and net income in a cassava + maize + rice - peanut cropping system in Tamanbogo, Lampung, Indonesia in 1991/92.

Table 11 shows the benefit/cost ratio of fertilizer application for cassava only and for all crops together in intercropped cassava grown at three locations. When cassava was fertilized with 50 N, 20 P_2O_5 and 50 kg K_2O/ha, while the first intercrop was fertilized (constant rate) with 30 N, 20 P_2O_5 and 30 kg K_2O/ha and the second intercrop with 10 N, 10 P_2O_5 and 10 kg K_2O/ha (Treatment 4), the highest benefit/cost ratio was

Table 11. The benefit/cost ratio of cassava and cassava+intdrcrops as a result of fertilizing cassava at different rates of N, P and K in three locations in 1992/1993.

Fertilization of cassava (kg/ha)			B/C ratio ('000 Rp/1000 Rp spent on fertilizers)					
			B/C for cassava			B/C for cassava+intercrops		
N	P_2O_5	K_2O	Bogor	Yogya	Lampung	Bogor	Yogya	Lampung
0	0	0	-	-	-	-	-	-
0	20	50	-0.6	-1.3	0.8	-0.5	1.3	2.2
25	20	50	0.8	0.3	-0.3	2.7	1.8	2.2
50	20	50	2.4	1.0	2.2	3.3	3.5	2.7
100	20	50	1.8	0.4	0.8	2.0	1.9	1.5
50	0	50	2.4	0.9	3.0	2.8	2.3	3.0
50	10	50	0.6	1.4	1.8	2.0	3.6	3.6
50	40	50	0.8	0.8	4.5	1.3	1.7	3.3
50	20	0	1.5	-0.8	0.7	3.1	0.6	2.2
50	20	25	1.4	0.7	1.7	2.0	1.7	2.8
50	20	100	1.1	0.8	1.7	2.0	3.2	3.3

Note: Cropping system: C+R+M-MB in Bogor and Yogyakarta and C+R+M-P in Lampung.
Rice fertilized at constant rate of 60 N, 30 P_2O_5 and 60 kg K_2O/ha.
Peanuts fertilized at constant rate of 25 N, 30 P_2O_5 and 30 kg K_2O/ha.

obtained. This ranged from Rp. 1,000-2,400 for cassava alone and from Rp. 2,700-3,500 per Rp. 1,000 of fertilizer input for all crops combined. This indicates that fertilization can increase farmers' income, while it can also reduce erosion and improve biomass production, the latter being a source of organic matter, which can be returned to the soil or used as animal feed.

Table 12 shows that intercropping cassava increased the total crop value about 50% over cassava monoculture when no fertilizer was applied and about 16% with fertilizer application. Fertilizer application in the intercropping system reduced the competition for nutrients between cassava and the intercrops. Light competition between cassava and the intercrops was fairly strong, resulting in etiolated growth of cassava; the degree of competition was affected by the type of intercrop. The peanut and rice intercrops

Table 12. The effect of fertilizer application, plant spacing and cropping system on the gross and net income from cassava and intercrops in Tamanbogo, Sumatra in 1991/1992.

Treatments	Crop value ('000 Rp/ha)[1]			Fertilizer cost	Net profit
	Cassava	Intercrop	Total	('000Rp/ha)	
Without fertilizer					
Cassava (1.0x1.0m) monoculture	1,067	-	1,067	0	1,067
C (2.0 x 0.5m)+M+R-P	738	825	1,563	0	1,563
C (2.73 x 0.6 x 0.6m)+M+R-P	752	900	1,652	0	1,652
With fertilizer[2]					
Cassava (1.0 x 1.0m)	1,661	-	1,661	95	1,566
C (2.0 x 0.5m)+M+R-P	954	967	1,921	208	1,713
C (2.73 x 0.6 x 0.6m)+M+R-P	1,049	871	1,920	208	1,712
Upland rice monoculture	-	575 [3]	575	167	408
Maize monoculture	-	619 [3]	619	167	452
Peanut monoculture	-	624 [3]	624	135	489

[1] Price : Cassava (C) = Rp 45/kg
Rice (R) = Rp 250/kg
Maize (M) = Rp 150/kg
Peanut (P) = Rp 800/kg

[2] Fertilizer : for cassava : 90 N, 30 P_2O_5, 90 kg K_2O/ha
for rice : 60 N, 40 P_2O_5, 60 kg K_2O/ha
for peanut : 30 N, 30 P_2O_5, 30 kg K_2O/ha

[3] One crop only

were harvested at about 100 days after planting. It was found that monoculture cassava at 4 months after planting was taller than cassava that had been intercropped with rice or peanut. This indicates that the initial etiolation also reduces the growth in the next phase. Although intercropping generally reduces the cassava yield, this yield loss can be compensated for by the yield of the intercrops; thus, intercropping generally increases the total gross income of the farmer (Moreno and Hart, 1978; Thung and Cock, 1978). The total gross income can be further increased by increasing the yield of the second intercrop. This can be achieved by increasing the light interception of the intercrop, by planting high-yielding cassava varieties which have a narrow canopy diameter and no branches.

On-farm trials at Tulangbawang in Lampung **(Table 13)** indicate that there was no significant effect of fertilizer application on cassava yield in various intercropping systems. However, the type of intercrop affected significantly the growth and yield of cassava, while there was no interaction between fertilizer application and intercrop. Peanut intercropping slightly increased the growth and yield of cassava, while maize significantly decreased cassava yields. This is probably because peanuts do not significantly compete with cassava for light, while they may supply some additional N through symbiosis with *Rhizobium*.

Table 13. The effect of fertilizer application and intercropping on the fresh and dry root yields of cassava planted in an on-farm trial in Tulangbawang, Lampung in 1992.

Treatment	Cassava yield (t/ha)	
	Fresh roots	Dry roots
Fertilization		
With	34.65	14.18
Without	31.20	12.45
LSD (15%)	NS	NS
Intercrops:		
None	33.56 a	14.42 ab
maize	26.52 b	10.83 c
peanut	37.66 a	15.82 a
Crotalaria sp.	33.95 a	12.19 bc
LSD (15%)	5.48	3.19

Results of on-farm trials in South Sulawesi show that adopting a package of improved technology, including high-yielding varieties and fertilizers, is economically attractive, as indicated by a benefit/cost ratio of more than two **(Table 14)**.

Table 14. Effect of improved technology on the yield and economic returns of various cassava clones in on-farm trials in South Sulawesi.

Variety/fertilizer treatments	Fresh root yield (t/ha)	Crop value	Production costs	Benefit/ cost ratio
		(Rp'000/ha)		
W1435-85+fertilizer[1]	55.4	1,248	623.2	2.50
Adira-4 +fertilizer	52.6	1,105	642.7	2.15
Valenca+fertilizer	37.4	810	630.6	1.61
Valenca-fertilizer	12.4	186	272.8	0.75

[1] Fertilizers applied: 90 kg N, 72 P_2O_5 and 50 K_2O/ha.

Source: Widodo *et al.,* 1993.

CONCLUSIONS

1. The cassava production area in Indonesia is located mainly in Java (60%) with smaller areas in Lampung, East Nusa Tenggara and Sulawesi. These production areas generally have marginal soils.
2. Land productivity may be increased through improvements in cropping systems, planting time, and fertilization:
   a. Intercropping with adequate fertilization for all crops resulted in higher gross income than planting cassava in monoculture.
   b. A more even distribution of cassava production throughout the year is difficult because most farmers plant cassava at the beginning of the rainy season. However, by using intercropping systems, the planting time of cassava can be delayed. Although the cassava yield decreased, total income increased by an increase in the intercrop yield.
   c. Results of fertilization experiments differed among locations. In Malang the main response was to N; there was only a minor response to P and no significant response to K. In Yogyakarta, NPK fertilization had only a significant effect on the total crop value, but the yields of most crops were not significantly affected. However, in Lampung fertilizer application increased significantly the production of cassava, rice and maize, as well as the total crop value.
3. Erosion control experiments in Lampung using various cultural practices showed that intercropping reduced soil erosion markedly compared to planting in monoculture, but only when cassava was planted in a wide-row or double-row system. Planting cassava in a square planting arrangement of 1.0x1.0 m significantly re-

duced erosion and increased the total crop value. Other experiments in Malang showed that planting contour strips with elephant grass or hedgerows of *Leucaena leucocephala* or *Gliricidia sepium* markedly reduced erosion, increased cassava yields and improved the soil's physical condition.

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RECENT PROGRESS OF CASSAVA VARIETAL IMPROVEMENT IN INDONESIA

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ABSTRACT

The role of cassava in Indonesia is becoming more important, whether it is used for food, for industrial processing or for export. The government of Indonesia has established two policies in the agricultural sector, namely: food diversification and increased productivity in the uplands. Food diversification is needed to reduce dependency on rice as the principal food by way of utilizing various other carbohydrate sources, especially cassava. The policy to increase productivity in the uplands, on the other hand, is launched because the acreage of lowland rice fields has been declining over the years with the conversion of some of this land to non-agricultural use, especially on Java. One way of increasing productivity in the uplands is through crop diversification. However, this diversification program should not affect the current productivity of cassava, since cassava has always functioned as a dominant commodity produced in the uplands. For this reason, the intensification of cassava becomes necessary, through, for example, application of intercropping systems that use suitable plant types, varieties as well as appropriate cultural technologies.

Efforts to improve cassava cultivars should be made and the methods to introduce them to the farmers should be improved. When cassava is meant to substitute for rice as a source of carbohydrate, a high-quality cultivar, characterized by low HCN in the roots, needs to be developed. On the other hand, when it is meant for industrial use, a high-yielding cultivar with high starch content, needs to be developed. Special cultivars may also need to be developed when cassava is to be grown under intercropping systems.

Cassava breeding in Indonesia is presently done jointly by MARIF, CIAT and Brawijaya University in Malang. MARIF has recently released two new high-quality cultivars, named Malang 1 (parents: CM1015-19 x CM849-1) and Malang 2 (parents: CM922-2 x CM507-37). The selection program carried out by Brawijaya University has produced a number of promising cassava clones, labelled UB 1-2 (parents: MCol 22 x CM849-1), UB 15-10 (parents: CM586-1 x CM523-7), UB 477-2 (parents: CM1002-4), UB 881-5 (parents: CM849-1) and UB 566-8 (parents: MBra 35). These clones show their greatest potential in the uplands of subhumid regions like East Java. UB 477-2 is a sweet clone, while clones UB 15-10 and UB 566-8 are suitable for growing under intercropping systems. These promising clones will not be released as high-quality cultivars before they undergo multi-location trials in at least 5 provinces, as stipulated by the Minister of Agriculture of the Republic of Indonesia.

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INTRODUCTION

In Indonesia cassava is one of the most important crops used as a basic source of carbohydrates. Cassava is mainly processed into human food (57%), but is also used as industrial raw material (17%), for production of animal feed (2%) or for export (10%), while 13% is considered as postharvest losses (CBS, 1989).

Cassava is cultivated mainly in upland areas and in marginal soils. Most agricultural land in Indonesia is rainfed, so the government pays much attention to the improvement of the productivity of this land. Among these efforts is the introduction of some new commodities besides traditional staple crops like cassava, corn, rice and peanut. Consequently, cassava has to compete with these new commodities.

As a source of carbohydrate, cassava is considered an important alternative food crop which must be further developed. Depending on the farmers' conditions, the improvement of cassava production can be achieved in two main ways; firstly, by the use of appropriate varieties and better technologies; and secondly, by intercropping. Different regions, having different macro-environments, need specific recommendations, so that the application of improved varieties and technologies will be more effective. For this reason, cassava breeding must play an important role.

Soil and Agroclimate

Indonesia is an archipelago which is divided into 27 provinces consisting of thousands of islands. Among these, there are only a few big islands, like Java, Sumatra, Kalimantan, Sulawesi and West Irian. This condition creates large differences among regions with respect to soils and agroclimates.

According to Oldeman (1975), the agroclimates of Indonesia may be divided into five types, i.e. type A, B, C, D and E, depending on the amount of rainfall and its distribution. Sumatra, Kalimantan and West Irian are dominated by type A and B climates (about 70%), while Java, Sulawesi and some islands in the eastern part are dominated by type C and D climates (about 75%). Thus, in general terms, the agroclimate in Indonesia can be divided into wet and dry climates. Characteristic of a tropical climate, there are only two seasons, i.e. a wet and a dry season. In the western region the dry season lasts less than two months, but in the dry regions of the southeast the dry season extends for 3-6 months.

The soils of Indonesia are highly variable; they are classified as Ultisols, Inceptisols, Entisols, Vertisols, Oxisols and Histosols. The wet region (annual rainfall 2000-5000 mm) is dominated by Ultisols, which are characterized by low soil fertility, low pH, high porosity of the top soil but low permeability of the subsoil. In contrast, in the dry region the major constraint for cassava production is the heavy clay soils, like some Entisols and Vertisols (Bambang and Utomo, 1988).

Cassava Growing Areas and Production Problems

Cassava is grown in all provinces in Indonesia, but the crop is concentrated in Java, South Sumatra, South Sulawesi, Bali and Nusa Tenggara. East Java is the main center of production where about 26% of cassava in Indonesia is produced (Biro Pusat Statistik, 1990). The total cassava area in Indonesia is about 1.4 million ha, with an average yield of 12.2 t/ha. The planted area has been relatively constant since the early 1970s, because cassava must compete with other food crops, especially in the upland areas. Compared with research results obtained, the average national yield of 12 t/ha is very low, because experimental yields may reach 40 t/ha.

The following are some of the problems encountered in cassava production in Indonesia:

1. Most of the small-scale farmers grow sweet local varieties, which are generally low yielding; in contrast, bitter cassava is usually grown on big plantations.
2. Cassava is generally grown in upland areas with low soil fertility and with limited rainfall.
3. Generally, cassava is intercropped with other cereals or legumes, especially by small-scale farmers, who use a relatively wide cassava spacing resulting in a low plant population.
4. During the main harvest season the cassava price is very low, so farmers tend to have a low income.
5. The number of high yielding cultivars is still limited; consequently, the same variety tends to be grown in different locations with very different macro-environments.

Many local and old improved varieties are still widely grown by farmers, like Mentega, Mentek, Ketan, Gading, Valenka, Kretek, Gendruwo, Bogor, Faroka, Vandemir and Sao Paulo Preto (SPP). In 1978 two high yielding varieties were released, i.e. Adira 1 (sweet) and Adira 2 (bitter), while Adira 4 (bitter) was released in 1986. This last variety is more popular and more widely planted than the first two varieties. Recently, Malang Research Institute for Food Crops (MARIF) released two new varieties, i.e. Malang 1 (parents CM1015-19xCM849-1) and Malang 2 (parents: CM922-2xCM507-37).

An important step in solving the low productivity of cassava in Indonesia is to develop new cultivars that are suitable for specific purposes. Therefore, a continuous cassava breeding program, having the objective of developing varieties for different end-uses and for specific environments, is needed. To achieve these objectives requires much work, not only to conduct trials at various stages of selection, but also to do these trials in many different environments. The main constraint being faced is the limited availability of research funds, which leads to the difficulty of securing the continuous flow of germplasm input and its evaluation. Therefore, the continued cooperation with

CIAT is particularly important for the further development of cassava research, including breeding.

Breeding Strategies and Objectives

Cassava breeding in Indonesia is mainly conducted by three entities, i.e. the Bogor Research Institute for Food Crops (BORIF) located in Bogor, West Java; the Umas Java Farm (UJF) in southern Lampung, Sumatra, which started as a three-way cooperation with BORIF and CIAT; and the University of Brawijaya (UNIBRAW) together with MARIF in Malang, East Java. BORIF used mainly local clones from both wet and dry regions as potential cross parents (Soenarjo *et al.*, 1988), while Umas Jaya, UNIBRAW and MARIF have used introduced cassava germplasm from CIAT as the major source of selection material. From 1985 to 1990 CIAT has distributed 21,200 cassava F_1 hybrid seeds to Indonesia (Kawano, 1992).

Varietal improvement at Umas Jaya is mainly directed towards achieving promising clones which are suitable for wet regions, while the breeding program at UNIBRAW/MARIF has as a main objective the development of better clones for both wet and dry regions.

In general, the breeding objectives in Indonesia are to develop promising clones with the following characteristics:

- High root yield and high harvest index
- High root starch content
- Tolerance to major pests and diseases
- Non-branching growth habit
- Good root shape

Beside these general objectives, there are also some specific objectives related to specific production areas or end-uses:

- Sweet clones mainly for small-scale subsistence farmers and bitter ones for large plantations and industrial use
- Suitable clones for intercropping
- Tolerance to certain adverse soil and climatic conditions
- Specific adaptation to a given region

Achievements

At present there are two promising clones that could be released, i.e. UB 1-2 (parents MCol 22 x CM849-1) and UB15-10 (parents CM586-1xCM523-7). The UB1-2 clone is suitable for drier climates like that of Madura and Kediri, while UB15-10 is particularly suitable for intercropping. Both clones were higher yielding than Adira 4 at three locations (Madura, Malang and Kediri). The yields of clone UB1-2 at Madura, Malang and Kediri were 30.4, 32.3 and 33.2 t/ha, respectively. The yields of clone UB15-10 at the above three locations were 23.5, 36.3 and 31.8 t/ha, respectively. Beside these two bitter clones, there is one sweet clone, UB477-2 (parent CM1022-4), which might be released after conducting multilocation trials in 1993.

The results of a replicated yield trial conducted at the Jatikerto station of the University of Brawijaya in Malang is shown in **Table 1.** This trial was planted in December 1990 and harvested in October 1991. It can be seen that only two clones, i.e. SM881-5 BU and SM937-3BU, had relatively high root dry matter contents (RDMC), but their yields were still lower than those of Adira 4 and Faroka (control).

Tableb 1. Results of a Replicated Yield Trial conducted at Jatikerto Station of Brawijaya University in Malang, Indonesia, 1990/1991.

Clones	Parents	Dry yield (t/ha)	Fresh yield (t/ha)	Root DM content (%)	Harvest index
Adira 4	BORIF 528	13.1	34.2	38.4	0.60
SM881-3BU	CM849-1	12.0	29.1	41.1	0.63
Faroka	Local check	11.9	31.0	38.5	0.63
SM881-5BU	CM849-1	11.5	29.6	39.0	0.64
SM969-1BU	CM523-7	10.9	29.2	37.4	0.63
SM879-3BU	CM681-2	10.1	27.4	36.8	0.60
SM944-4BU	MCub 18	9.9	26.8	36.8	0.56
OMR30-9-13BU	21-18Q	9.6	26.2	36.5	0.57
SM825-16BU	CG5-79	9.6	25.8	37.4	0.70
SM881-4BU	CM849-1	9.5	24.0	39.7	0.52
SM937-3BU	MCol 72	9.4	22.8	41.1	0.61
SM938-2BU	MCol 1468	9.3	25.6	36.3	0.66
SM879-7BU	CM681-2	8.8	25.7	34.4	0.64
SM795-5BU	MCol 1505	8.7	23.4	37.3	0.56
SM978-1BU	CM2177-2	8.6	27.0	32.8	0.64
SM816-2BU	CM1533-19	8.3	22.8	36.2	0.60
SM952-2BU	CM342-170	8.2	22.4	36.7	0.55
SM795-1BU	MCol 1505	8.1	22.2	36.7	0.49
SM796-2BU	MCol 1823	7.8	22.4	34.8	0.55
SM873-4BU	MTai 1	7.6	20.1	37.9	0.48
SM955-6BU	CM681-2	7.5	19.8	37.9	0.75
SM879-1BU	CM681-2	7.3	21.4	34.1	0.62
SM814-2BU	CM1223-11	7.1	19.2	36.8	0.48
OMR30-41-1BU	Rayong 3	6.4	19.4	33.2	0.56

From the multilocation trials conducted in 1991, two promising clones were selected, i.e. SM881-5UB and SM566-8UJ **(Table 2).** Clone SM881-5UB is characterized by high root yield, high starch content (39.0%) and tolerance to mites. Clone SM566-8UJ is characterized by high root yield, high starch consent (37.4%) and greater suitability for intercropping **(Table 3).** The introduced clone Rayong 60 will need several more years of testing, especially under adverse conditions, like in Tulungagung and Kediri.

Table 2. The fresh root yield (t/ha) of promising cassava clones grown at three locations in East Java, 1992.

Clones	Malang	Tulungagung	Kediri
SM881-5BU	52.1	29.3	26.4
SM881-4BU	35.7	32.9	13.9
CM4049-2 (Malang 1)	57.0	27.9	15.9
SM881-3BU	54.4	19.2	15.8
Adira 4	44.0	18.5	20.9
Rayong 60	47.3	18.0	12.3
CM4031-10 (Malang 2)	53.4	15.5	12.4
SM566-8UJ	61.1	16.8	12.5
SM969-1BU	52.6	16.4	11.9
CMR30-110-9UJ	47.0	12.4	17.1
SM937-3BU	38.1	14.2	11.8
OMR28-47-10	47.0	18.1	10.1
SM477-2BU	56.1	-	-
Local (Faroka)	60.4	19.9	10.9
Local (Vandemir)	-	-	20.7
Local (Mentega)	-	16.1	-

A Replicated Yield Trial conducted at Umas Jaya in Lampung in 1992 identified clones with good dry root yields, RDCM and HI, as shown in **Table 4.** From this trial nine clones were selected, which will be tested in further trials.

Table 3. Land Equivalent Ratio (LER) of some cassava intercropping systems.

Intercropping combinations	Land Equivalent Ratio
Rayong 60 + peanut	1.12
CM4049-2 + peanut	1.17
SM566-8 + peanut	1.76
Local (Vandemir) + peanut	1.07
Adira 4 + peanut	1.39
Rayong 60 + corn	0.79
CM4049-2 + corn	1.86
SM566-8 + corn	1.75
Local (Vandemir) + corn	1.44
Adira 4 + corn	1.39
Rayong 60 + rice	0.64
CM4049-2 + rice	0.79
SM566-8 + rice	0.75
Local (Vandemir) + rice	0.72
Adira 4 + rice	0.98

Table 4. Results of a Replicated Yield Trial conducted at Umas Jaya in Lampung, Indonesia in 1991/92.

Clones	Parents	Dry root yield (t/ha)	Fresh root yield (t/ha)	Root DM content (%)	Harvest index
SM566-8	MBra 35	17.7	50.2	35.2	0.65
Bogor 6-3 (UJ-3)		15.9	45.4	35.0	0.50
OMR30-22-5	CMR25-34-159	15.3	41.0	37.3	0.50
SM554-3	CM681-2	15.1	41.9	36.0	0.50
CMR30-35-7	OMR23-29-15	15.1	41.8	36.0	0.49
CM4031-10 (UJ-2, Malang 2)		14.9	39.4	38.2	0.44
Adira 4	BORIF 528	14.8	39.4	37.7	0.41
OMR28-47-10	Rayong 60	14.7	40.5	36.2	0.48
CM4049-2 (UJ-1, Malang 1)		14.5	38.8	37.4	0.44
Rayong 60		14.2	35.9	39.5	0.42
CMR30-56-1	CMR23-17-251 x Rayong 90	14.1	37.3	37.8	0.48
CMR30-111-2	CMR25-82-88 x CMR25-32-502 Q	13.7	36.6	37.5	0.47
CMR30-110-9	CMR25-82-88 x CMC76	13.2	34.9	37.7	0.41
OMR30-20-5	CMR25-33-157Q	12.4	33.9	36.5	0.46
Rayong 3	MMex 55 x MVen 307	11.6	30.3	38.2	0.52
OMR30-20-3	CMR25-33-157Q	11.3	29.4	38.3	0.42
OMR30-35-5	CMR23-29-15	11.2	29.5	38.1	0.41
OMR30-110-1	CMR25-82-88 x CMC76	10.4	29.8	35.0	0.43
Kretek (Local)		9.4	28.3	33.1	0.37

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CASSAVA TECHNOLOGY TRANSFER IN INDONESIA

Ahmad Dimyati [1)]

ABSTRACT

Economically and politically, cassava is considered less important than rice, soybean and maize. Government's investment in the infrastructure and institutions for cassava extension and technology transfer is far less than those for the three major food crops. The infrastructure for varietal dissemination is relatively better than that for other components of technology. Due to the lack of such infrastructure and institutions, non-conventional ways of technology transfer take place and play a major role. The role of private companies in delivering planting material of newly released varieties is quite significant. The same role for transferring cassava flour processing technology has not happened due to socio-economic barriers. Despite the obligatory role of the Directorate General of Food Crop Agriculture to verify and disseminate the production technology, farmers can get the benefit of accessing directly to the source of technology by participating in the large-scale on-farm research, development research, and research-extension linkage activities. Corrections in the institutional set-up and mechanisms of technology transfer will be the appropriate way to enhance the effectiveness and efficiency of the technology transfer process. The establishment of knowledge centers or fora at the provincial or district levels, where farmers, researchers and extensionists work integratedly to formulate location-specific technologies, is viable and compatible with the current integration of Agricultural Information Centers into the Agency for Agricultural Research and Development.

INTRODUCTION

The nature of cassava technology transfer in Indonesia is determined by the role and function of cassava in the agricultural economy of the country, the characteristics of the technology itself, the nature of the farmers involved in cassava production and the institutional framework of the technology transfer mechanisms in this country. Each of the four factors, in solitary or combination, influences the effectiveness and efficiency of the cassava technology transfer process.

The technology transfer process is effective when the need for the technology developed through research had been properly diagnosed, the technology is properly used at the users' level and functions as expected. An efficient process of technology transfer is reflected in the short lag-period between the maturity stage of the technology and the onset of its adoption by users.

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Efforts to improve the effectiveness and efficiency of the technology transfer process should be directed towards the correction of the institutional framework, as well as legal regulations regarding the mechanisms of technology transfer. The position of the crop in the national economy is not likely to improve much with the current trend of cassava utilization.

IMPLICATIONS OF CASSAVA'S POSITION IN THE ECONOMY

The national agricultural production program and its supporting peripherals are based on the economic, social and political importance of various commodities. Cassava is one of the major food crops, but its cash value is much less than that of rice, and slightly less than those of maize and soybean **(Table 1).** In addition, the growth of production for this crop, in contrast with those of maize and soybean, is projected to be stagnant, assuming no significant changes in the current trend of utilization with the existing processing technology **(Table 2).**

Table 1. Production and estimated value of major food crops in Indonesia, 1991.

Commodity	Production ('000 t)	Value (US $ '000)	Import Value (US $'000)
Rice	44,688	5,563,010	53,064
Maize	6,256	580,800	45,951
Soybean	1,555	512,790	226,394
Peanut	652	289,470	55,131
Cassava	15,954	530'080	-
Sweet potato	2,039	106,420	-

Source : Recalculated from Central Bureau of Statistics, 1993; Indonesian Statistics, 1992.

Table 2. Projection of the production of various food crops in Indonesia, 1993–1998.

Commodity	Projected production ('000 tonnes)						Annual growth (%)
	1993	1994	1995	1996	1997	1998	
Rice	48,200	49,169	50,157	51,165	52,194	53,243	2.01
Maize	7,987	8,288	8,601	8,925	9,261	9,611	3.77
Soybean	1,792	1,849	1,907	1,968	2,030	2,095	3.17
Peanut	703	723	744	770	800	840	3.64
Mungbean	319	335	352	369	388	407	5.00
Cassava	16,356	16,384	16,412	16,439	16,467	16,495	0.17
Sweet potato	2,277	2,334	2,381	2,242	2,467	2,509	1.96

Source : National Bureau of Planning, 1993.

Consequently, cassava has been given less attention in the intensification scheme, which include extension, financial assistance, infrastructure construction, institutional development and research support. Most of the efforts have been aimed towards the production of rice, which contributed to the achievement of rice self-sufficiency since 1984.

Cassava roots are a perishable commodity, which require quick marketing . Any delay in the marketing of the fresh produce will cause a substantial decrease in product quality and price. Limited processing possibilities have induced a monopsonistic marketing of the commodity, leaving the farmers with a weakened bargaining position (Pakpahan *et al.*, 1992). Uncertainty of the market situation has been a disincentive for the farmers to adopt new technologies, which are supposed to increase productivity and improve quality. Many farmers do not apply any fertilizers, because in many cases the additional yield they obtain will not be sufficient to cover the additional expenses (Hartojo, 1992).

Moreover, farmers are not interested in improving chip quality since there is no bonus for better quality chips (Abdul Rachim *et al.*, 1993). Efforts to improve farmers' profit through high quality chips and better marketing opportunities were made via the introduction of cassava flour production technologies in cooperation with small-scale chip producers and medium- to large-scale flour producers in Lampung, West Java, Central Java, and East Java provinces (Adnyana, 1990; Abdul Rachim *et al.*, 1993).

Poor infrastructure and institutional framework for extension and delivery of planting material to the farmers were demonstrated by the fact that out of 391 farmers not adopting Adira 4, 388 farmers mentioned that the planting material was not available **(Table 3).** Poor infrastructure for the marketing of cassava products has also been claimed as the main cause for the lack of adoption of cassava flour processing technology (Adnyana *et al.*, 1993).

Table 3. Frequency of farmers mentioning a particular reason for not adopting Adira 4, according to a survey of 790 cassava growers in 1992.

Category of reasons	No. of farmers citing[1)]
Unfamiliar with the variety	25
Planting material is not available	388
Poor market price	49
Low productivity	46
Susceptibility to pests/diseases	0

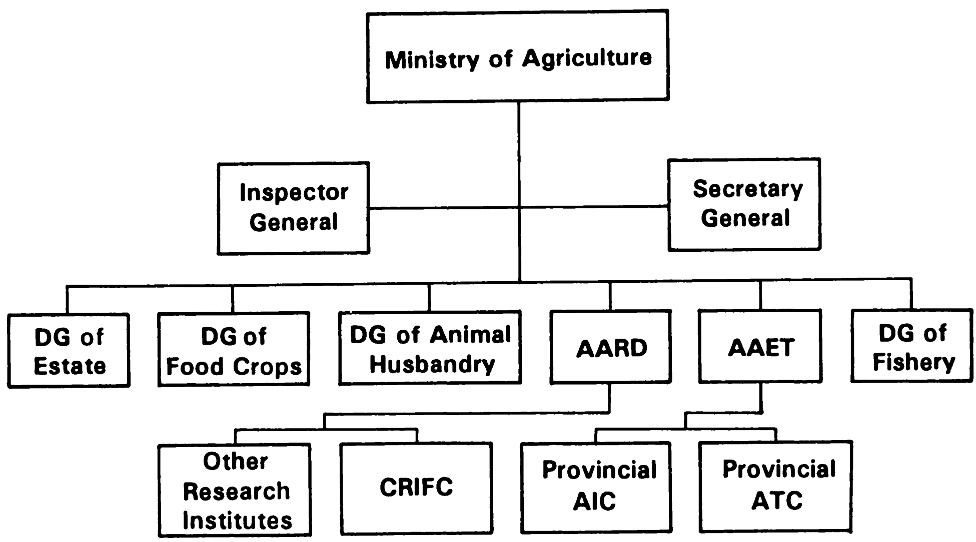
[1)] farmers may mention more than one reason

Source : CRIFC-CIAT, unpublished data.

The lack of government's investment in cassava infrastructure and institutional development despite the fact that the demand for cassava technology exists, has encouraged the participation of private companies in the endeavour. The role of Umas Jaya Farm in the dissemination of cassava variety Adira 4, quoted by Nugroho *et al.* (1992), is an example. In the case of cassava flour production, the government of Indonesia has tried to involve several private companies in a fostering system, but failed due to failure in reaching a concensus on the flour price at the farm level (Adnyana *et al.*, 1993).

INSTITUTIONAL FRAMEWORK

The organizational structure of the Ministry of Agriculture in Indonesia is diagrammatically described in **Figure 1.** Research and extension activities are carried out by separate organizations. All activities of technology generation and development are the responsibility of the Agency for Agricultural Research and Development (AARD), whereas extension activities are carried out by extension workers, who belong to provincial and district governments and whose program follows the guidelines of the various commodity-oriented Directorate Generals. Formally, all technology recommendations needed to be verified and cleared by the respective Directorate General before they were released to the users and became the material for extension activities.



AARD : Agency for Agricultural Research Development
AAET : Agency for Agriculture Education and Training
CRIFC : Central Research Institute for Food Crops
AIC : Agricultural Information Center
ATC : Agricultural Training Center

Figure 1. Simplified organogram of the Ministry of Agriculture of Indonesia.

The release of new varieties is decreed by the Minister of Agriculture upon recommendation from the Team for Varietal Evaluation and Release, an *ad hoc* team consisting of officials from AARD, Directorate Generals, and a number of senior researchers (breeders). The Team is one of the entities under the coordination of the National Seed Board, which is also an *ad hoc* organization responsible directly to the Minister of Agriculture. One of the prerequisites for the release of a new variety is sufficient supporting data from a series of multilocational trials in 15 environments (locations by seasons).

Materials for extension are developed by provincial Agricultural Information Centers (AIC), which used to be the provincial arms of the Agency for Agricultural Education and Training (AAET). The material is developed by extensionists based on the information from research and development institutions in the form of scientific journals, technical bulletins, seminar proceedings and other forms of publications. These extensionists are also often involved in seminars, field days, or in conducting on-farm research carried out by these research institutions. At the provincial level there are also Centers for Education and Training, which are the provincial arms of AAET and responsible for all kinds of training of personnel of the Ministry of Agriculture.

The separation of research and extension institutions, as well as the existing regulations pertaining to the mechanisms of technology transfer, have been considered as the main causes of the ineffectiveness and inefficiency of the transfer of technology process in Indonesia. Among the efforts made to alleviate these problems are the integration of the provincial AIC as the provincial arms of AARD. The actual name, mandate and function of these Centers are still being developed. The impact of this integration and development will be interesting to observe. Another effort is to organize a program, called Research-Extension Linkage (REL), carried out by AARD during the past three years in cooperation with the Provincial Representative of the Ministry of Agriculture, AIC, other agriculture-related offices in the province, and the provincial as well as district governments.

DISSEMINATION OF DIFFERENT TYPES OF TECHNOLOGY

Dissemination of Cassava Varieties

Compared to other components of technology, the adoption and impact of a newly released cassava variety is theoretically the easiest to measure. A clear-cut distinction between adoption and non-adoption of a certain cassava variety is possible. However, the lack of data on varietal adoption and distribution has made assessment as difficult as for other components. Data are only available at the district level. It will take a great deal of time and energy to gather data at the national level. In addition, a close review of the data indicates that they are neither very reliable nor consistent.

The mechanisms and the institutional framework needed for varietal dissemination are also relatively easy to implement. High quality planting material from breeders are distributed to Seed Production and Distribution Stations in major cassava-producing provinces, or to various major private companies. Provincial Seed Control and Certification Stations (SCCS) will supervise the production to assure good quality planting material. The officials from these SCCSs are periodically trained at one of the Research Institutes for Food Crops to be able to identify the newest food crop varieties, including those of cassava.

The planting material from these provincial Seed Stations are distributed to major cassava producing districts for further distribution to the subdistrict Extension Station, which will distribute it to the leading farmers (contact farmers in the extension activities).

Assuming this regular mechanism, a four to five year lag-period for the adoption of new varieties can be expected. Many cases of short-cuts may happen due to wide publicity given to varietal releases. In this respect, varietal dissemination has enjoyed a better treatment than most other technology components, since formal announcements of new releases are usually part of widely publicized ceremonies, such as the World Food Day or National Agriculture Day. Farmers may get the planting material from private companies, provincial Seed Stations, or even from Research Institutes.

The vegetative propagation of cassava and the medium storability of the planting material make the mechanism of varietal dissemination of this crop rather unique. Once the farmers grow their cassava, planting material for the following season is almost assured. They can even distribute further their planting material to their friends or neighbors with or without charge. This way of varietal dissemination is of significance, particularly in the later stages of dissemination.

A recent study on Adira 4 adoption in the provinces of Lampung, East Java, and Central Java, including a total of 790 cassava growers **(Table 4)**, indicates that out of 399 farmers adopting Adira 4, 33% of farmers obtained the first planting material from private companies, 24% from various government extension offices, 13% from cooperatives and 30% from friends and neighbors. The total number of stakes distributed through the four source categories are also shown in **Table 4**. The data demonstrate the importance of non-government agencies in disseminating new cassava varieties. The involvement of these different agencies are in most cases beyond the control of the government agencies or personnel for obvious reasons. However, the nature of vegetative propagation of cassava has made this mechanism possible, while it is not possible for seed propagated crops, especially those that are cross pollinating.

The conventional mechanisms are fully legal, but inefficient. The major objective is

Table 4. Source of planting material of cultivar Adira 4 adopted by farmers in Lampung and Java, according to a survey of 790 cassava growers in 1992.

Source of planting material	No. of farmers	%	No. of stakes	%
Government offices	95	23.8	259,830	13.0
Cooperatives	52	13.0	268,800	13.5
Private companies	131	32.8	725,350	36.3
Friends/neighbors	121	30.4	743,552	37.2
Total	399	100	1,997,532	100

to protect farmers from planting non-verified varieties, which may show desirable characteristics in one year or two, but may cause unexpected catastrophy in the years afterward. The non-conventional mechanisms are quite efficient but less protective, and may be considered illegal in some respects.

Figure 2 describes the diagrammatic flow of planting material of Adira 4, indicating the role of various sources of planting material.

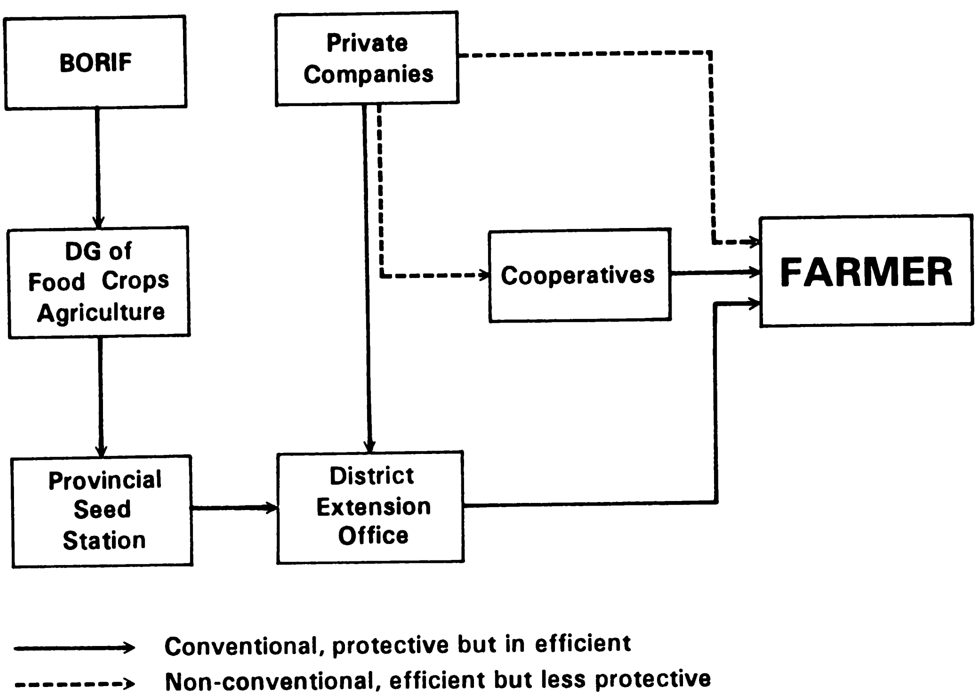


Figure 2. Diagrammatic flow of planting material of Adira 4.

Dissemination of Other Technology Components

For other components of technology, such as cultural practices, fertilizer application and post-harvest handling and processing, discrete and perfect adoption is not likely to happen. There is always partial adoption, such as application of one or two of all types of fertilizers recommended, lower than recommended rates of fertilizer, fewer frequency of weeding, incomplete drying of chips, coarser size of flour, and so on. In this sense it is more difficult to measure the adoption of such components of technology. Recent surveys indicate that farmers residing close to processing industries do grow improved cultivars and apply adequate rates of complete (N, P and K) fertilizers. However, the rate varied according to farmers' financial abilities (CRIFC-CIAT unpublished data).

Distinct characteristics of these components of technology require different mechanisms of technology transfer and a different institutional framework. CRIFC has pioneered the application of the development research scheme to enhance the process of technology transfer from research entities to the end-users. Development research is the final stage of technology development, wherein a particular mature technology in solitary or in packaged fashion is evaluated under real farmers' circumstances in a commercial-scale trial unit. The performance of the technology, as well as the required supporting systems, which include government policy, production input supply, marketing channels, and farmers' participation, are also assessed. The respective institutions and personnel, related to the technology being evaluated, are involved with planning, execution, and evaluation of research activities (Manwan and Adnyana, 1992). By so doing, the lag-period for technology adoption is shortened and hence the efficiency of technology transfer is increased.

This scheme was used for enhancing the adoption of cassava flour production in Lampung and Java (Adnyana, 1990; Abdul Rachim *et al.*, 1993). The technology for flour production is adapted from the technology used in Brazil, and was a result of a comparative study conducted in 1990. Some modifications in chipping and grinding methods were made by Indonesian researchers. Prototypes of manual and motorized equipment for making chips were developed following the models used in Brazil.

The following procedures were followed in conducting development research for cassava flour production (Adnyana, 1990; Abdul Rachim *et al.*, 1992):

1. **Preparatory steps consisting of**:
   - identification of potential problems and opportunities for cassava flour production, using the rapid rural appraisal procedure
   - introduction of equipment prototypes to small workshops, so they can make the equipment themselves

- introduction, demonstration and training of small-scale processors in using the appropriate equipment for making cassava flour
- introduction and training of leading women in using cassava flour for preparing some food items for their own or for commercial use
- formulation of models for the cassava flour industry in the area with participation of various parties concerned.

2. **Execution of research:**
   - farmers and small-scale processors were provided with the necessary equipment and capital to initiate the processing business
   - various schemes were followed as agreed during the preparatory steps
   - performances of the models in general and of the technology in particular were assessed, including technical performances, social acceptance and economic feasibility.
3. **Assessement of the adoption and impact:**
   This is conducted currently, by identifying the performance of the models as well as the technology after the financial assistance is withdrawn.

Similar procedures of development research have also been used for evaluation of the performance of agronomic technologies of cassava under marginal soil conditions in southern Malang and Ponorogo districts of East Java (Hartojo, 1992). A large number of farmers were involved in the scheme, covering an area of 200 and 60 ha, respectively. Results show that farmers adopt the new production technology quite aggressively, provided they have access to the information, can afford the cost and understand the benefits.

CASSAVA FARMERS' CHARACTERISTICS

It is quite natural that commercial farmers are more progressive and more active in seeking and adopting new technologies. Evidence shows that subsistence farmers do not care or know about new superior clones. They do not apply fertilizer either. This behavior, however, does not mean that they are not willing to adopt the improved technology, but in many instances that they are uninformed, have little technical assistance and are not capable of affording the cost of the technology. In other instances, they do not have sufficient acces to the source of knowledge or technology (Dimyati *et al.*, 1992).

In this respect, it is quite easily understood that the distribution of superior clones is limited to suburban areas, which are close to processing industries and consumption centers. It is the easy acces to transportation infrastructure linking the farmers and farming activities with input supply as well as marketing channels that induces commercialization of cassava farming.

From the Adira 4 adoption study, preliminary results show that the level of education of most cassava farmers is between 1 and 6 years of elementary school. However, higher levels of education do not improve the ability to adopt new superior varieties **(Table 5)**, as there was no positive correlation between educational level and the adoption of Adira 4.

The area of land devoted to cassava is relatively small compared to the total land owned by most cassava farmers **(Table 5)**. This indicates that cassava is considered as less important by most farmers. Farmers also tend to devote a smaller proportion of their total land to cassava when the total area of land owned increases. The data also shows that there is no correlation between the total land area owned by farmers, or the portion of land devoted to cassava, with the ability of farmers to adopt the new variety.

In general, farmers' adoption of new varieties, as one component of the production

Table 5. Various characteristics of farmers in relation to the adoption of Adira 4, according to a survey of 790 cassava growers in 1992.

Farmers' characteristics and category	Adopter	%	Non-adopter	%	Total
a. Educational level					
None	26	6.5	19	4.9	45
1-6 years	294	73.3	323	82.6	617
7-9 years	39	9.8	27	6.9	66
> 9 years	40	10.0	22	5.6	62
b. Lenght of farming experience					
1-10 years	139	34.8	150	38.4	289
11-20 years	152	38.1	156	39.9	308
21-30 years	89	22.3	57	14.6	146
> 30 years	19	4.8	28	7.2	47
c. Land area owned					
< 0.75 ha	77	19.3	121	30.9	198
0.76-1.5 ha	127	31.8	169	43.2	296
> 1.5 ha	195	48.9	101	25.8	296
d. Land area devoted to cassava					
< 0.75 ha	161	40.4	190	48.3	351
0.76-1.5 ha	159	37.3	143	36.4	302
> 1.5 ha	89	22.3	60	15.3	149

Source : CRIFC-CIAT, unpublished data.

technology, is independent of most farmers characteristics, which may have a significant meaning economically. This seems to indicate that commercial orientation of cassava farmers in the surveyed areas has reached all economic or prosperity levels. This may have happened because there are a lot of processing industries in the surveyed areas.

REORIENTATION OF FUTURE STRATEGIES

In the foreseeable future, there will be no significant progress in the economic and political importance of cassava in Indonesia. The predominant perception of the people and policy makers about cassava has created mental barriers, which affect priority and budgetary decisions. Better processing and utilization technologies will require some additional time to create any significant changes in the trend of cassava utilization, which should open the possibility of improving the market demand. Without this, the cassava economy in Indonesia will not further develop.

In the Second Long-Term Development Plan emphasis is given to economic development in conjunction with human resource development. There is a concerted effort towards a more liberalized economy and more decentralized development programs. In the agricultural sector this is implemented among others in the form of farmers' freedom to choose any crop they wish to grow without much intervention from the government, as set forth in the Law No. 12/1992 regarding Crop Cultivation Systems. Consequently, the farmers will grow whatever crop that gives them higher income, with the least risk and at the most affordable production cost. Among the logical consequences of these changes, is the process of consolidation of crops in those areas where they have the greatest comparative advantages and give farmers highest profits and income. This may imply that cassava production activities may take place in very specialized locations with highly specialized farmers having good skills and knowledge regarding the crop. However, in the more marginal areas with fewer crop opportunities, cassava will still be grown both for farm household use and as a commercial cash crop. There will be no more instructions to substitute cassava with other crops with higher priorities in the vision of the government.

The farmers are expected to be more progressive and more aggressive in seeking new knowledge and technology. It has been realized that in many instances the current Training and Visit (T&V) system of extension is not suitable (Dimyati *et al.*, 1992). Therefore, new methods and approaches should be utilized to anticipate and even to encourage the growth of these future farmers' characteristics. The new strategy should acknowledge and utilize the dynamic nature of farmers' values, knowledge, aspiration and skills, as well as acknowledge the limitations and handicaps faced by researchers and extension workers in delivering their knowledge and skills to the farmers.

One of the ways to implement this strategy is to develop knowledge centers throughout major production areas, where researchers, extension workers and leading farmers can exchange ideas and knowledge. The combined knowledge is formulated into location-specific technologies for cassava production. Such knowledge centers are now in operation in the Netherlands (Dr. Abraham Huijsman, personal communication). This new strategy will be compatible with the new institutional framework, in which the former provincial Agricultural Information Centers are under the umbrella of the Agency for Agricultural Research and Development (AARD).

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RECENT PROGRESS IN CASSAVA AGRONOMY RESEARCH IN CHINA

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ABSTRACT

In recent years, cassava agronomy research in China has emphasized soil fertility maintenance, erosion control, planting methods and date of planting and harvesting. The research was conducted in cooperation between the Guangxi Subtropical Crops Research Institute, the South China Academy of Tropical Crops, and the Upland Crops Research Institute with CIAT.

Results of three long-term fertility trials indicate that fertilizer application markedly increased cassava root yields. But different varieties showed a different response to fertilizers. SC205 was more responsive to fertilizer application than SC201 or SC124; high rates of fertilizers resulted in high yields of SC205, but not of SC201 or SC124. The experiments also showed that during four cropping cycles of cassava in southern China, N was the most important nutrient for increasing cassava root yields, but that K and in some cases P also became increasingly important. Application of farm yard manure or burned soil, in addition to medium levels of chemical fertilizers, had no significant effect on increasing cassava root yields.

Experiments on soil erosion control conducted in Hainan and Guangxi showed that contour ridging, intercropping with peanut, or barrier strips of *Brachiaria* pasture were the most effective practices for reducing soil erosion when planting cassava. Intercropping of cassava with peanut or cassava with seed watermelon increased income more than 65-200% compared with cassava monoculture. Cassava grown with *Stylosanthes guianensis* barriers reduced soil erosion 14-27%, while increasing income 23-43%.

Among several methods of planting cassava, vertical planting resulted in more rapid sprouting than horizontal or inclined planting, especially during periods of drought, but root yields were not significantly different. Among planting on the flat, or on single-row or double-row ridges, there was not much difference in germination and root yield.

Research to determine the optimum time of planting and harvest of cassava, conducted at SCATC, showed that when cassava was harvested at 8 months after planting, highest yields were obtained when cassava was planted during the spring (Feb- May); however, when cassava was harvested at 12 months, time of planting had no consistent effect on yield.

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INTRODUCTION

In recent years, cassava agronomy research in China has developed due to greater support from the government. In some provinces, agronomy research has been conducted to establish the best cultural practices for the crop. For instance, in Guangxi province, which is a major cassava producer (cassava area and production comprise nearly 50% and 40% of that in China, respectively), the government appropriated 3.5 million yuan (RMB) for developing new varieties of cassava in 1991. This is unprecedented. Due to the support of the Guangxi government, great achievements have been made in Guangxi in developing new varieties of cassava, using advanced cultivation techniques and promoting the production of cassava. The area planted to new promising varieties of cassava has markedly increased. In 1993 the area grown to new cassava varieties was estimated at about 30,000 ha. Meanwhile, some better cultivation techniques, such as fertilizer application, intercropping and interplanting, and better field management etc. have also been gradually accepted by farmers. This has resulted in an increase in cassava root yields year after year **(Table 1).**

In other cassava growing areas, research on improving cassava cultivation techniques has also continued. Since 1990, cassava agronomy research in China has emphasized soil fertility maintainance, erosion control, planting methods and time of planting and harvesting.

RESEARCH RESULTS

I. Long-term Fertilizer Application

It has been shown that root yields decrease when cassava is planted year after year without fertilizer application. Though farmers also realize this, they seldom understand the exact reason why fertilizer application can keep yields stable or increase yields and they maintain soil fertility mainly by planting cassava intercropped or by crop rotation or fallowing.

To determine the effect of fertilizer application on cassava root yield, a long-term NPK trial has been conducted at three locations in China, i.e. in Guangdong, in Guangxi and in Hainan, which are the principal cassava growing areas.

Table 2 shows the results of the long-term NPK trial conducted at the Upland Crops Research Institute (UCRI) in Guangzhou from 1990 to 1992. The data indicate that fertilizer application had a significant effect on increasing cassava root yields. The longer the time of continuous cropping, the more significant the fertilizer response. However, the sensitivity of the two varieties, SC201 and SC205, to N, P and K were found to be very different. For SC201, there was always a significant response to N, but seldom a significant response to P or K; but for SC205 there was generally a good response to all three nutrients. This means that SC205 requires a higher level of soil

Table 1. Cassava harvested area ('000 ha), production ('000 t) and yield (t/ha) in Guangxi, China in 1990–1992.

	1990			1991			1992		
	area	production	yield	area	production	yield	area	production	yield
Nanning City	13.24	159.8	12.07	13.32	158.8	11.92	12.39	167.2	13.49
Liuzhou City	7.53	46.2	6.14	6.05	37.0	6.12	4.94	36.9	7.47
Guilin City	3.05	22.2	7.28	3.24	25.5	7.87	3.10	25.5	8.23
Wuzhou City	3.45	24.6	7.13	3.94	26.8	6.80	3.76	24.8	6.61
Beihai City	-	-	-	6.74	139.7	20.73	7.73	209.7	27.14
Nanning District	35.33	276.6	7.83	34.13	240.3	7.04	31.85	242.2	7.60
Liuzhou District	29.26	126.6	4.34	28.30	169.4	5.99	26.65	146.7	5.50
Guilin District	7.20	40.7	5.66	8.06	47.2	5.85	7.56	58.6	7.75
Wuzhou District	33.44	345.4	10.33	34.21	354.8	10.37	34.49	389.1	11.28
Yulin District	37.78	403.7	10.68	38.81	419.1	10.08	37.07	444.6	12.00
Baise District	9.15	74.0	8.09	11.07	94.5	8.54	11.21	100.6	8.98
Hechi District	18.27	136.5	7.47	18.33	123.0	6.71	17.03	106.9	6.28
Qinzhou District	15.68	151.8	9.68	15.33	154.0	10.04	15.56	167.9	10.79
Guangxi	213.28	1808.1	8.48	221.53	1991.1	8.99	213.34	2120.7	9.94

Source : Guangxi Statistic Bureau.

fertility than SC201. In other words, under the conditions of exhausted or low-fertility soils or poor management, the productivity of SC201 is higher than that of SC205. We can see this from **Table 2**. In plots which were unfertilized or in which one or two nutrients were not applied or were applied at low levels, the yield of SC201 was higher than the yield of SC205. But in plots with high levels of applied nutrients the yield of SC205 was generally higher than of SC201.

Similar results were also obtained in Hainan island. **Table 3** shows that with the application of 50 kg N/ha, the yield of SC124 increased 46%. But the application of high levels of N may result in an excessive stimulation of top growth and a decrease in cassava yield. The application of P and K had no significant effect on the yield of SC124. Compared with SC124, it seems that SC205 is more sensitive to fertilizers and the application of high levels of N, P and K increased its yield very significantly. However, the application of burned soil, in addition to medium levels of chemical fertilizers, had no significant effect on cassava yields. That is probably due to the low nutrient content of burned soil.

Table 2. Effect of different levels of applied N, P and K on cassava root yield of two cultivars in UCRI, Guangzhou, Guangdong, from 1990 to 1992.

	Root yield (t/ha)					
	1990		1991		1992	
	SC201	SC205	SC201	SC205	SC201	SC205
0-0-0	12.22	5.98	11.01	7.26	7.94	3.31
0-50-100	12.96	10.25	14.01	13.23	13.17	8.38
50-50-100	18.63	14.98	18.02	16.71	20.41	18.33
100-50-100	18.59	17.02	18.26	19.24	19.17	18.48
200-50-100	17.84	17.39	18.98	20.38	22.85	19.05
100-0-100	19.21	11.73	18.18	13.50	16.44	9.94
100-25-100	20.75	15.75	18.63	20.94	20.69	16..78
100-100-100	25.44	18.74	19.55	22.90	22.50	21.99
100-50-0	19.20	14.96	16.46	13.88	12.37	11.26
100-50-50	19.14	16.48	17.84	20.32	19.71	16.41
100-50-200	19.56	15.29	19.39	20.29	23.44	18.54
200-100-200	25.15	19.96	21.48	26.01	20.22	25.87

Table 3. Effect of different levels of applied N, P and K on cassava yield in two cultivars in SCATC, Hainan, in 1992 (first year).

$N-P_2O_5-K_2O$ (kg/ha)	Cassava root yield (t/ha)	
	SC124	SC205
0-0-0	11.25 e	12.30 e
0-50-100	15.30 de	16.80 de
50-50-100	22.35 ab	19.65 bcd
100-50-100	20.85 abc	18.58 bcd
200-50-100	16.65 cd	23.23 ab
100-0-100	19.13 abcd	19.88 bcd
100-25-100	19.65 abcd	29.95 ab
100-100-100	20.68 abc	23.55 ab
100-50-0	16.88 cd	20.53 abcd
100-50-50	18.75 abcd	18.15 cd
100-50-200	22.78 a	21.61 abc
200-100-200	17.90 bcd	25.13 a
50-25-50	16.43 cd	19.50 bcd
50-25-50+15 t/ha burned soil	16.43 cd	17.90 cd
50-25-50+30 t/ha burned soil	18.50 abcd	17.23 cd
50-25-50+60 t/ha burned soil	18.05 abcd	18.05 cd
LSD (0.05)	4.76	4.80

Figure 1 shows the response to the application of N, P and K in GSCRI from 1989 to 1992. There was a significant response to N throughout the period and only a significant response to P in case of SC201 in 1992 (4th year). There was a significant response to K throughout the period except the third year. The results indicate that the sensitivity of the two varieties to fertilizer was again very different. High levels of fertilizer application increased the root yields of SC205 markedly, while the yields of SC201 tended to decrease. This is because high nutrient applications (especially N) stimulated excessive top growth of SC201 (or SC124), and reduced the harvest index, resulting in a decline of root production **(Figure 2).** High levels of N application produced 85% more foliage, while root yields were reduced 11%. According to this experiment, the recommendation for N application to cassava in Guangxi should be 50-100 kg N/ha. The trial also showed that the soil fertility requirement of SC205 is much higher than that of SC201. In fact, in Guangxi province, SC205 is planted almost entirely in the south and coastal areas where soil fertility is much higher than in the north and the middle part of the province where SC201 is concentrated. Thus, the distribution of cassava varieties is quite reasonable.

Applications of 5 or 10 t/ha of farm yard manure, in addition to medium levels of chemical fertilizers, had no significant effect on increasing cassava root yields. This may be because of the way the manure was spread, which may have resulted in an inefficient uptake of nutrients from the manure by cassava, while most may have washed away during heavy rains.

We may conclude that N, P and K application had a significant effect on increasing cassava root yield. However, there are large differences among different areas. In Guangzhou, cassava root yields increased from 7 to 22 t/ha (average data of 1989-1992) when 200 N, 100 P_2O_5 and 200 kg K_2O/ha were applied. With the same levels of N, P and K application, cassava yields increased from 12 to 25 t/ha in SCATC in Hainan. In Nanning of Guangxi, yields increased from 16 to 22 t/ha (average data of two varieties from 1989 to 1992) when 100 N, 50 P_2O_5 and 50 kg K_2O/ha were applied. The highest economic returns from fertilizer application may be a little lower than that corresponding to highest yield. Also, while K is the nutrient removed in largest quantities with the harvest of cassava roots (Cock, 1985), it is not the principal nutrient required for increasing cassava yields in the south of China, at least not before the 5th consecutive planting; N application is more important compared with that of K and P.

II. Cultural Practices for Erosion Control

Three trials to measure soil losses due to erosion were conducted at SCATC and at GSCRI.

Among the tillage practices investigated in SCATC, contour ridging produced high yields and was very effective in reducing soil erosion **(Table 4).** *Brachiaria* contour barriers significantly reduced soil loss and had only a small effect on yield. Planting without ridges and without fertilizer application usually resulted in the highest levels of erosion. Fertilizer application increased cassava yields significantly, while it also contributed to reduced erosion (12%). The treatments of high plant population and vertical planting had no significant effect on soil erosion, but slightly decreased yields. Peanut intercropping not only produced a low level of soil erosion, but it also increased the total net income.

Table 5 shows the effect of various methods of land preparation on dry soil loss due to erosion and on fresh root yields of cassava planted on 25% slope in SCATC (average data for 1989-1991). Contour ridging after land preparation of plowing and discing was again the most effective method for increasing cassava yields and reducing erosion. The treatment of one plowing without ridging reduced soil losses significantly, because the rough land surface increased water infiltration; this reduced level of tillage had only a small effect on yield.

Table 6 shows the results of a similar experiment conducted on 12% slope at GSCRI in Guangxi province from 1990 to 1992. Contour ridging and peanut intercropping significantly reduced soil losses (65% and 60%, respectively) without seriously affecting cassava yields. The treatment of high plant population also significantly reduced soil losses (43%). **Figure 3** shows the result of the experiment conducted at GSCRI in 1992. Contour ridging and peanut intercropping reduced soil losses by 78% and 84%, respectively, while cassava yields were not affected. In the experiment in Nanning, fertilizer application (225 kg/ha of 10:10:10 or 15:15:15 compound fertilizer) had no significant effect on increasing cassava yields or on reducing soil losses. The main reason may be the relatively high level of soil fertility in the plot, which had recently been opened up from bamboo vegetation. The highly branching variety of CM513-1 had a plant height of only 1.6 m; it sprouted about one month later than SC201 and had a very slow initial growth, resulting in a late canopy closure and increased erosion.

The conclusion is that contour ridging, peanut intercropping, and high plant populations were quite effective in reducing erosion without seriously affecting cassava yields. Planting without fertilization and without ridging usually caused highest levels of erosion. Without fertilizers cassava grows slowly, resulting in late canopy closure, precisely during the period of heavy rains in southern China; this causes high surface runoff and washing away of soil. The amount of soil eroded during the first four months accounts for the largest proportion of total soil loss. For instance, the results of the experiment conducted in GSCRI shows that the amount of soil eroded during the first four months was about 94% of the total, while after August only an additional 6% of the soil was lost by erosion. So it is very important to prevent soil erosion during the initial period of cassava growth. The recommendation is that cassava should be planted on contour ridges, or intercropped with legumes. The treatment of no-ridging after plowing and discing usually caused high levels of soil erosion, especially in Hainan island where erosion is more serious than in Guangdong and Guangxi due to the effect of storms and typhoons. In 1991, the highest soil loss (250 t/ha) was obtained in Hainan when cassava was planted on 25% slope with intensive land preparation of twice plowing and discing but without ridging.

Cassava intercropping with peanut, maize, or melon (for seed harvest) may also be effective practices for reducing erosion while increasing income and land use efficiency **(Table 7).** Cassava intercropping with legumes may also contribute to maintaining soil fertility (Howeler, 1992), while the crop residues could be used as a mulch to prevent soil erosion. Intercropping cassava with peanut or other legumes, or with maize, requires only small additional costs while increasing income considerably. This would be a good recommendation for farmers in cassava growing areas of China.

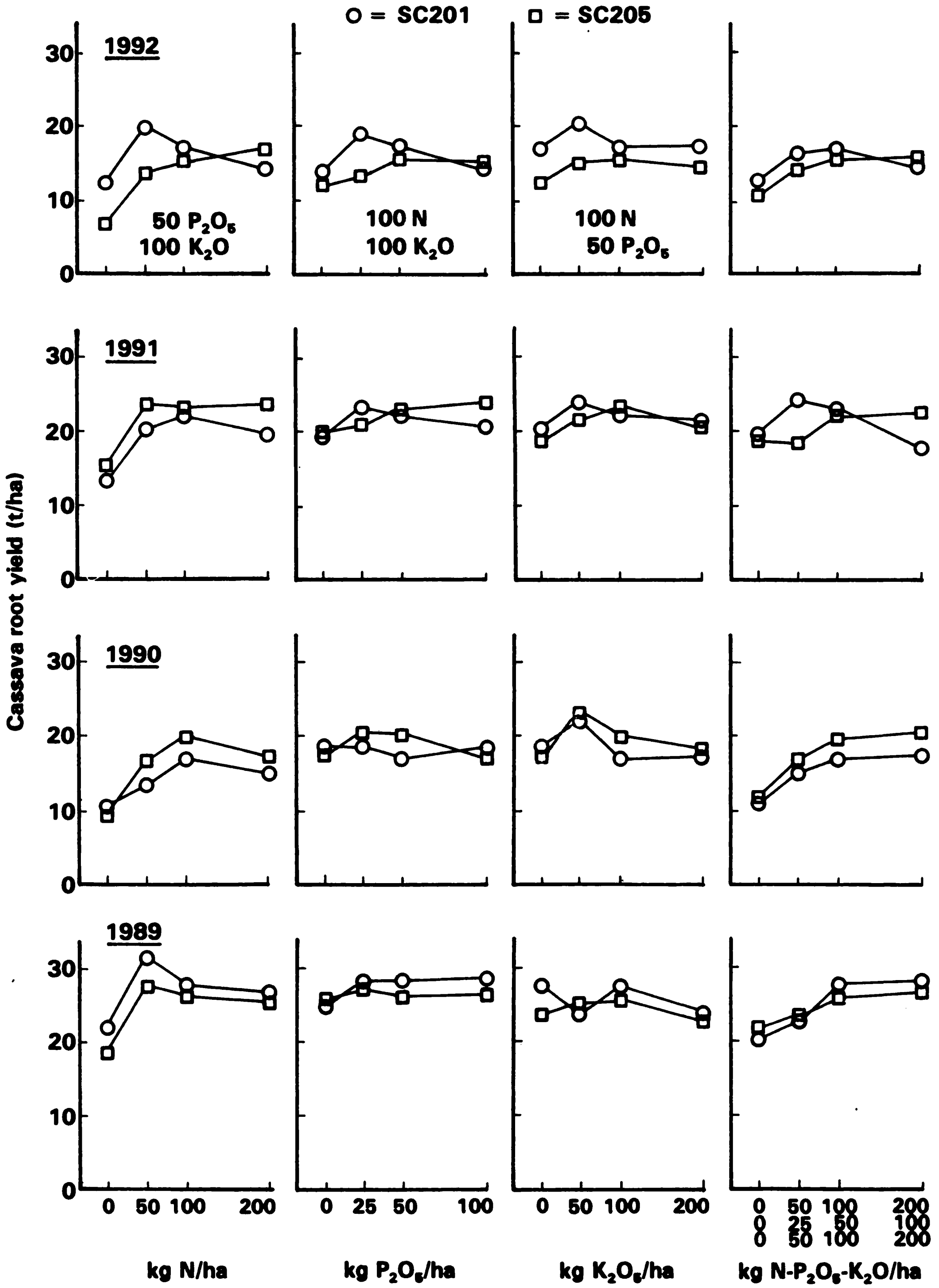

Figure 1. Effect of N, P and K application on the cassava yields of SC201 and SC205 in Nanning, Guangxi, China, 1989-1992.

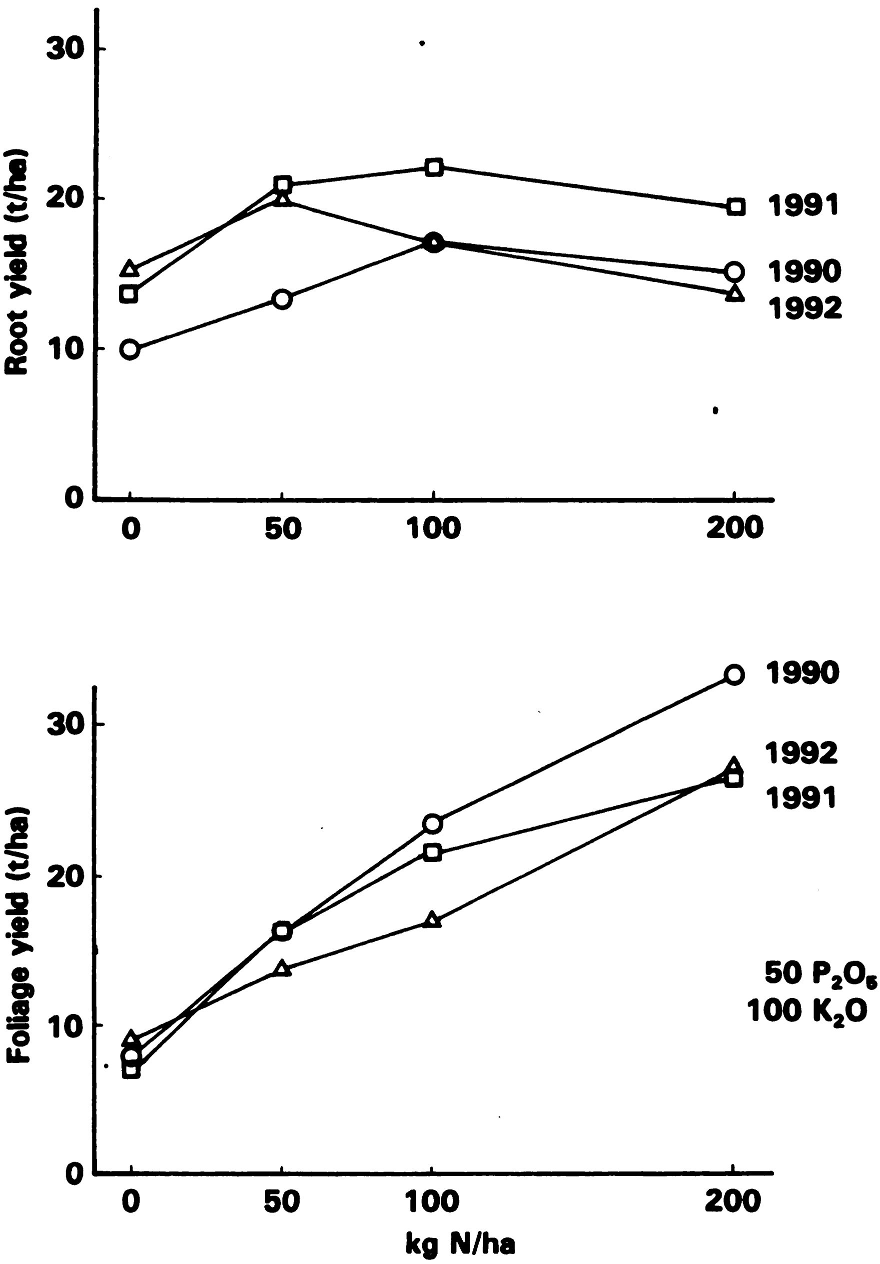

Figure 2. Effect of N application on cassava root and foliage yield for SC201 in GSCRI in Nanning, Guangxi, China in 1990, 1991 and 1992.

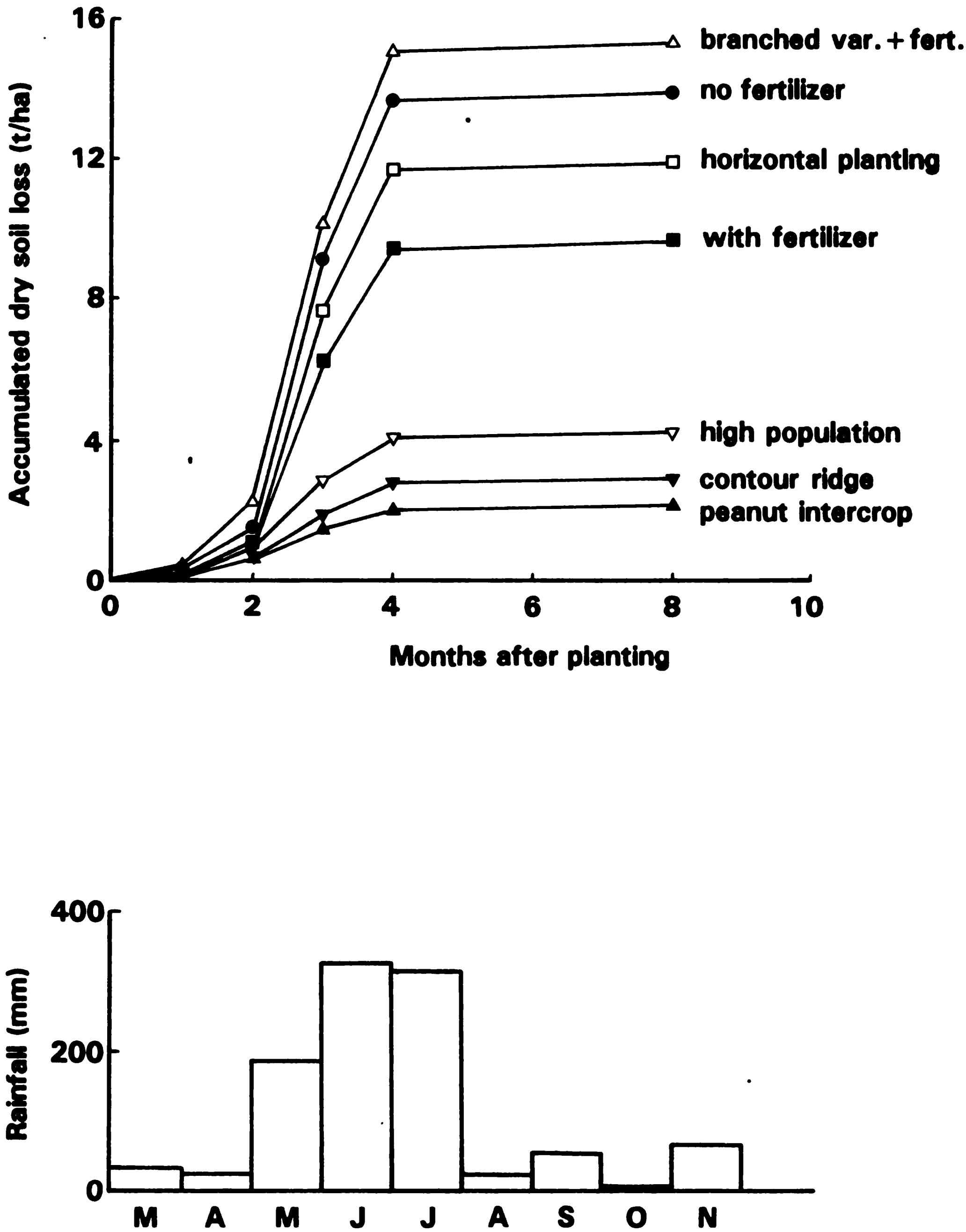

Figure 3. Effect of various agronomic practices on dry soil losses due to erosion in cassava planted on 12% slope in Nanning, Guangxi, China in 1992.

Table 4. Effect of various cultural practices on dry soil loss due to erosion and on fresh root yield of cassava planted on 15% slope in SCATC, Hainan, China (Average data of 2 years, 1990–1991).

Treatments	Dry soil loss (t/ha)	Root yield (t/ha)
no ridge, no fertilizers, horizontal planting, 1.0x0.8 m	160.0	19.54 c
no ridge, with fertilizers, horizontal planting, 1.0x0.8 m	141.0	27.52 a
no ridge, with fertilizers, horizontal planting, 0.8x0.8 m	143.4	26.92 ab
no ridge, with fertilizers, vertical planting, 0.8x0.8 m	144.9	25.74 ab
contour ridge, with fertilizers, horizontal planting, 0.8x0.8 m	99.6	26.12 ab
planting holes, with fertilizers, horizontal planting, 0.8x0.8 m	125.9	27.03 ab
no ridge, with fertilizers, horizontal planting, 9 rows cassava + 1 row *Brachiaria*	99.9	24.72 ab
no ridge, with fertilizers, horizontal planting, 9 rows cassava + 1 row *Stylosanthes*	119.9	23.99 b
no ridge, with fertilizers, horizontal planting, intercropped with peanut	120.0	25.32 ab
F-test	NS	**

Mean separation: DMRT (0.05).

Table 5. Effect of various methods of land preparation on dry soil loss due to erosion and on fresh root yield of cassava planted on 25% slope in SCATC, Hainan, China (Average of 3 years, 1989–1991)

Treatments	Dry soil loss (t/ha)	Root yield (t/ha)
2 oxen plowing + 2 discing + contour ridging	124.90 b	26.02 a
2 oxen plowing + 2 discing + no ridging	198.49 a	24.58 a
1 plowing, no ridging	121.12 b	23.62 a
4 m wide plowed strip alternated with 1 m strip without preparation	199.97 a	24.10 a
2 m wide plowed strip alternated with 0.5 m strip without preparation	136.41 b	22.87 a
Preparation of planting holes with hoe	115.39 b	24.59 a
No land preparation	116.35 b	22.77 a
LSD (0.05)	26.54	3.33

Table 6. Effect of cultural practices on canopy formation at 3 months, and on root yield and dry soil losses due to erosion at 9 months when grown on about 12% slope in GSCRI, Nanning, Guangxi, China. Data are average for 1990, 1991 and 1992.

Treatments	Canopy cover (%)	Root yield (t/ha)	Soil loss (t/ha)
Plowing + discing, no ridge, no fertilizer	63	16.7	16.2 a
Plowing + discing, no ridge, with ferilizer	66	15.0	14.6 ab
Plowing + discing, contour ridging, with fertilizer	76	16.1	5.7 c
Plowing + discing, no ridge, with fert., high population	83	16.1	9.3 bc
Plowing + discing, no ridge, with fert., horizontal planting	74	16.9	13.6 ab
Plowing + discing, no ridge, with fert., branching variety	45	14.1	17.3 a
Plowing + discing, no ridge, with fert. peanut intercrop	77	16.7	6.5 c
LSD (0.05)			6.04

Intercropping cassava with forage grasses or legumes could also reduce soil erosion while increasing economic returns. **Table 8** shows that cassava intercropped with *Brachiaria brizantha* increased gross income by 27%. Similarly, intercropping with *Stylosanthes guianensis* reduced soil loss by 14-27% and increased gross income by 23-43% (Cai Shouchuang, 1992).

Minimum or zero tillage usually produced a low level of erosion while it had only a small effect on cassava yield and markedly reduced production costs. It would be recommended in areas where cassava is planted on steep slopes, for example in the mountainous regions of Guangxi province.

III. Cassava Planting Methods

In China, most farmers plant cassava horizontally. According to Mr. Liang Yufei (1977), cassava yields obtained with inclined planting were 8% higher than those obtained with vertical planting and 10% higher than horizontal planting. Therefore, an experiment was conducted in GSCRI from 1990 to 1992 to determine the most effective method of cassava planting.

Among the three methods investigated, the sprouting of stakes was fastest and the per cent germination was highest at 4 weeks when stakes had been planted vertically; germination of horizontally or inclined planted stakes was only 78% and 82%, respectively. This shows the superiority of vertical planting compared with horizontal or inclined planting in terms of germination; this is especially true during periods of drought **(Figure 4).** In 1991, a year of exceptional early drought in Guangxi province, germination at 4 weeks of horizontally planted stakes was only 51%, while that of vertically planted stakes was 70%. The rate of germination of inclined planted stakes was always in between those of vertical and horizontal planting.

The results of these experiments indicate that germination of cassava stakes is mainly related to the depth of planting, especially in dry areas or during periods of drought. Cassava stakes planted vertically could take up moisture from deeper soil layers, resulting in a greater tolerance to drought.

There were no significant differences in germination or in yield between different plant bed configurations of flat, single-row ridges and double-row ridges, and there were also no significant differences in yield among horizontal, inclined and vertical planting **(Table 9).** So, in general, the method of cassava planting is not too important. However, under conditions of a shallow soil and/or low rainfall in cassava growing areas in China, germination of horizontally planted stakes will be lower, while with vertical planting the roots are smaller and grow deeper, resulting in low yields and more difficulty in the harvest. In view of this, we recommend inclined planting.

Table 7. Yield and gross income of two intercropping systems as compared to monoculture of cassava in Guangdong and Guangxi, China.

	Cassava root yield (t/ha)		Peanut or melon seed yield (t/ha)		Gross income (yuan/ha)	
	GD	GX	GD	GX	GD	GX
Cassava + peanut	15.1	16.7	2.5	0.96	7029	4400
Cassava + melon (seed harvest)	18.0	15.8	0.6	0.40	7200	5328
Cassava monoculture	13.5	16.7	-	-	2250	2672

Note: GD = Guangdong; GX = Guangxi

Price: Cassava roots: Y 170/t (Guangdong) ; Y 160/t (Guangxi)

peanuts: Y 1800/t ; melon seeds: Y 7000/t

Source: Zhang Weite, 1992 and Tian Yinong, 1992.

Table 8. Yield and gross income of cassava intercropped with *Brachiaria brizantha* compared with cassava monoculture in Meizhou, Guangdong, China.

	Cassava root yield (t/ha)	*Brachiaria* yield (t/ha)	Gross income (yuan/ha)
Cassava + *Brachiaria brizantha*	6.14	5.05	3061
Cassava monoculture	14.13		2402

Price: Cassava roots: Y 170/t

Brachiaria brizantha: Y 400/t

Source: Cai Shouchuang, 1992.

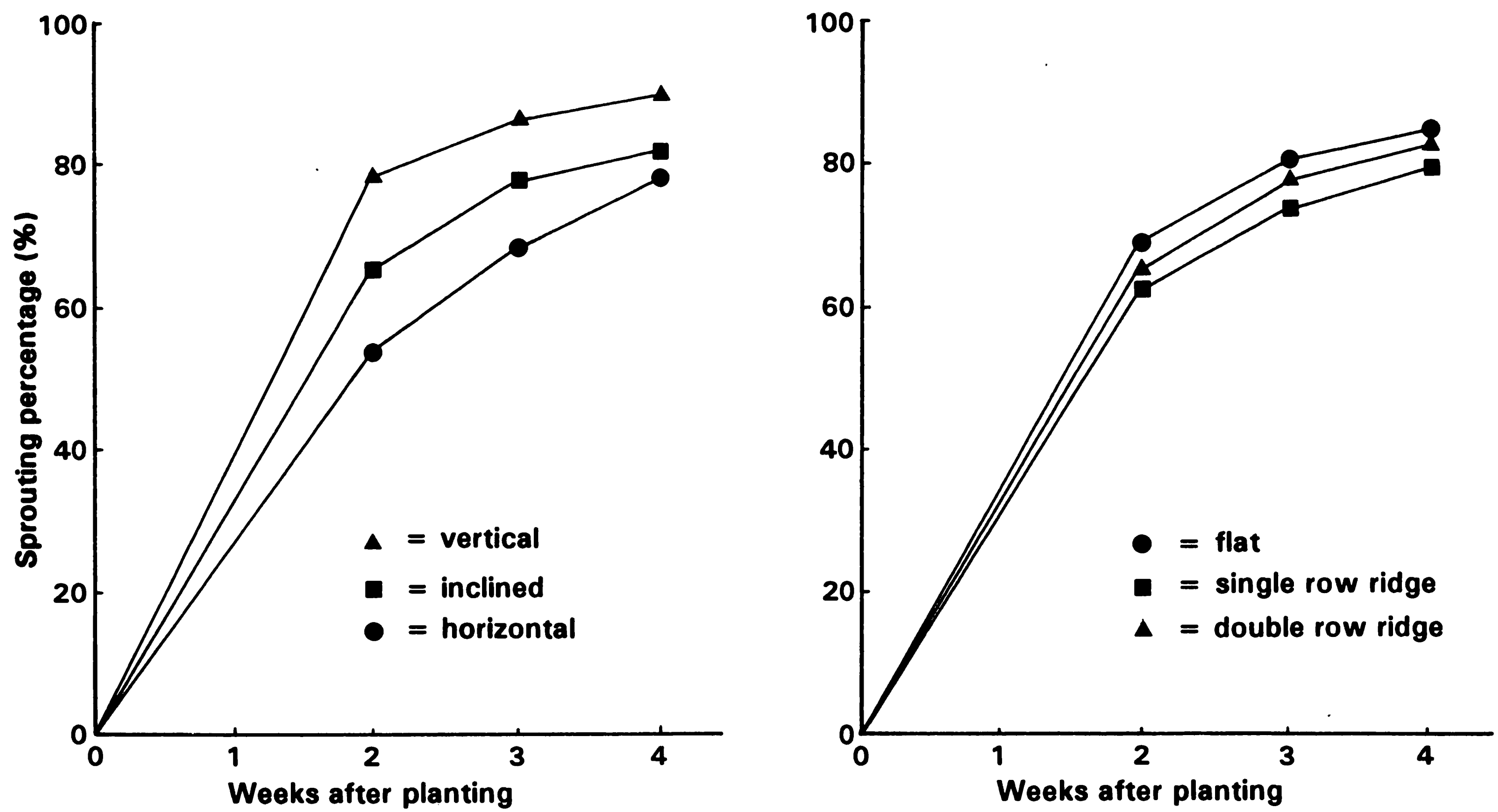

Figure 4. Effect of plant bed configuration (right) and planting position (left) on cassava sprouting percentage in Nanning, Guangxi, China. Data are the average for 1990, 1991 and 1992.

IV. Time of Planting and Harvesting

From 1991 to 1993 an experiment was conducted in SCATC to determine the optimum planting and harvesting times of two cassava varieties, SC201 and Nanzhi 188. At this location the winter is characterized by cold (mean minimum temperature about 10 ^{o}C) and dry weather. During these two years cassava was planted monthly and was harvested at either 8 or 12 months. The results for two years **(Figure 5)** indicate that when cassava was planted in Feb-May and harvested at 8 months (Oct-Jan), high yields as well as high starch contents were obtained for both varieties, but when cassava was planted in Sep-Nov and harvested in May-June of the following year, the yield was quite low. However, when cassava was harvested at 12 months, the yield was much less effected by the date of planting, while the highest starch content was obtained when cassava was planted and harvested in Jan-Mar.

The conclusion of this experiment is that whether cassava was harvested at 8 or 12 months after planting, highest yields were observed when cassava was planted during the spring season (Feb-Apr). In fact, it is difficult for cassava to grow in the winter (Dec-Feb) in China except in small areas of southern Hainan. So, we believe that the optimum time for planting cassava in China is in Feb-Apr with the harvest at about 10-12 months.

FUTURE DEVELOPMENTS FOR CASSAVA PRODUCTION AND UTILIZATION IN CHINA

1. The Processing Industry

It is expected that starch will continue to be the major product made from cassava (including modified starch), while the processing into animal feed will be of secondary importance. In addition, the production of alcohol and other starch-based products will also become increasingly important. Research on production processes for chemical products made from cassava starch will continue and some of these products, such as monosodium glutamate, citric acid and various sweeteners, seem to have a bright future. Recently, the total economic value of cassava products in China has been increasing substantially year after year. Remarkable successes have been achieved so far in Guangdong province, where cassava is used to produce starch, monosodium glutamate, alcohol etc. with a total output value of about 350 million yuan a year (not including private enterprises) (Fang, 1992). Taxes on these products totalled over 60 million yuan and the export value of these products was 5 million U.S dollars. In 1991 Guangxi province produced 170,000 t starch and 12,000 t monosodium glutamate in addition to various other starch products. The total output value was about 400 million yuan, and that trend is rising. Take monosodium glutamate for example. In China, about one sixth of this is made from cassava starch (Zhang, 1992). From 1978 to 1987 the production of Chinese monosodium glutamate has increased at an average rate of

Table 9. Effect of planting position and plant bed configuration on cassava root yield (t/ha) in GSCRI, Guangxi, China in 1990 and 1992.

Treatments[1]	1990		1992	
	SC201	SC205	SC201	SC205
Plant bed configuration				
Flat bed	15.75	12.59	15.96	14.72
Single row	14.61	11.88	18.17	16.18
Double row	14.83	12.96	18.45	15.78
LSD (0.05)	7.12	2.74	5.43	3.97
Planting position				
Horizontal	14.57	11.94	19.95	14.58
Inclined	15.08	13.08	17.10	16.48
Vertical	15.54	12.14	15.52	15.61
LSD (0.05)	3.90	1.90	6.30	4.70

[1] Data for plant bed configuration are averaged over three planting positions and *vice versa*.

Table 10. Present and expected cassava utilization ('000 t of dry chip equivalent) in Guangxi in 1990, 1995 and 2000.

	1990	1995	2000
Starch production	180	340	480
Animal feed and other uses	80	160	240
Alcohol and other industries	80	160	240
Export	150	100	100
For sale to other provinces	80	100	120
Other	30	40	20
Total	600	900	1,200

Source: Wang Chi, 1992.

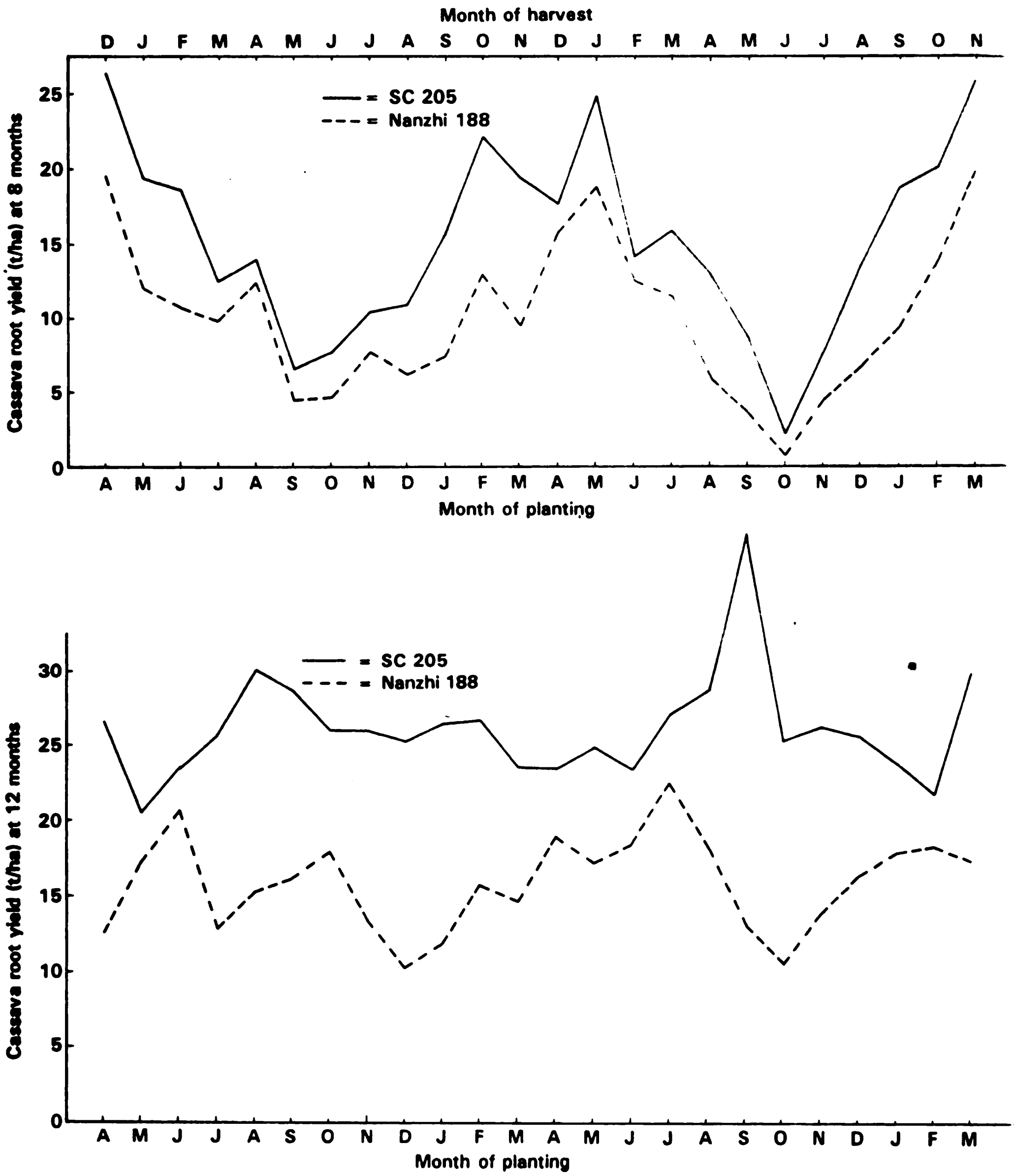

Figure 5. Root yield at 8 and 12 months of two cassava cultivars planted at monthly intervals during two years at SCATC, Hainan, China from 1990 to 1992.

22% a year, while in Guangxi this reached 44%. Total production of Chinese monosodium glutamate reached 270 thousand ton in 1991, twice the level in 1987. Cassava starch is a cheap and high quality raw material for producing monosodium glutamate and it is in high demand by factories. Cassava also plays more and more an important role in the animal feed industry. According to the latest statistics, the animal feed processing industry in China utilizes about 600,000 t dry cassava chips each year (Zhang, 1992), which accounts for about 40% of total cassava production.

2. Agricultural Production and Research

China has a very large population and limited land resources. Since farm land is quite limited and cassava is still a low-value crop **(Table 11)**, increases in cassava production can not depend on increasing the planted area to any great extent, but it must be done by increasing yields.

As a result of the requirements of a developing economy, traditional farming has been greatly affected by the introduction of high-efficiency agriculture. As an economic crop of low output value, cassava has been partly replaced in some areas by other higher value crops. That has happened especially in more developed areas. Under the present situation, there is a tendency for the main cassava growing area to move westward, mainly into the central part of Guangxi province. There are several reasons for this:

a. In Guangxi there are good natural conditions for growing cassava;
b. The province has large areas of poor soils, especially in the hilly country (about 152,000 km^2 or 64% of the total provincial territory). It is difficult to obtain high yields of maize, sugarcane and other crops in these exhausted soils; however, they are suitable for growing cassava;
c. There are many poor people in Guangxi and cassava is still their staple food and an important economic resource;
d. Research on cassava processing utilization in Guangxi province has always been the most advanced in the country and has achieved great successes. These accomplishments have greatly increased the value of cassava and has laid the foundation for further development of cassava production.

As a traditional food and animal feed crop, cassava cultivation still plays an important role in the agricultural economy of certain areas of Guangxi, especially in the mountains.

Due to the successful development of several cassava-based chemical products, the cassava market has improved in recent years and many people have changed their traditional ideas about cassava. Farmers will now increase their investments in cultivating cassava and it is estimated that the cassava planted area of China will maintain at its present level or may increase a little, while cassava root yields should increase substantially. The Chinese government will therefore attach more importance to research on cassava than ever before. But the funding for research will be provided through various channels. For example, those enterprises which will obtain profits from cassava processing will spend some money as special funding for certain research topics or experiments. Factories and farms can also set up special study groups, etc. In order to further develop cassava production technologies, in the future cassava agronomy research in China will include the following aspects:

1. Cultural practices for increasing yields;
2. Experiments on long-term fertility maintainance;
3. Intercropping and interplanting systems of high output value and with benefits for cassava;
4. Cultivation techniques that can control soil erosion effectively.

Table 11. Comparison between several crops in terms of production costs, gross and net income in Guangxi province in 1990.

Crop	Yield (t/ha)	Gross income (yuan/ha)	Production costs (yuan/ha)	Net income (yuan/ha)
Rice	5.74	3,057	2,250	734
Sugarcane	67.45	7,994	4,166	3,778
Maize	2.54	1,272	778	483
Peanut	2.00	3,987	3,145	787
Orange	18.26	18,178	11,190	5,648
Cassava	9.20	1,411	1,132	279

Source: Chinese Agriculture Year Book, 1991.

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RECENT PROGRESS IN CASSAVA VARIETAL IMPROVEMENT IN CHINA

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ABSTRACT

The paper discusses the research progress mainly for the period of 1990-1993. There are three institutions, SCATC, UCRI and GSCRI, which are systematically working on cassava breeding in China. Since the principal constraint to cassava varietal improvement is the lack of genetic variability, the main approach currently used is the evaluation and selection of hybrid seeds introduced from CIAT/Colombia and from the Thai-CIAT program.

In the past few years, remarkable progress has been made in these three institutions, mainly as follows:

1) At SCATC, advanced clones continue to show promising results in comparison with the respectable local control (SC205). Many high-yielding clones were identified in preliminary trials, in which Thai-CIAT material showed a clearly superior performance.

2) At UCRI of the Guangdong Academy of Agric. Sciences, very convincing yield data of a pre-released clone (ZM8002) were obtained from four years of regional trials and another three years of demonstration trials. In addition, many clearly superior new clones were selected from CIAT seed material in a replicated yield trial, nearly doubling the yields of ZM8002 or SC201. Two advanced clones, selected from locally hybridized seeds, showed a high yield potential.

3) At GSCRI, several clones selected from CIAT-introduced seeds showed for the first time a clearly superior yield and dry matter content over local controls in 1992.

4) Additional genetic variability was obtained at SCATC through induced mutations using colchicine treatments. These mutants are presently being evaluated.

INTRODUCTION

Cassava is an important crop only in the southern parts of China. In recent years, about 4.5 million tons of fresh cassava roots are harvested annually from an area of approximately 440 thousand hectares. More than 95% of the total production comes from Guangdong, Guangxi and Hainan provinces.

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Cassava yields in China have increased rapidly in the last two decades. However, this increase was mainly attributed to the increased use of chemical fertilizers rather than to the use of improved cultivars. In fact, the two local cultivars, SC201 and SC205, have continued to occupy more than 95% of the cassava planting areas, but the application of chemical fertilizers has significantly increased during this period.

Although higher yields can be obtained with fertilization, it may not always be profitable. Considering the fact that cassava is a low-value crop, only a very limited amount of fertilizer can be economically applied. Therefore, in the future, cassava varietal improvement can probably make the greatest contribution to increasing cassava yields.

Breeding Program

Research on cassava breeding has been conducted at the South China Academy of Tropical Crops (SCATC), at the Upland Crops Research Institute (UCRI) of the Guangdong Academy of Agricultural Sciences and at the Guangxi Subtropical Crops Research Institute (GSCRI) since 1979, 1982 and 1986, respectively. Collaboration with CIAT, including personnel training and the introduction of cassava germplasm, started in 1987. Because the main constraint to cassava breeding in China is the lack of genetic variability as well as the fact that only a few clones will flower and produce seeds at UCRI, Guangzhou and at GSCRI, Nanning due to climatic limitations, cassava breeding activities, especially at the latter two institutes, have concentrated on the evaluation and selection of hybrid seeds introduced from CIAT. The scale of annual evaluations in the different institutions are shown in **Table 1.**

Table 1. Scale of annual evaluations at the different institutions in recent years.

	SCATC	UCRI	GSCRI
Seedling trial	3,000-6,000	2,000-3,000	1,500-3,400
Single-row trial	200-400	200-300	40-250
Preliminary Yield trial	60-70	30-50	20-40
Advanced Yield trial	20-30	10-15	10-15

Recent Progress

Pre–release of ZM8002

ZM8002 was selected at SCATC from open-pollinated seeds mainly because of its disease and cold tolerance. It was introduced to UCRI in 1985. After a replication trial in 1986, four years of regional yield trials and three years of demonstration trials were conducted by UCRI from 1987 to 1992. The clone's high yield potential was shown not only in small plots but also in farmers' fields **(Table 2).** From these trials, several desirable characters, such as good plant-type, high dry matter content, ease of harvest, tolerance to drought, cold and infertile soil conditions were observed in comparison to the local control, SC201. Very high farmer acceptance was also obtained from the feedback information of the demonstration trials. It is expected that ZM8002 will soon be registered as a new cultivar and be officially considered for immediate release.

Table 2. Comparison of ZM8002 with the local control in fresh root yield in evaluation trials conducted by UCRI in Guangdong province during 1987–1992.

Year	Trial	No. of trials	Mean fresh root yield of ZM8002 as % of the local control, SC201
1987-1990	Regional trial	23	109.7
1990	Demonstration trial	2	133.8
1991	Demonstration trial	9	141.4
1992	Demonstration trial	7	159.6

Germplasm introduction

Since the principal constraint for cassava breeding is the lack of genetic variability in China, breeding activities have been based mainly on germplasm introductions. From 1990-1992, about 8000 hybrid seeds were introduced annually from the Thai-CIAT program or from CIAT/Colombia **(Table 3).** Also, about 3000 locally-produced hybrid seeds from controlled or open-pollinated crosses were obtained each year, mainly from SCATC. The hybrid seeds were evaluated through the F_1 Seedling trial, Single-row trial, Preliminary Yield trial and the Advanced Yield trial. Meanwhile, some clones have also been introduced in recent years in the form of meristem tissue culture.

Table 3. Number of hybrid seeds introduced from CIAT/Colombia or the Thai–CIAT program over the period 1990–1992 in different institutions in China.

Year	SCATC	UCRI	GSCRI
1990	1,550	2,000	3,350
1991	5,926	2,087	1,560
1992	3,837	2,000	1,500
1993	-	2,916	2,198

Promising clones

A number of clones selected from the introduced and the locally hybridized seeds appeared promising at various evaluation stages in different institutions. At SCATC several promising clones selected from CIAT seed material entered into advanced stages of selection already several years ago. At UCRI and GSCRI the progenies selected from CIAT seed material entered into Advanced Yield trials in the 1992 crop cycle.

At SCATC, the advanced clones SM965-3 and SM965-5, continued to show promising results in comparison with the local control in the 1991 and 1992 crop cycles **(Table 4).** Other sets of promising advanced clones also showed high yield potential in 1992 **(Table 5).** At UCRI, two promising clones, NH188-1 and NH90-1, selected from locally-crossed material, showed a high yield potential in the Advanced Yield trial in the 1992 crop cycle **(Table 5).** At GSCRI three advanced clones, selected from CIAT-introduced seeds, showed for the first time a clearly superior yield and dry matter content over the local control, SC201, in 1992 **(Table 5).** From these results, it seems that progress in both high yield potential and high root dry matter content can be achieved.

In addition, many new promising lines were selected in the Preliminary Yield trials at SCATC, UCRI, and GSCRI **(Table 6).** In 1992 over two times the number of superior clones were selected compared with 1991. At UCRI, many clearly superior new clones were also identified from CIAT seed material in a Replicated Yield trial; some clones had yields nearly double those of ZM8002 or SC201 **(Table 7).**

Comparison of different sources of seed material

Evaluations and selections have been made at SCATC among three sources of hybrid material, which included the locally generated seeds, the introduced seeds from

Table 4. Performance of promising advanced clones in 1990 and 1992 at SCATC.

	SM965-3		SM965-5		Control (SC205)	
	1991	1992	1991	1992	1991	1992
Dry root yield (t/ha)	8.8	10.5	6.5	9.7	5.2	9.6
Fresh root yield (t/ha)	20.6	26.1	11.3	22.3	13.5	23.0
Root DM content (%)	42.5	40.4	39.7	43.5	38.2	41.7

Table 5. Performance of some superior advanced clones at SCATC, UCRI and GSCRI in the 1992 crop cycle.

Location	Clones	Parent	Dry root yield (t/ha)	Fresh root yield (t/ha)	RDMC (%)
SCATC	CM7530-3	CM3320-4*MPan 51	11.9	31.7	37.6
	SM1111-3	MCol 1505	10.6	25.4	41.9
	SM863-4	MBra 14	9.6	25.2	38.1
	SM1149-1	CM2059-2	9.5	24.5	38.8
	SM902-1	CM507-31	9.4	25.0	37.4
	SC205	(Control)	9.3	22.8	40.8
UCRI	NH188-1	Nanzhi-188	9.4	23.5	39.9
	NH90-1	SC201	9.0	24.9	35.9
	NH188-2	Nanzhi-188	8.5	22.1	38.3
	SC201	(Control)	8.1	20.6	39.5
GSCRI	SM1113-1	MCol 2215	7.7	19.0	40.5
	SM1113-4	MCol 2215	5.9	14.5	40.7
	SM1089-2	CM1491-5	5.5	13.6	40.1
	SC201	(Control)	4.9	13.4	36.9

Table 6. Performance of superior clones in comparison with the local control in preliminary yield trials in three locations in China in the 1991 and 1992 crop cycles.

Institution	Year	No. of clones superior to SC201 or SC205	Avg. fresh root yield (t/ha)	Avg. dry root yield (t/ha)	Avg. RDMC (%)
SCATC	1991	12	23.16	8.80	38.28
		(SC205)	20.60	7.80	37.90
	1992	34	25.00	9.95	39.20
		(SC205)	21.70	8.50	39.20
UCRI	1991	6	23.83	-	35.03
		(SC201)	19.28	-	36.88
	1992	27	24.40	8.87	36.50
		(SC201)	15.80	5.90	37.00
GSCRI	1991	5	16.13	-	34.54
		(SC201)	14.90	-	34.50
	1992	11	15.20	-	-
		(SC201)	13.50	-	-

Table 7. Some superior clones in the Replicated Yield trial in the 1992 crop cycle at UCRI.

UCRI Code	CIAT Code	Parent	Dry root yield (t/ha)	Fresh root yield (t/ha)	RDMC (%)
901201	SM1150	CM2563-5	13.3	35.0	37.9
900321	SM1073	MCub 32	12.8	32.6	39.5
901531	SM1183	MBra 235	11.6	29.6	39.1
901236	SM1226	CM2563-5	10.5	24.5	42.8
903401	SM1237	CM3276-1	10.2	27.3	37.4
900401	SM1090	CM3299-4	10.1	24.3	41.5
ZM8002	(Control)	D 44	7.7	20.1	38.1
SC201	(Control)		5.9	15.8	37.0

Table 8. Comparison in yield capacity among clones of different origins in a preliminary trial at SCATC, Hainan, China in 1992.

Clones Code	Clones Code		No. of clones	Average dry root yield (t/ha)	Average fresh root yield (t/ha)	Avg. root dry matter content (%)	Avg. root harvest index (%)
CMR/OMR	Thai-CIAT	Total	16	9.22	22.6	40.8	0.40
		Superior to SC205	10	10.40	25.2	41.1	0.46
CM/SM	CIAT/Colombia	Total	20	7.68	20.1	38.2	0.40
		Superior to SC205	8	9.60	21.9	39.3	0.46
ZM	Local hybrids	Total	29	8.99	22.9	39.3	0.42
		Superior to SC205	17	9.80	24.9	39.4	0.44
SC205				8.50	21.7	39.2	0.46
Total mean			64	8.60	22.0	39.3	0.42

CIAT/Colombia and those from the Thai-CIAT program. Many high-yielding clones were identified from these three sources of seed materials, but the Thai-CIAT material showed a clearly superior performance. The Thai-CIAT progenies gave the highest population mean (all entries from the same source in the trial) and the selection population mean (mean of all selected clones from the same source) in terms of fresh yield and root dry matter content **(Table 8).** It is therefore expected that the highest selection efficiency will be obtained from the Thai-CIAT hybrid seed material in comparison with the locally generated hybrid seeds or those from CIAT/Colombia.

Induction of mutations

With respect to mutation breeding, some attempts have been made at SCATC to induce mutations using colchicine treatments. The young emerging buds were treated with colchicine at the rate of 0.8-1.0%. Five mutation lines were identified from this treatment, in which the main mutations were found in leaf shape, leaf color and branching habit. An improvement in yield has not been achieved, but the protein content of roots has been slightly increased. The mutants are presently being evaluated at SCATC.

METHODS AND STRATEGIES FOR CASSAVA TECHNOLOGY TRANSFER IN CHINA

Lin Xiong and Li Kaimian[1]

ABSTRACT

This paper describes the general situation and the existing problems of the extension of new cassava varieties, agronomic practices as well as processing technologies under the conditions of highly intensive agriculture in China.

Cassava has been cultivated in China for over 170 years. Its production evolved from a small-scale backyard crop to large-scale commercial production; from a basic food crop to an upland cash crop used for animal feeding and industrial processing, while cropping systems gradually changed from predominantly monocropping to intercropping and crop rotations. However, the area under cassava production is decreasing due to the development of highly intensive agriculture on flat land and a policy of reforestation on steep slopes. Therefore, it is very important to improve the extension of new cassava technologies so as to increase yields and the production value of cassava.

Presently, several research institutes, such as SCATC, UCRI and GSCRI, have cassava breeding programs. Since the 1960s SCATC has collected, evaluated, propagated and recommended some good varieties, such as SC205 and SC201, for release and promotion among cassava farmers in southern China. Recently, a national cassava cooperation network, led by research institutes, has been established with the objective of introducing, propagating, demonstrating and testing of promising breeding lines in regional trials. This is a combination of research and production, simultaneously testing, demonstrating and promoting good varieties with the help of agricultural extension units and financed by agricultural authorities in the government.

Two new high-yielding varieties, namely SC124 and Nanzhi-188 (the latter introduced from CIAT in tissue culture), have recently been released and are now grown on about 26,000 ha with an average yield of 30-40% over previous varieties, which represents an increase in income of 12-15 million yuan. Similarly, the intercropping or rotational cropping of cassava with pasture species, such as *Stylosanthes* 184, increased gross income 23-43% and reduced soil erosion by 14-27%. Research on cassava further-processing, conducted by the Guangxi Nanning Cassava Technical Development Centre, has also contributed greatly to increase the value of cassava-based products and to expand marketing channels, both at home and abroad.

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However, there are still some problems in the transfer of cassava technology in China, mainly due to a fragmented extension system, lack of interest by the authorities, lack of funding, lack of adequate testing sites, resulting in a slow rate of adoption of new technologies.

INTRODUCTION

Cassava is an important upland crop in southern China. The area harvested annually is about 400,000-450,000 ha. Cassava is playing an important role in upland agriculture in south China by increasing the income of farmers, providing industrial raw material, enhancing foreign currency earnings, etc. In recent years, more attention has been paid to cassava technology transfer by local governments, which have promoted the release of promising varieties as well as better cultivation and processing techniques. However, there are still some difficulties in cassava technology transfer due to its low economic value and the change-over to more intensive agriculture. Therefore, research should be conducted to develop methods and strategies to solve these problems.

This paper describes the general situation and the progress made in cassava technology transfer in China, put forward the major existing problems, and presents some measures and strategies for cassava technology transfer, especially the release of new promising varieties.

I. General Situation and Progress in Cassava Technology Transfer

1. General situation

Before the 1950s cassava was grown by slash-and-burn cultivation or as a backyard crop. Local governments and relevant departments were rarely concerned about the transfer of better varieties and cultivation techniques. Cultivars adopted were all low-yielding edible ones. There were almost no large cassava plantations at that time. Hence, yields were low, resulting in poor economic benefits. After the late 50s and in response to the call of the central government to make great efforts to develop agriculture, cassava was rapidly developed in south China, especially in Guangdong, Guangxi and Hainan provinces. For instance, from 1958 to 1964 cassava cultivation reached a peak with an annual growing area of about 500,000 ha. It was mainly used as food and little was processed into starch. Meanwhile, more attention was paid to varietal collection, evaluation and release. Farmers also started to receive technologies and employ some cultivation techniques which increased production and economic returns. Advised by local government and agricultural management department officials, different cultivation methods and planting patterns were adopted to carry out intercropping, interplanting and rotation-cropping according to the local conditions. Among these the construction of terraced fields was recommended in mountainous regions and open forests. These techniques had an effect in decreasing soil erosion while increasing the multiple crop index and economic returns. In order to develop and transfer cassava cultivation technology, studies on cassava cultivation, breeding and comprehensive utilization were vigorously conducted by a great number of researchers. A lot of experience in cassava production in different regions was also obtained and then fed back to farmers, providing a solid basis for cassava technology transfer. For example, Liang Guang-shang, a well-known researcher, combined research, production and comprehensive utilization and wrote several books such as "Cassava", "Cultivation and Utilization of Cassava", etc. In these books he described the social and economic status of cassava, summarized and presented technologies like varieties, cultivation techniques and comprehensive utilization; he also divided cassava growing regions in China, depending on planting scale and climatic conditions, into major growing regions (Guangdong, Guangxi and Hainan), regions for expansion (Fujian and Yunan) and regions for trial plantings (Jiangxi, Hunan, Sichuan and Guizhou). His work played an important role in transferring and adopting improved techniques and cassava cultivars adapted to the local conditions.

Historically, cassava technology transfer developed slowly, going through a process from slash-and-burn cultivation to the gradual adoption of promising clones, better farming practices as well as more intensive cultivation. In collaboration with other research institutions and the local agricultural authorities, SCATC successfully conducted screening tests and released local cassava cultivars; it developed and recommended rapid propagation techniques using single and double-bud cuttings as planting material, ring-cutting to hasten germination, storage of planting stakes in ditches and pits to prevent cold damage; and it promoted the use of advanced cultivars and the expansion of the cassava growing area. Recently, other research institutions, such as the Guangdong Academy of Agricultural Science (GAAS), the Guangxi Subtropical Crops Research Institute (GSCRI), the South China Institute of Botany (SCIB) and the Guangxi Nanning Cassava Technical Development Centre, also became involved in the introduction, selection and release of promising clones, the development and application of better cultivation techniques, and the development of improved cassava processing techniques.

2. Progress in cassava technology transfer

Progress has been made in cassava technology transfer in China, mainly in the introduction, selection and release of advanced varieties, and in the development and application of better cultivation techniques. The details are as follows:

Screening and recommendation of local cultivars: The collection, evaluation and recommendation of local cultivars played a very important role in expanding the cassava growing area, increasing the yield and stimulating the development of cassava production in China. There were over 20 local clones that had been introduced previously and that had been sporadically cultivated, but not in large plantations. SCATC made every effort, together with local governments and other research institutions, to carry out nation-wide collections of local cultivars. Through clonal trials and regional tests, SC205 and SC201, two high-yielding bitter cultivars, were selected and recommended to farmers, thus commencing the release of promising clones on a large scale, while the low-yielding local cultivars were gradually replaced. For the time being SC205 and SC201 were the only varieties to be planted in large areas in China. SC205 was a dwarf and high-yielding variety with relatively strong wind-tolerance but with poorer cold-tolerance as compared to SC201. Thus, SC205 was mainly recommended for Hainan and the south of both Guangdong and Guangxi. It is still one of the major cultivars in China, accounting for a large percentage of the total growing area in the country. SC201 was tolerant to poor soils, drought and cold; it was also high-yielding but had relatively poor wind-tolerance. It was mainly released in the northern regions of the cassava areas and now occupies about 50% of the total growing area. Because of the release of these high-yielding cultivars, cassava yields increased progressively from 4.5 to about 9.0 t/ha, making an important social and economic contribution. For example, in Fengshun county of Guangdong province, the cassava cultivars "Red Stake" and "Green Stake" were previously planted, producing 3.0-4.5 t/ha. After the introduction of SC205 from SCATC, followed by trial plantings and demonstrations, this new cultivar has been recommended county-wide since the 1980s. As a result, the area planted with SC205 reached 5,145 ha in 1991, corresponding to 64% of the total cassava area in the county, while yields increased from 4.35 in 1979 to 8.16 t/ha in 1990. The cumulative increase in the production of dry chips due to the planting of SC205 during the five year period from 1987 to 1991 was calculated at 7,986 t, having a value of 6.39 million Yuan RMB (Wu Chonghan, 1992).

In Hainan, the sweet cultivars SC101 and SC102 were dominantly cultivated during the 60s and 70s, yielding less than 7.5 t/ha. With the release of SC205 since the 80s, however, the yield is now about 15 t/ha, double that obtained before. Each year there was an increased production of 150,000 t of fresh roots, having a value of 24 million Yuan RMB. Thus, the collection, evaluation and the release of high-yielding local varieties brought about good economic effects in the development of cassava production in China.

Release of new varieties: Since the 1980s, SCATC has recommended to farmers several new varieties like SC6068 and SC124. Among these, SC6068 is an edible sweet cultivar developed in the 1980s; its yield is about 40% higher than that of SC101. It has a higher dry matter and starch content (30-35%) and a better flavor. It is early-maturing and could be harvested at 7-8 months after planting. It was released mainly in Hainan. Guangdong and Fujian and reached, somewhere, a yield of 45 t/ha. SC124 was developed and released by the end of the 1980s. It is cold-tolerant, resistant to poor soils and is thus well-suited for growing in the subtropics; the yield is 38% and 29% higher than that of SC205 and SC201, respectively. Therefore, it is a very promising cultivar. It is now planted principally in those regions without typhoons in Guangdong, Guangxi and Fujian, covering a total area of 10,000 ha, and giving an increase in gross income of over 9 million Yuan RMB. Hence, the recent release of several new varieties offers the farmers various varietal resources for cassava development based on their adaptation to the local conditions.

Release of introduced clones: In order to accelerate the breeding and release of advanced cassava clones and to promote cassava production in China, CIAT recently sent a collection of high-yielding clones/lines, from which some well adapted ones were selected by SCIB. Among these, Nanzhi-188 (CM321-188) has been released in Guangdong, Guangxi and Hainan. Propagated by in-vitro culture using shoot-tips as starting material, 160,000 plantlets were provided to farmers. It was further multiplied and expanded by cassava growers and now covers an area of 6,666 ha. It has a high yield potential in fertile soils, producing 13.7-31.8% higher yields than that of SC201. So it is going to be released in other regions depending on the local conditions.

Adaptability trials of promising high-yielding clones: Adaptability trials of promising high-yielding clones form the basis for selection and varietal release; these are also very effective for demonstration and propaganda purposes. Through many years of collaboration with CIAT, a large number of advanced varieties were obtained by SCATC, GAAS and GSCRI. For instance, NH188-1 and NH90-1 were selected by GAAS, while SM786-1 was selected at GSCRI. These are now being tested in regional trials and offer the possibility of release of well-adapted new germplasm. In recent years, many good clones were also bred by SCATC using over 4,000 accessions of clonal progeny of both local and CIAT/Colombia origin. These are being tested in adaptability trials located in 14 regions in Guangdong, Guangxi, Fujian, and Hainan provinces. From these more than 20 promising lines were selected, including CM4031-2, CM4040-1, CM4044-1, CM3970-8, ZM8013, ZM8002, ZM8316, ZM8641, ZM8639, etc. They all had higher yields than SC205 and SC201. For example, CM4031-2 has a great potential to increase yields combined with strong wind-tolerance, as shown in Beihai of Guangxi, Jiexi of Guangdong and Changjiang of Hainan. Moreover, CM4044-1 and CM3970-8 were also found to be high-yielding in some regions in Guangdong and Guangxi, while ZM8013 and ZM8002 were high-yielding in most locations where they were tested; they might thus be released soon. The further testing and selection of these lines will lay a firm foundation for extending new cassava cultivars and will provide a wide range of genetic resources for local adaption and adoption of promising clones.

Adaptation and release of better cultivation techniques: The recommendation of cassava farming techniques should be targeted to the particular local conditions. In China, cassava production practices which farmers readily adopted were based on intercropping/interplanting and rotation-cropping on slopes and in sugarcane growing regions. For instance, in Ding'an of Hainan and in Zhanjiang of Guangdong, cassava was recommended to be rotated with sugarcane, while in Beihai and Guilin of Guangxi, Shaoguan and Dongguan of Guangdong it was generally intercropped with peanuts or other legumes or with seed watermelon. Hence, not only the multiple crop index but also the yield and economic returns were increased.

Recently, intercropping or rotation-cropping of cassava with pastures was developed and has been recommended by Meizhou City of Guangdong. It provides a new way of reducing soil erosion, preventing soil fertility decline when cassava is grown on slopes, enhancing feed production and developing both crop and animal production. It brought about significant ecological and economic effects of decreasing surface run-off by 17.3-36.7% and soil erosion by 14.3-27.3%, while increasing the gross income by 22.7-42.9% (Cai Shouchuang, 1992).

II. Methodology for the Release of Promising Cassava Varieties

1. Varietal release

All promising cassava varieties consist of either breeding lines selected by research institutions, high-yielding clones introduced from abroad, or locally collected cultivars. These were principally released through agricultural extension stations at the county or township level, where they were tested and demonstrated and then recommended to farmers by research institutions or the relevant authorities of agriculture. The procedure is shown in detail in **Figure 1.**

2. Main steps in varietal release

a. Establishment of demonstration blocks. New varieties provided by breeders or relevant authorities were usually demonstrated and then multiplied by extension organizations in the major growing regions. For instance, when SC124 and Nanzhi-188 were released by the Science and Technology Committee of Guangxi and the Guangzhou Research Institute of Agricultural Science, they were bought from breeders and then massively propagated and distributed to each demonstration point to be tested in large plots. At time of harvest, local farmers were organized to evaluate their performance. At the same time TV and newspapers were also employed to make them known to

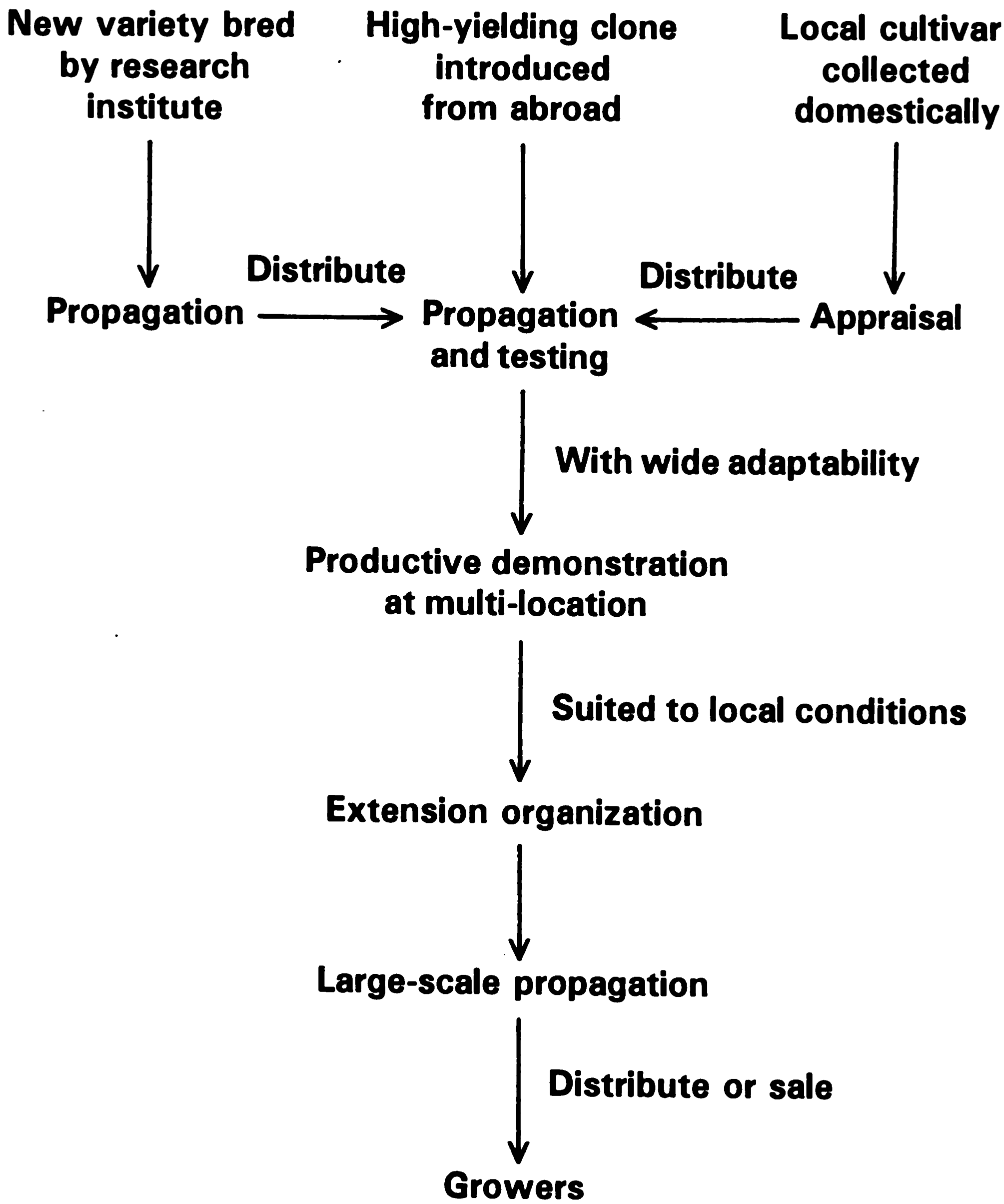

Figure 1. Procedure of cassava release in China.

growers. After harvest, the planting material was sold to producers for further multiplication and commercial cultivation. As a result, the area planted was expanded and the growing regions constantly increased.

b. Rapid propagation to ensure the supply of planting materials. Rapid multiplication of new cassava cultivars is imperative in order to enhance the supply of planting material since the propagation index is very low in this crop. In China cassava is generally multiplied by dense planting, ring-cutting the stem and cutting of 2-3 node stakes. Sometimes, however, even green shoots are used as planting material. For example, the Science and Technology Committee of Beihai City of Guangxi used all cassava shoots, including green ones, to be germinated in plant beds and then transferred to the field, thus doubling the amount of planting material obtained. Dense planting mainly increased the plant population and the multiplication index per unit area. Moreover, dividing stakes was a method also adopted for many years, such as single or double-bud stakes and longitudinally split stakes with two buds. Thus, every part of the stem could be used as planting material, germinated in nursery beds and then transferred to the field. For instance, the propagation of SC124 by single or double-bud stakes resulted in a germination rate of 80-99%, which was similar to that obtained by conventional multiplication; the yield was also similar **(Table 1)**. The propagation rate, however, was 10-20 times higher than using the conventional methods. With capping, ring cutting was usually done every 2-3 nodes on 4-5 month old stems in order to induce sprouting of foliage buds, from which tender shoots could be excised several times as planting material, thus increasing the multiplication index another 20 times. *In-vitro* culture of meristems of shoot-tips was also employed to speed up propagation, but it was difficult to be mastered by farmers and could only be carried out by a few research institutes like SCIB, which released Nanzhi-188 by this method.

Table 1. Germination rate and yield performance using different methods of propagation of planting material of SC124. Data are average of four locations.

Planting material propagation method	Germination rate (%)	Yield (t/ha)
Longitudinal splitting	98.8	20.1
Single-bud stake	80.0	24.3
Double-bud stake	86.0	25.0
Triple-bud stake	95.0	21.6
Upper immature stem	97.2	11.8
Lower immature stem	99.4	11.5
Control of conventional stake	98.5	18.2

Source: He Guangguan and Lee Jixi, 1992.

c. Improve the storage of planting material to ensure its survival during winter. Since the cassava growing regions of China are located in the subtropical zone where frost may occur in winter, planting stems must be stored in ditches or pits to ensure their survival during the winter. Ditch-storage is presently the major method for storing stakes. It is simple and can easily be done. After choosing a suitable place a ditch is dug, its size depending on the quantity of material to be stored and the method used.

In case stems are stored horizontally, the ditch should be 1.0-1.5 m deep, but where a steep hillside is available a hole of 0.5-0.6 m is deep enough for vertical storages. After placing in the ditch, the stems are covered with soil to form a mound. This way stakes can be conserved for 4-5 months.

III. Major Problems of Cassava Technology Transfer and Ways to Solve Them

1. Major existing problems

Cassava is a high-yielding upland crop, but it has not been cultivated as a major economic crop, accounting for only a small fraction of the agricultural economy. Hence, there are some problems of cassava technology transfer, mainly due to competition from more economic crops.

a. Low prices and poor economic returns. Cassava accounts for only 1% of the gross value of agricultural products in south China, and does not play a major role in the farmers' income. Compared with other major economic crops, its production and economic value per unit area is rather low. For example, the output value of tea and fruits is over 15,000 Yuan RMB/ha, while the highest value of cassava prior to further processing is only 6,000-7,500 Yuan/ha. Comparing the economic value of cassava with those of other commodities, 1 kg of dry cassava chips is equal only to 1 kg of rice bran, 0.22 kg soybean, 0.27 kg ginger, 0.25 kg citrus, etc. As a result of this low economic value, the farmers' enthusiasm for growing cassava has diminished. At the same time, local governments have paid attention mainly to important economic crops rather than cassava, and only a small part of the budget was given to cassava technology transfer, which resulted in a slow release of advanced cultivation techniques and varieties. This has been the principal difficulty in cassava technology transfer.

b. Shortage of budget and full-time personnel for demonstrations and variety release. Cassava technology transfer in China was carried out only by a few research institutions without any long-term budget from either central or local governments. Moreover, there was no full-time personnel in the relevant departments of agriculture in charge of cassava demonstrations and variety release. Therefore, it was difficult to establish a stable long-term network of cassava technology transfer personnel, resulting in a lack of technical advice and training, and a slow release and adoption of advanced farming techniques and new cultivars.

c. Lack of linking of production, processing and marketing. With the vigorous development of animal husbandry in China, demand for feed has doubled and redoubled, which should improve market demand for cassava. But due to the lack of interest in cassava by local governments and relevant agricultural authorities, there was no coordination of cassava production, processing and marketing; instead, production and marketing was done entirely by cassava farmers. Processing factories merely dealt with processing and rarely invested any capital in helping farmers develop cassava cultivation and improve their economic returns. Furthermore, the products that were manufactured and marketed were limited mainly to starch and dry chips. The result was that market fluctuations and reduced sales always led to an oversupply and low prices of these products. The decrease of price and economic returns dampened the farmers' enthusiasm for growing cassava or for using up-to-date farming techniques and higher yielding varieties. This was also a major problem in cassava technology transfer.

d. Adverse environmental effects. Since cassava in China could not compete for land with other major crops, it was usually grown on dry and poor soils on mountain slopes. It was seldom cultivated as an important commodity, and made only a small contribution to the household income. Hence, there was no urgent need for improved production technologies. But, the growing of the crops on steep slopes often caused soil erosion leading to adverse effects on the environment. As a result a new policy of prohibiting agricultural production on hillsides in order to facilitate reforestation was implemented country-wide; this further restricted the development of cassava production. In addition, the technology transfer was also affected by cassava being mainly considered as a poor man's crop.

2. Ways of dealing with the problems of cassava technology transfer.

Although there are still some problems in cassava technology transfer, the area under cassava is expected to remain constant or to increase in south China in the foreseeable future. In addition, collaborative research in other disciplines, like cultural practices and processing, to make cassava-based products more competitive in the market, will help to overcome these cassava production problems.

The following measures should be taken to overcome the problems:

a. Strengthening of the development of new cassava products in industry, in order to expand its market and enhance its competitive ability. Cassava is high-yielding, has a high content of starch, and the particular starch characteristics make its use imperative in some industries, which would not be able to substitute cassava starch with those derived from other crops like maize. For that reason, cassava continues to be utilized both in industry and in animal husbandry. More attention should therefore be paid to industrial utilization and the further development of new cassava products. Medium and large-scale enterprises, equipped with up-to-date facilities, should be set up so as to optimize modern processing techniques, improve information exchange and marketing, in order to develop new products, increase both domestic sales and exports, and expand market demand. For example, the Mingyang Starch Factory of Guangxi, by developing denatured starch, had excellent economic returns of 3 million Yuan RMB as profit from 22.7 million Yuan of annual sales, which resulted in a much better marketing of cassava products. It made cassava production more profitable and thereby achieved the goal of stimulating the development of cassava cultivation, enhancing the adoption of better cultivars and advanced farming techniques. This was an important strategy for developing cassava production and enhancing cassava technology transfer.

b. Changing the old concept of cassava being a low-value crop. Research institutions should provide more technical advice and services and present to farmers the latest technology for improving yields and cassava utilization. Every effort should be made by officials of local governments, growers, and extension agents to realize cassava's socio-economic potential in certain regions and enhance its role in upland agriculture. A more rational crop distribution, or the rotation and intercropping of cassava with other upland crops such as sugarcane, peanut and beans, as well as the use of some land for intensive cultivation in order to increase yields and economic benefits, will help to promote cassava technology transfer and change the crop's image into that of a highly profitable commercial crop.

c. Conducting a survey on cassava production, processing and marketing. The present situation of cassava utilization, product development and market demand should be evaluated to determine both the opportunities and the constraints in cassava production. With this information policy makers are more likely to provide funds for promoting cassava technology transfer.

d. Establishing a network of cassava technology transfer agents. These should combine research with production, and integrate demonstration with propagation as well as release. This is the key link in cassava technology transfer. To form an extension network, demonstration blocks should be rationally laid out at representative locations by research institutions financed by local governments or relevant agricultural authorities. These blocks should be managed by agricultural technical extension personnel or by growers. Along with these demonstration plots propagation nurseries should be set up. In the commercialization of multiplication of promising cultivars, the sale of planting stakes not only favors the release of promising varieties and farming techniques, but also benefits the departments involved by paying for expenses or even by making small profits, thus, encouraging their enthusiasm for cassava technology transfer. For instance, SC124 and Nanzhi-188 were efficiently released in this way.

e. Strengthening of collaboration with other national and international organizations. At present, cassava technology transfer in China includes only the extension of promising cultivars. Therefore, varietal improvement should be progressively improved by means of various breeding methods and techniques in order to develop high-yielding, cold-tolerant and high-starch content clones suitable for the local conditions. This is the basis of cassava technology transfer. However, due to a lack of genetic variability in cassava germplasm in China, it is difficult to make new breakthroughs in cassava breeding. Thus, close collaboration with CIAT is essential for making progress in cassava varietal improvement and release. By making full use of breeding techniques and materials from CIAT to carry out further selection and hybridization with local lines/varieties, new cultivars with more useful characteristics will be developed.

We believe that by making these efforts the above-mentioned strategic measures could be implemented and further progress could be achieved in cassava technology transfer in China.

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RECENT PROGRESS IN CASSAVA AGRONOMY RESEARCH IN VIETNAM

Nguyen Huu Hy[1], Tran Dai Nghia[2] and Pham Van Bien[3]

ABSTRACT

Cassava is an important root crop in Vietnam, and after rice and maize it is the major source of calories for human consumption and animal feed.

Recently, cassava research has been supported by the National Root and Tuber Crops Research Program and by CIAT.

Cassava agronomy research has produced the following results:

- Among various intercropping systems, the interplanting of cassava with peanut, mungbean or maize were the most promising in the South, while intercropping with peanut was most promising in the North.
- Cassava planted vertically and on single ridges gave higher yields than planting in other positions or with other types of plant bed configurations. Differences in yield due to stake position or plant bed configuration were not significant, however.
- Long-term NPK trials showed that in Hung Loc Center in Dong Nai there was still no response of cassava to fertilizers after three years of continuous cropping, while in Agric. College #3 in Bac Thai highly significant responses to N, P and K were already observed in the first year.

INTRODUCTION

Among the root crops, cassava is an important food crop in Vietnam. It was introduced at the beginning of the 19th century. It is now grown mainly by small farmers and is considered the major source of calories after rice and maize for human consumption and animal feed **(Table 1)**. In the 1960s and at the beginning of the 1970s, 1.0 to 1.2 million tons of cassava were produced. Presently, the crop is well-known in Vietnam and is grown in almost every province **(Figure 1)**. However, cassava production has not been stable. Planted area is highly variable from year to year: it reached 500 thousand ha in 1985 and declined to 257 thousand ha in 1990 **(Table 2)**. This sudden decline is due to many causes, such as low price, poor processing facilities and competition with other crops.

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Table 1. Planted area, yield and production of major field crops in Vietnam in 1991.

Field crops	Planted area ('000 ha)	Production ('000 t)	Yield (t/ha)
Rice	6,302.7	19,621.9	3.11
Maize	447.6	672.0	1.50
Cassava	273.2	2,454.9	8.98
Sweet potato	356.1	2,137.3	6.00
Sugarcane	143.7	6,130.9	38.30
Vegetable	268.5	3,213.7	11.96
Groundnut	210.9	234.8	11.10
Soybean	101.1	80.0	0.79

Source : Vietnam Department of Agric. Statistics, 1991.

Table 2. Cassava area, production and yield in Vietnam from 1961 to 1991.

Year	Area ('000 ha)	Production ('000 t)	Yield (t/ha)
1961	122.0	965.0	7.91
1970	131.0	945.0	7.21
1975	160.0	1,191.0	7.44
1980	434.0	3,290.0	7.58
1985	500.0	3,450.0	6.90
1990	256.8	2,275.8	8.86
1991	273.2	2,454.9	8.98

Source : Vietnam Department of Agric. Statistics.

Cassava Utilization

In Vietnam, most cassava is used for animal feed and for human consumption in the form of many different types of processed products. These include: food and beverages, dry chips, dry starch and noodles. The quantity of cassava exported is very small. According to the results of a 1991 survey, cassava utilization varies markedly among agro-ecological regions **(Figure 2).** Cassava used for on-farm processing was highest, followed by on-farm animal consumption, fresh root sales (mainly for further processing) and on-farm human consumption. However, cassava production for on-farm human consumption was highest in the North Central Coast and lowest in the Central Highlands, while cassava for on-farm processing was highest in the Southeastern region.

Climatic Conditions

Lying between 8° and 23° latitude N and 102-110° longitude E, Vietnam is a long

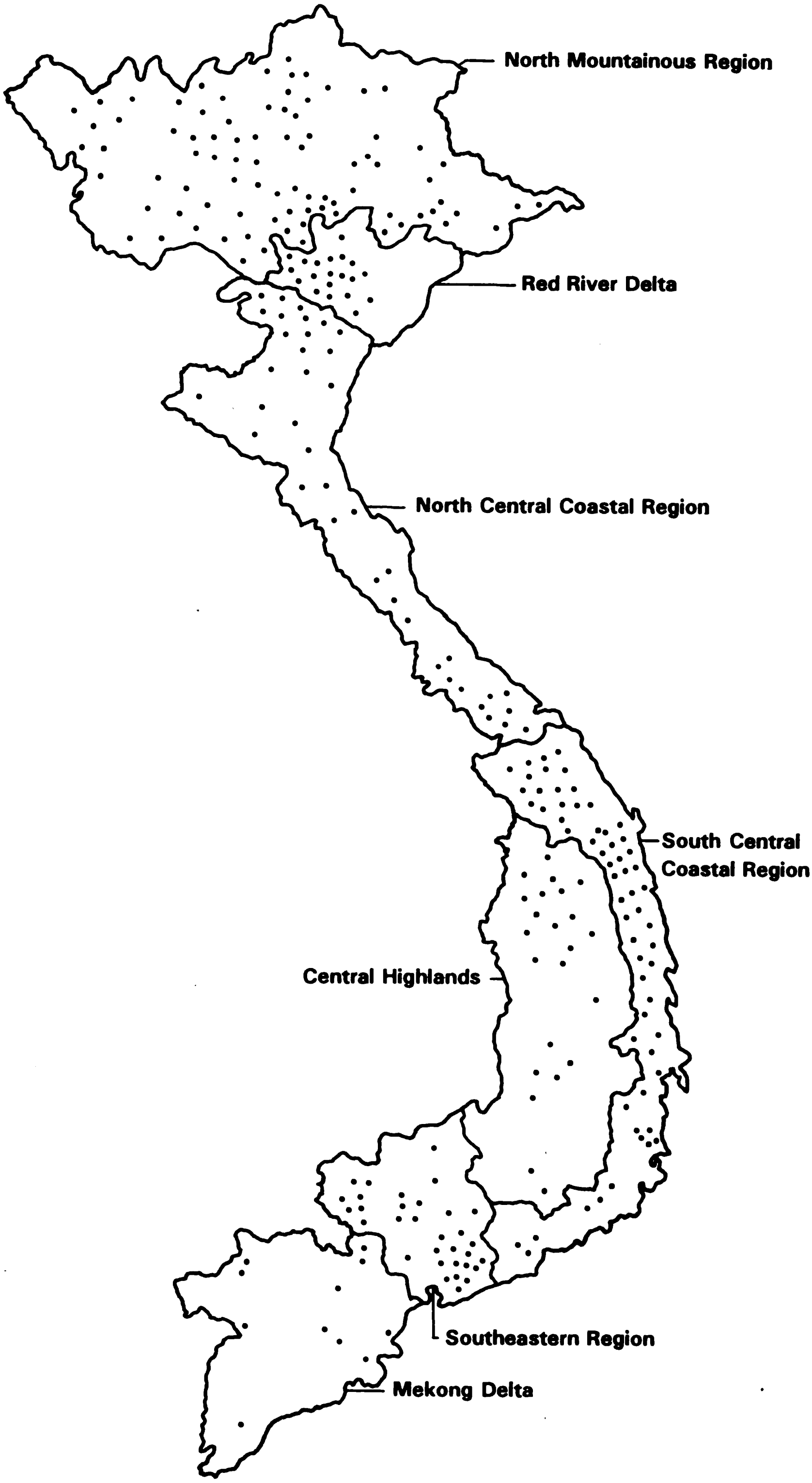

Figure 1. Cassava production areas in Vietnam in 1991. Each dot represents 1000 ha of cassava.

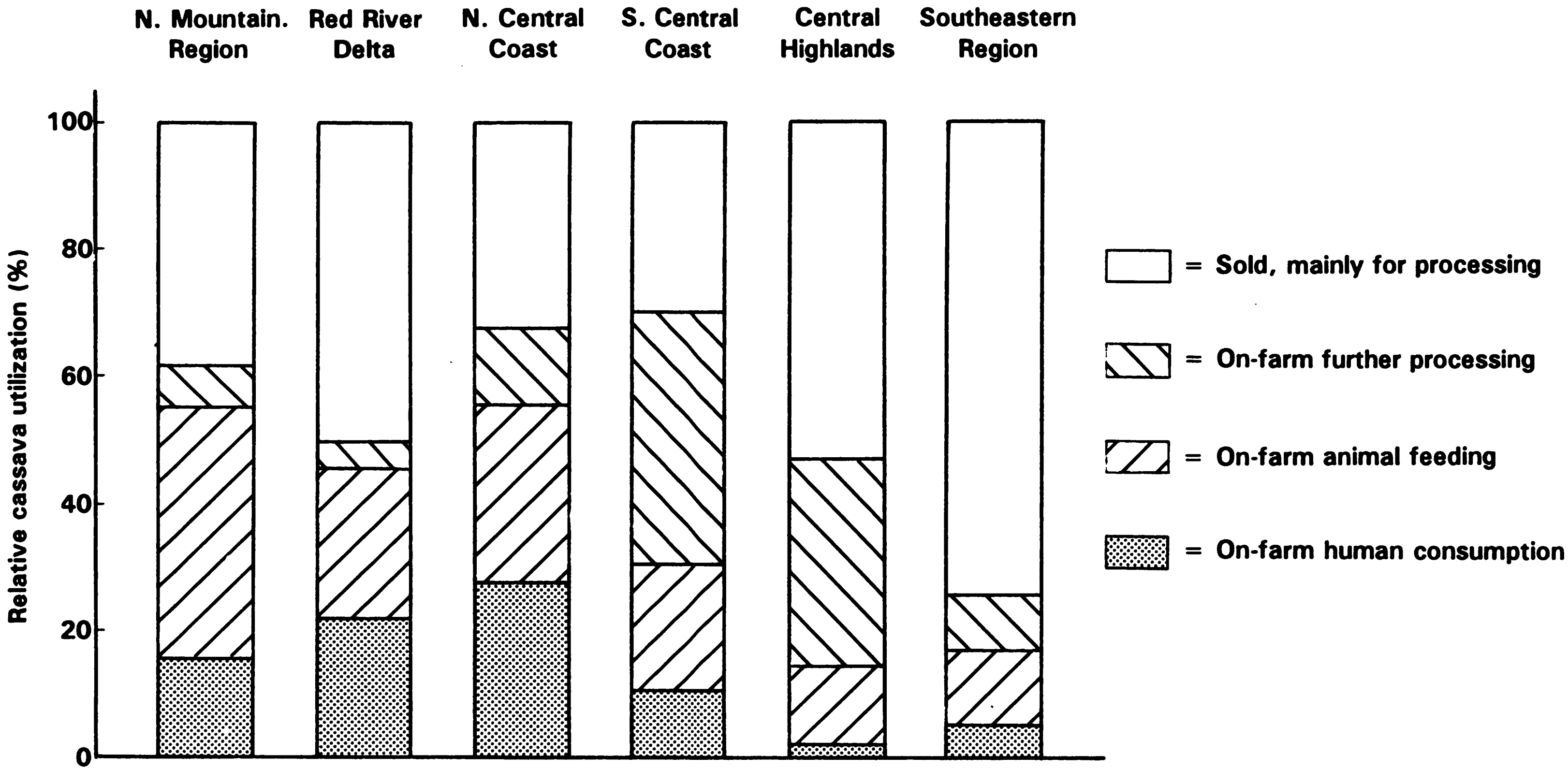

Figure 2. Relative utilization of cassava in six agro-ecological regions of Vietnam in 1991

Source: *Pham Van Bien et al., 1992.*

and narrow country with a tropical climate in the south and subtropical climate in the north. Cassava is grown in areas with a mean annual temperatures of 20 to 25°C in the south to about 15° to 25°C in the cooler areas of the north **(Figure 3).** The total annual rainfall varies from 1500 mm to nearly 3000 mm and the dry season extends from 2-4 to 6-8 months **(Figure 4).** Farmers usually plant cassava without irrigation, either at the beginning or at the end of the rainy season **(Figure 5).** Cassava is harvested at 8-12 months after planting.

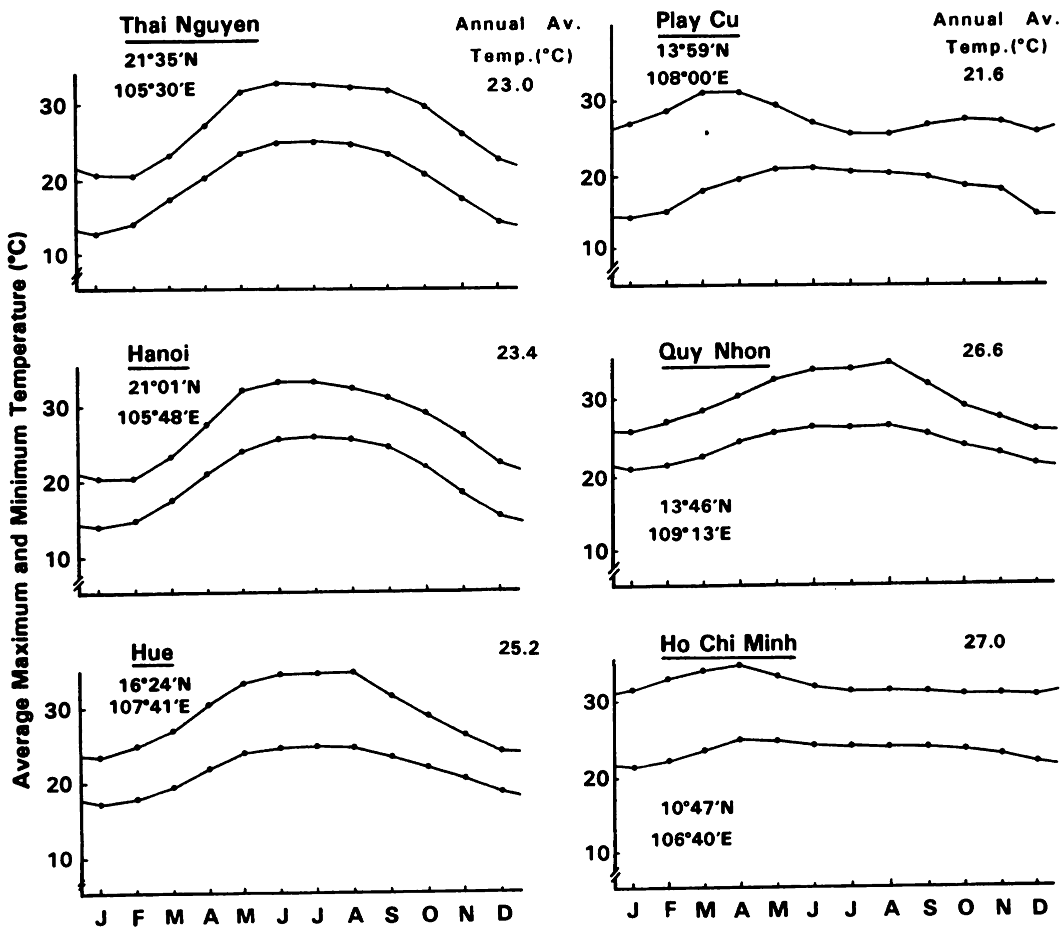

Figure 3. Annual variation in mean maximum and minimum temperatures at six locations in Vietnam.

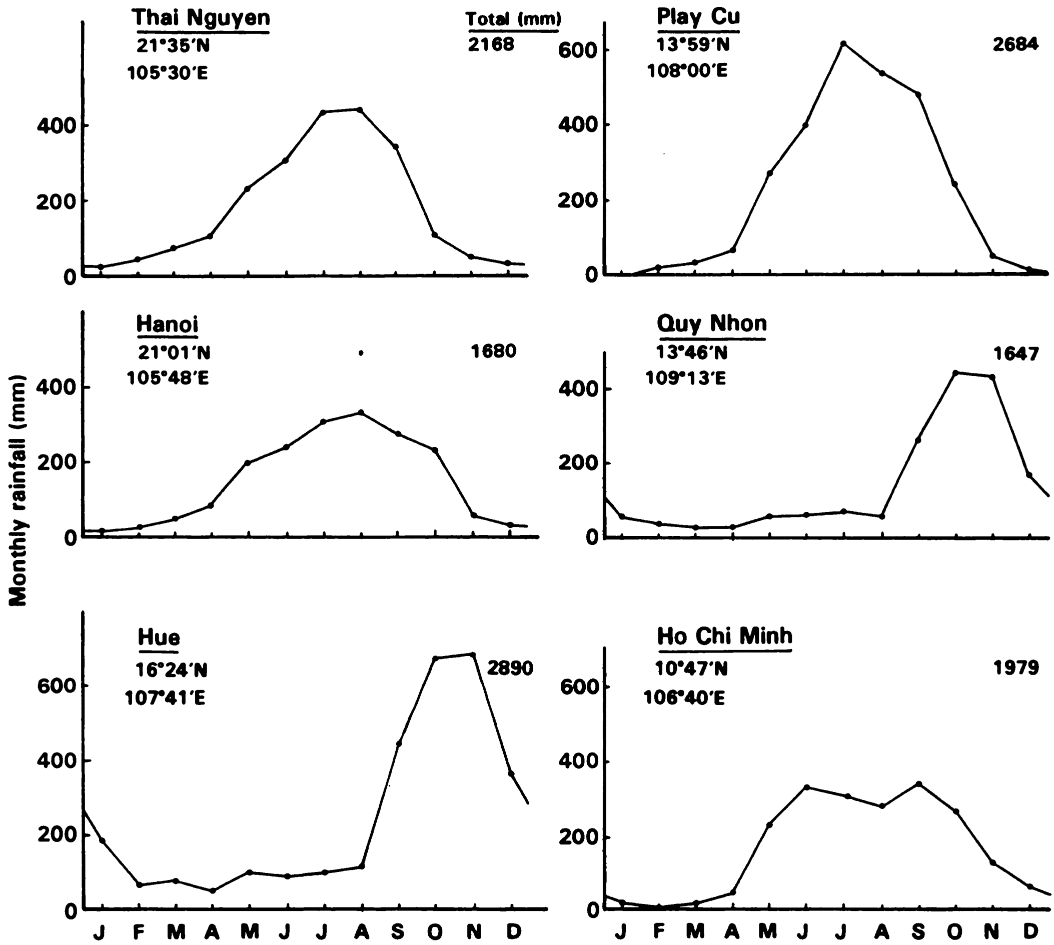

Figure 4. Rainfall distribution at six locations in Vietnam.

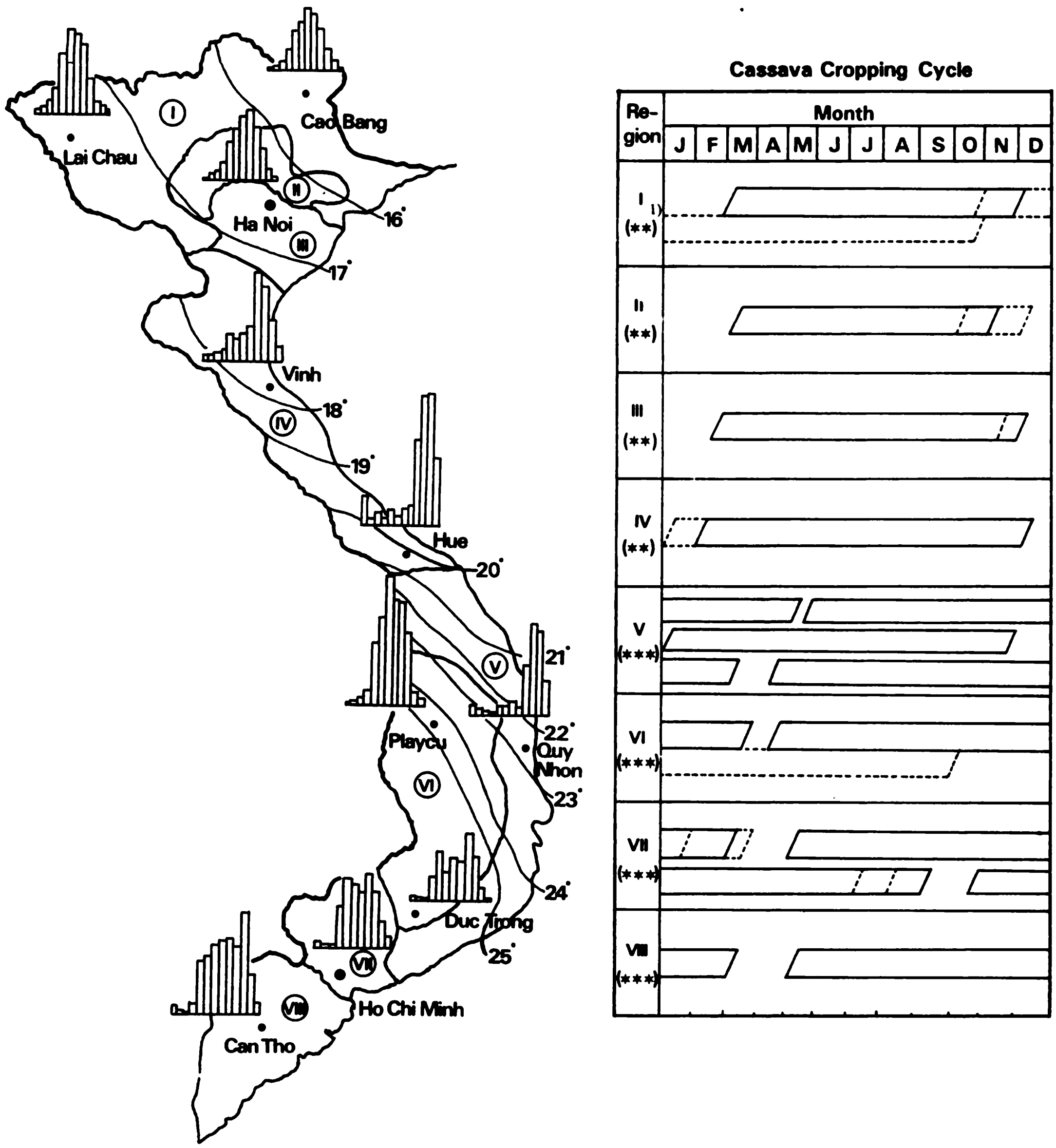

Figure 5. Cassava cropping times in eight agro-ecological regions of Vietnam. Dotted lines in diagram indicate the earliest or latest harvesting dates of cassava. Map indicates isotherms for the mean temperature during January, as well as the rainfall distribution in various locations.

Source: *Adapted from Khi Hau, Vietnam, 1987.*
*1)** Data from Truong Van Ho, Mai Thach Hoanh et al., 1989-91.*
**** Data from Hoang Kim, Nguyen Thanh Binh et al., 1989-91.*

Soils

Considering the distribution of various soils of Vietnam, cassava is grown on almost any kind of soil, but mainly on Ultisols, followed by Inceptisols, Oxisols and Alfisols. Analysis of soil samples taken in some locations **(Table 3)** indicate that the pH varied from 4.5-6.2; organic matter levels were low to medium, ranging from 0.9-7.8%; P levels tended to be medium-high, while K levels were high in some areas of Dong Nai and Ha Son Binh, but very low in areas of Bac Thai and Song Be provinces.

Table 3. Soil characteristics[1] at some locations in Vietnam.

Province	Sample No.	pH	% OM	ppm P	me/100g K	Ca	Mg
-Bac Thai	1	5.2	1.6	15.1	0.08	2.22	0.11
	2	4.5	2.5	9.1	0.03	1.26	0.05
-Ha Son Binh	1	4.7	2.7	11.7	0.49	2.14	0.82
-Dong Nai	1	5.3	2.6	15.8	0.28	3.66	0.80
	2	4.7	2.9	18.4	0.19	1.14	0.40
-Song Be	1	6.2	0.9	25.7	0.11	1.57	0.21
	2	4.7	1.5	8.7	0.06	0.43	0.22
-Tay Ninh	1	4.6	1.4	27.0	0.06	0.14	0.03
-Ho Chi Minh	1	4.6	7.8	24.5	0.81	2.40	2.46

[1] Soil samples were analyzed at CIAT.

CASSAVA AGRONOMY RESEARCH

Research on cassava agronomy was conducted with the main objective of helping farmers increase their cassava production and income. In recent years, cassava research has been conducted at various locations, such as Hung Loc Agric. Research Center in Dong Nai province and in Agric. College #3 in Bac Thai, as well as in Hai Hung and Nghia Binh provinces. At Hung Loc Center the soil is a relatively fertile red latosol, annual rainfall is about 2000-2500 mm with a 4-5 months dry season from Dec to April, and the mean monthly temperature fluctuates from about 25 to 29°C. At Agric. College #3 the soil is a highly infertile Ultisol, annual rainfall is about 2200 mm with 3-4 dry months from Nov to Feb, while the mean monthly temperature fluctuates from 16°C in Jan to 29°C in July.

About four years ago, a National Root and Tuber Crops Research Program was established by the Ministry of Agriculture of Vietnam in cooperation with some international organizations such as IDRC, CIP and CIAT. Cassava agronomy research has been conducted in collaboration with CIAT and has given the following results:

Intercropping Trials

In Vietnam cassava is generally intercropped with legumes and other economic crops. Intercropping is practiced in about 10% of the area in the north and 30-40% of the area in the south. In some slopy areas farmers intercrop cassava with grasses or trees to prevent soil erosion.

Intercropping research has been conducted at Hung Loc Center during the past four years using legumes and maize, with the objective of controlling weeds, preventing soil erosion, improving soil fertility and increasing income. **Figure 6** shows that cassava intercropping with peanut, with mungbean or with maize were the most promising systems. However, cassava monocropping gave higher economic returns than any of the intercropping systems and cassava planted in single rows gave higher profits than planting in double rows **(Figure 7).**

Three years of cassava intercropping trials at Agric. College #3 indicate that intercropping with peanut produced by far the highest total crop value **(Table 4).**

Method of Cassava Planting and Plant Bed Configuration

The objective of the research was to determine both the planting method and plant bed configuration most suitable for growing cassava under the local soil and climatic conditions. The trial was planted at the beginning of the rainy season. The average results for three years **(Figure 8)** show that there were no significant differences among treatments, but that cassava planted vertically and cassava planted on single ridges gave higher yields than the other treatments.

Long–term NPK trials

Long-term NPK trials have been conducted in both the north and the south on various soil types of Vietnam. After three years the results indicate that:

In the south, in the rather fertile red soil at Hung Loc Center, the response of the two varieties, HL 23 and HL 24, to N, P and K were not statistically significant even after three years of continuous cropping on the same field. However, on the sandy clay loam Ultisol at Agric. College #3 in Bac Thai the response of two varieties, Chuoi and Vinh Phu, to N, P and K were highly significant already in the first year of cropping; root yields were highest when the maximum amounts of N, P and K were applied **(Figure 9).**

Short term NPK trial

In 1992, a short-term NPK trial was conducted on poor soils at Thanh Hoa district of Vinh Phu province in order to determine the response of cassava to different levels of N, P and K. The data **(Table 5)** indicate that there was a clear response of cassava

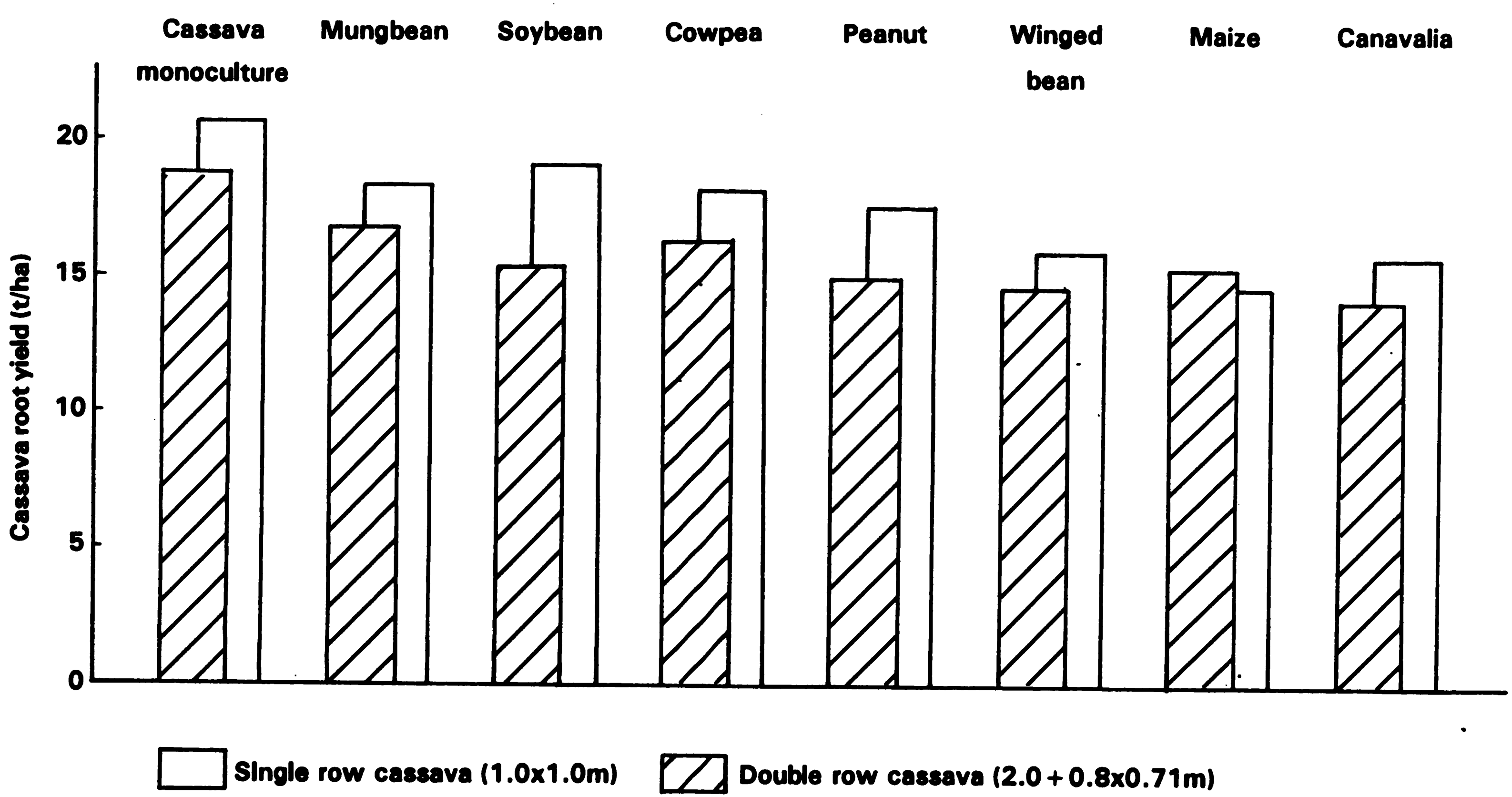

Figure 6. Effect of various intercropping systems on the yield of cassava planted either in a square planting arrangement of 1.0 x 1.0 m or in double rows of 2.0 x 0.8 x 0.71 m at Hung Loc Center, Dong Nai, Vietnam. Data are average values for 1989, 1990, 1991 and 1992.

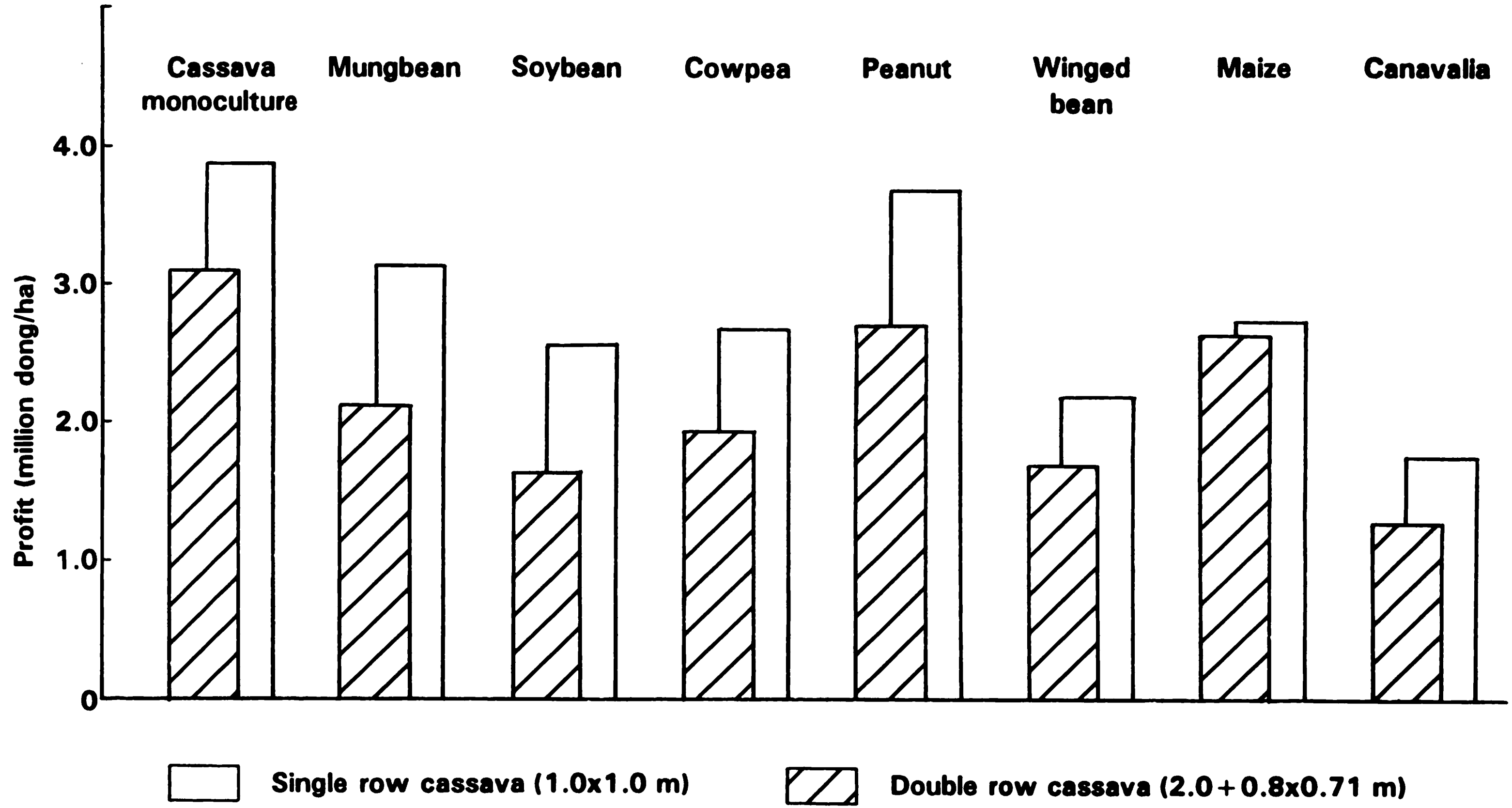

Figure 7. *Net profits obtained in various cassava intercropping systems evaluated at Hung Loc Research Center, Dong Nai, S. Vietnam. Data are average values for four years (1989-1993).*

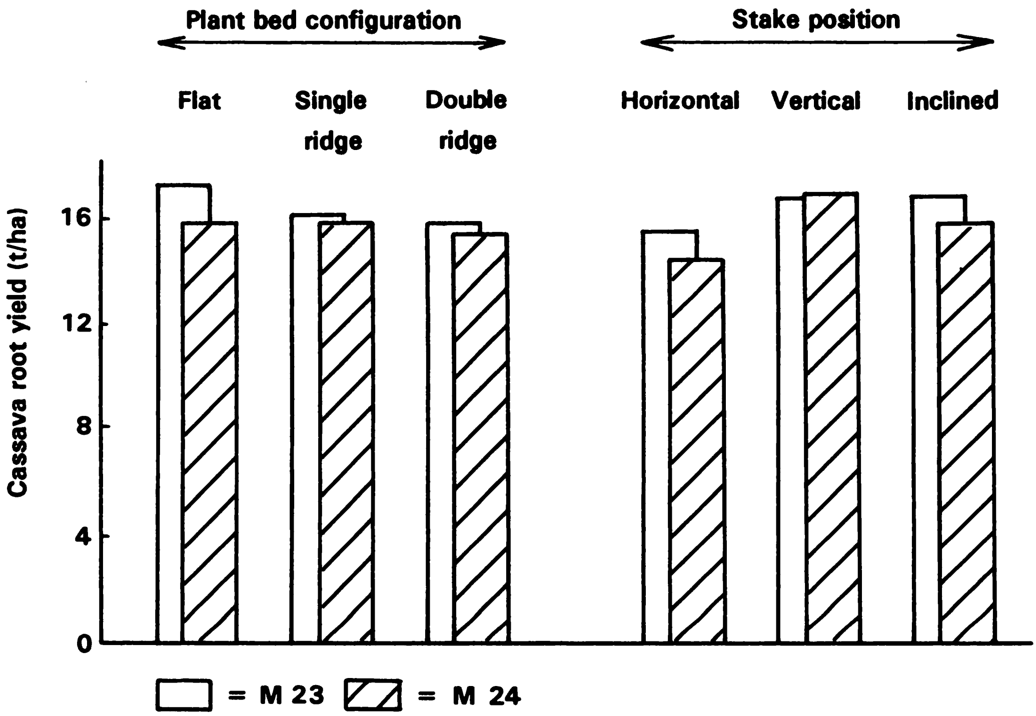

Figure 8. Effect of plant bed configuration or stake planting position on the yield of two cassava cultivars planted at Hung Loc Center, Dong Nai, Vietnam. Data are average values for 1989, 1990 and 1992.

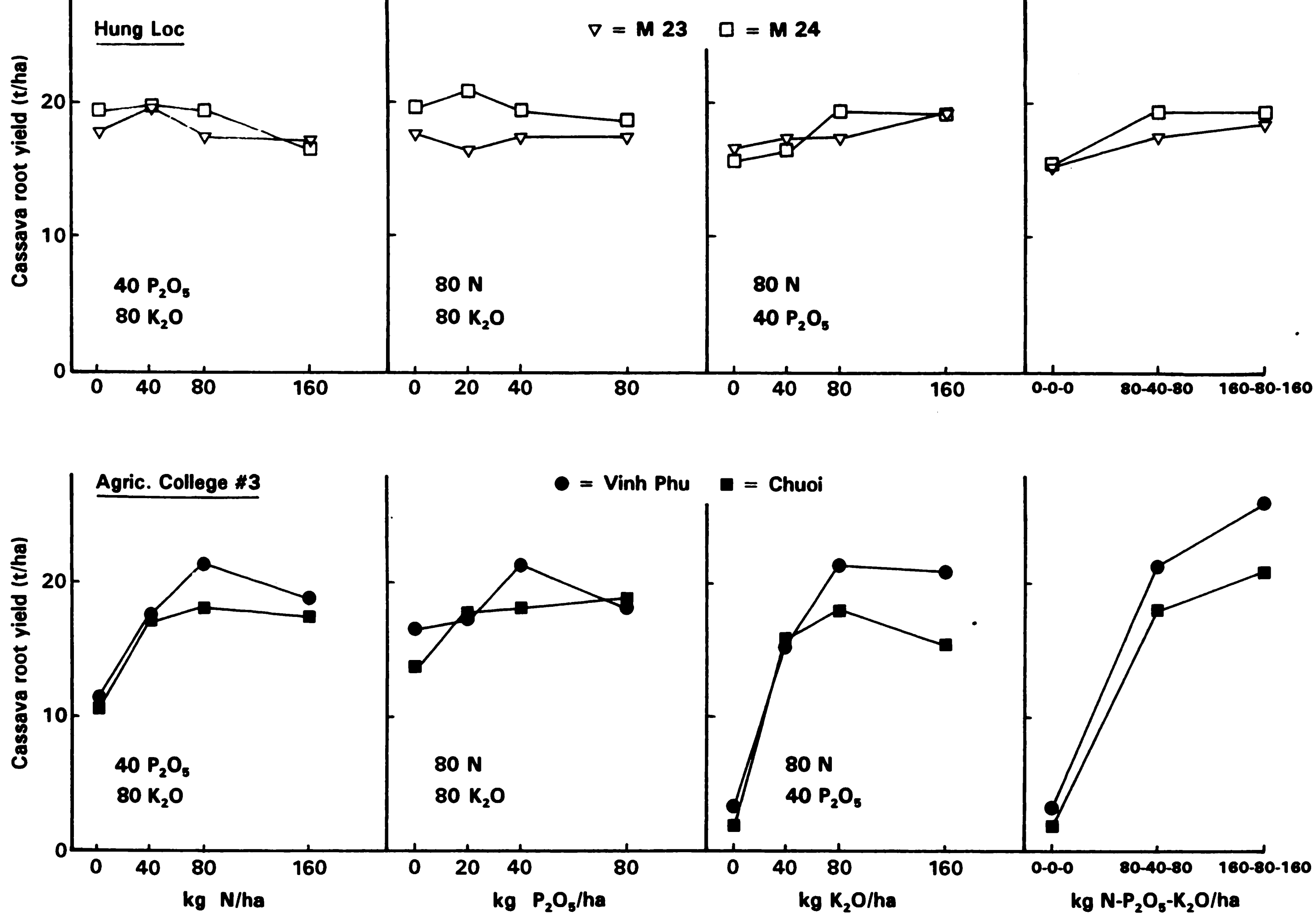

Figure 9. Effect of N, P and K application on the yield of two cassava cultivars planted in Hung Loc Center in Dong Nai province (top) and in Agric. College #3 in Bac Thai province (bottom) of Vietnam in 1992/93 (3rd year).

Table 4. Yields of cassava and intercrops as well as the corresponding crop value in various intercropping systems planted during three years in Agricultural College # 3 in Bac Thai, north Vietnam.

	Cassava yield (t/ha)				Intercrop yield (kg/ha)				Crop value ('000d)[1]		
	1990	1991	1992	Avg.	1990	1991	1992	Avg.	Cassava	Intercrop	Total
1. Cassava monoculture	17.6 a	30.8 a	17.1 a	21.8	-	-	-	-	4,905	-	4,905
2. " + peanut	17.0 a	31.0 a	13.5 ab	20.5	290	586	1,282	719	4,612	2,229	6,841
3. " + black bean	13.0 a	22.2 a	12.8 b	16.0	850	429	225	501	3,600	1,753	5,353
4. " + mungbean	17.0 a	32.8 a	14.9 ab	21.5	170	162	75	136	4,837	476	5,313
5. " + soybean	17.6 a	32.8 a	12.6 b	21.0	120	0	560	227	4,725	908	5,633
6. " + maize	12.0 b	31.4 a	11.8 b	18.4	600	640	2,610	1,283	4,140	1,411	5,551

[1] For average results of three years

Prices (1992) :	cassava	200-250 d/kg	
	peanut	3,000-3,200 d/kg	(in pods)
	black bean	3,500 d/kg	
	mungbean	3,500 d/kg	
	soybean	4,000 d/kg	
	maize	1,000-1,200 d/kg	

Table 5. Root yield at 10 months and nutrient concentrations in YFEL-blades at 6 months after planting cassava in Thanh Hoa, Vinh Phu in 1992.

$N-P_2O_5-K_2O$ Treatments	Root yield (t/ha)	Nutrient concentration (%) N	P	K
$N_{40}P_{40}K_{40}$	10.2	3.87	0.31	0.83
$N_{40}P_{40}K_{80}$	13.2	3.47	0.27	1.42
$N_{40}P_{40}K_{160}$	14.9	3.43	0.20	1.44
$N_{80}P_{80}K_{0}$	10.3	3.50	0.32	0.92
$N_{80}P_{80}K_{80}$	14.5	3.72	0.30	1.52
$N_{80}P_{80}K_{160}$	15.3	3.64	0.25	1.62

to fertilizer application, mainly to K. The K concentration in the YFEL-blades were very low in the treatments without K application.

FUTURE DIRECTION

According to the general conclusions of the National Cassava Workshop, held on Oct 29-Nov 1, 1992 in Hanoi, cassava agronomy research has to be conducted based on the conditions of each region, and the new technology needs to be transfered from on-station research to farmers' fields.

- Intercropping trials with the objectives of increasing cassava production, improvement of soil fertility and prevention of soil erosion, should be conducted in various regions, both in the north and in the south. The new cropping patterns with the greatest economic efficiency should be released to the farmers' fields as soon as possible.
- Long-term fertilizer trials: Using the soil map of Vietnam, soil analysis results and cassava field observations, and depending on the requests of farmers, these experiments can be conducted either on experiment stations or on farmers' fields.
- Planting method: The best planting position of stakes, which give highest yields on various soils, should be determined experimentally and then recommended to farmers.
- Time of cassava planting and age at harvest: Depending on the climatic conditions of the regions, experiments can be conducted at research stations and on farmers' fields for increasing both cassava production and quality.
- On-farm research: A research network has been organized on farmers' fields to improve the relationship between cassava researchers, as well as specialists from CIAT and other organizations, with the farmers in order to enhance the transfer of new technologies and the adoption of new promising varieties.

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RECENT PROGRESS IN CASSAVA VARIETAL IMPROVEMENT IN VIETNAM

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ABSTRACT

Cassava is after maize an important subsidiary crop in Vietnam. The amount of production used for human consumption is now only about 10-20%, that for animal feed increased to about 30%, for industrial processing about 30-40%, while about 20% is used for other requirements. Although in terms of area Vietnam is among the thirteen largest cassava producing countries in the world, its average yield is among the lowest in Asia. This is because cassava is considered a poor farmers' crop, which is generally neglected, both in research and in the production field.

Cassava breeding for high yield and high starch content and with adaptation to adverse soil and climatic conditions is the most important among the development strategies for cassava in Vietnam. KM-60 (Rayong 60) and promising clones selected from hybrid seeds are being tested in a network of on-farm evaluation trials throughout the country. This has been the result of close cooperation with CIAT since 1989. CIAT-introduced germplasm has already made a valuable contribution to the breeding program in Vietnam.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is grown throughout our country. In the past cassava was considered an important subsidiary crop, being used as a staple food for people, especially for those living in mountainous areas. In these regions cassava reached 43% of the total area devoted to food crops.

Since 1985 there has been an obvious change in the role cassava plays in the farming system. The results of the survey conducted in 1991 indicate that at present only about 10-20% of cassava production is used for human consumption. The amount used for animal feed increased to 30%, while 30-40% of total production is used as a raw material for processing and about 20% is used for other purposes.

Although cassava is an important crop, having strategical importance in the agriculture of Vietnam, especially in the rainfed areas, it is still not a well-developed crop. Because it is considered a poor farmers' crop, it has been neglected, both in research and in production fields.

Cassava breeding was part of the National Subsidiary Crops Research Program

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from 1980 to 1985. However, it focused only on collection and evaluation of indigenous cultivars and was not able to establish a research team for doing our own breeding.

A more comprehensive cassava breeding program started in 1988 in collaboration with CIAT. Cultivars and promising clones of the Thai-CIAT program were introduced. In addition, breeding materials in the form of hybrid seeds, both from CIAT headquarters and the Thai-CIAT program, have been introduced for selection at Hung Loc Research Center of the Institute of Agricultural Sciences of South Vietnam (IAS) and at the Agro-forestry Research and Development Center of the Agricultural College #3 (AC#3) in Bac Thai. The methodology for evaluation and selection, as well as the testing of promising lines followed the CIAT breeding scheme. A cassava breeding network has been established under the National Root and Tuber Crops Research Program in 1989.

VARIETAL IMPROVEMENT

Objectives

The following breeding objectives are being pursued:

- High yield potential and high dry matter and starch content in the roots.
- High harvest index.
- Early harvestability (9-10 months).
- Adaptation to acid unfertile soils and to low levels of inputs.
- Good plant type for association with other crops.

In the past farmers grew only sweet cultivars because cassava fresh roots were used mainly for human consumption. Presently, however, cassava is used mainly for animal feeding and processing and eating quality and HCN content are therefore only minor considerations in the breeding program.

Evaluation of Indigenous Cultivars

Within the National Subsidiary Crops Research Program local cassava cultivars were collected in the main cassava production areas of Vietnam.

Of the 22 cultivars that were collected and evaluated at Hung Loc Research Center, HL-20 was found to be the best one in terms of fresh root yield and starch yield, followed by HL-24 and HL-23 **(Table 1)**. These good local cultivars are now grown in a significant proportion of the cassava area in south Vietnam **(Table 2)**.

In the north, among 15 local cultivars collected and evaluated at the Agricultural College #3 in Bac Thai, Vinh Phu was found to be higher in fresh root yield and starch yield than other sweet cultivars, while the cultivar Du was the best one among the bitter cultivars **(Table 3)**. Vinh Phu has been recommented and is now planted by more than 50% of farm families in 11 provinces in the north **(Table 2)**.

Table 1. Yield potential of local cultivars in south Vietnam.[1)]

Group	Cultivar (local name)	Collection code	Starch yield (t/ha)	Fresh yield (t/ha)	Starch content (%)
Sweet	Gon Long Thanh (Mi Trang)	HL-20	8.9	29.8	29.2
	Trang Quang Ngai	HL-24	8.5	32.1	26.5
	Trang Thai Lan	HL-23	7.5	29.8	25.0
	Bun Cam Ranh	HL-22	7.2	28.3	25.4
	San Nep	HL-12	7.1	24.5	29.1
	Ba Thang Bien Hoa	HL-19	6.9	26.3	26.4
	Gon Hung Loc	HL-18	6.7	23.5	28.7
	Gon Phan Nhanh Cu Chi	HL-11	6.2	24.3	25.5
	Ba Thang Hoc Mon	HL-16	6.1	24.0	25.3
	Ba Thang Binh Chanh	HL-1	5.9	25.6	23.0
	Gon Ha noi	HL-2	5.6	22.8	24.4
	Bun Ham Tan	HL-13	5.2	18.5	28.3
	Gon Chia Thuy	HL-15	3.9	15.3	25.6
	Gon Binh Duong	HL-17	3.8	13.7	27.7
	Cu Chi	-	3.5	17.7	19.5
Bitter	Mi San Ham Tan	HL-21	7.5	25.0	30.0
	Tau Mo	HL-5	6.8	25.6	26.7
	An Do Dong Nai	HL-3	5.6	22.9	24.6
	An Do Phu Khanh	HL-7	5.2	18.5	27.9
	An Do Cam Ranh	HL-8	4.6	18.4	25.0
	An Do Binh Duong	HL-14	4.5	16.7	27.0
	An Do Ham Tan	HL-9	3.3	15.3	21.5

[1)] Data taken from yield trials conducted at Hung Loc Research Center in 1983-1986.

Table 2. Cultivar distribution in representative cassava growing regions in Vietnam (% in each region).

Cultivar (Local name)	Region					
	Northern Mountain Region	Red River Delta	North Central Coast	South Central Coast	Central Highland	South-eastern Region
Mi Xanh (Vinh Phu)	51.2	4.2	9.8	0	0	0
Mi Trang	16.0	92.7	27.5	0	0	0
Chuoi	12.9	0	0	0	0	0
Maw	0	2.1	6.9	0	0	0
Du	1.4	0	2.0	0	0	0
Ha Bac	1.1	0	2.5	0	0	0
Gon (Mi Do)	7.7	1.0	11.8	6.6	2.0	12.4
H-34	0	0	9.6	28.2	77.0	6.8
HL-20	0	0	0	0	0	33.6
HL-23	0	0	0	36.3	0	8.2
HL-24	0	0	0	0.7	21.0	30.9
Others	9.8	0	30.0	28.2	0	8.1

Table 3. Yield potential of local cultivars in north Vietnam.[1]

Group	Cultivar (Local name)	Collection code	Starch yield (t/ha)	Fresh yield (t/ha)	Starch content (%)
Sweet	Xanh Vinh Phu	VC-2	8.7	24.4	35.6
	Bun Trang	VC-6	7.7	24.2	31.8
	Chuoi Trang	VC-5	7.7	25.0	30.7
	Xanh Ha Bac	VC-3	6.7	20.5	32.5
	Canh Nong	VC-1	6.6	21.6	30.8
	Chuoi Do	VC-4	6.3	21.2	29.8
	Ha Nam	VC-8	6.1	18.9	32.3
	Trang	VC-9	5.5	18.1	30.5
	Gon	VC-10	5.4	18.9	28.3
	Nghe	VC-7	5.4	14.8	30.0
Bitter	Du	VC-11	8.8	28.8	30.7
	Than Den	VC-15	6.7	24.7	27.3
	202	VC-12	6.1	28.9	26.6
	205	VC-13	5.9	25.2	23.5
	H-34	VC-14	3.8	15.1	25.5

[1] Data taken from yield trials conducted at AC#3 in 1983-1985.

Progress in Cassava Varietal Improvement in Collaboration with CIAT

Since cassava is vegetatively propagated, superior genotypes identified in a seedling population can be maintained genetically stable indefinitely. Vegetative propagation combined with sexual reproduction allows a reliable estimate of the environmental and genotypic variation given that in-breeding is quite deleterious (Kawano *et al.,* 1978).

After the introduction of a number of foreign cultivars into a region, the selection of the most adapted is a very simple and low-cost approach to crop improvement (Bueno, 1985). Sixteen promising clones were introduced from Thailand in the form of stem cuttings, after which they were evaluated both at Hung Loc Research Center (characterized by a seasonally dry climate in south Vietnam) and at AC#3 (characterized by a subtropical climate in north Vietnam). Criteria for evaluating these clones include high yield potential, high root dry matter content, high harvest index and high starch content. The results of intensive evaluations of these materials at Hung Loc Center have shown that the most promising clones have a higher yield capacity and higher root dry matter content than the best indigenous cultivars **(Table 4).** Similar results have been obtained in the north. Initial evaluation results at Agricultural College #3 suggest that Rayong 60 has a significantly higher fresh root yield and root dry matter content than the best local cultivar, Vinh Phu **(Table 5).**

Table 4. Evaluation of clones introduced from the Thai–CIAT program and evaluated at Hung Loc Research Center. [1]

Clone	Origin		Dry root yield (t/ha)	Fresh root yield (t/ha)	RDMC[2] (%)	Total plant weight (t/ha)	HI
	Hybridization	Initial Selection					
Kasetsart 50	Thai-CIAT	Thai	11.5	30.0	38.3	48.4	0.62
Rayong 60	Thailand	Thai-CIAT	10.4	27.4	38.0	44.2	0.62
CM6125-125	CIAT HQ	Thai-CIAT	10.0	27.5	36.3	43.7	0.63
MKUC28-71-66	Thai-CIAT	Thai-CIAT	9.8	25.4	38.6	40.3	0.63
CM4785-29	CIAT HQ	Thai-CIAT	9.3	24.9	37.3	38.9	0.64
CM4231-32	CIAT HQ	Thai-CIAT	9.3	24.4	38.1	36.4	0.67
CM6125-129	CIAT HQ	Thai-CIAT	9.0	24.4	36.9	42.8	0.57
CM6125-117	CIAT HQ	Thai-CIAT	8.3	22.1	37.5	37.5	0.59
Rayong 3	CIAT HQ	Thailand	8.1	20.8	38.9	28.9	0.72
CM5262-27	CIAT HQ	Thai-CIAT	8.0	21.6	37.1	36.6	0.59
CM5257-33	CIAT HQ	Thai-CIAT	7.9	20.9	37.8	30.7	0.68
Rayong 1	Thai Traditional		7.8	20.9	37.4	47.5	0.44
CM5604-21	CIAT HQ	Thai-CIAT	7.2	19.6	36.8	33.2	0.59
HL-24	(Local control)		6.9	19.2	35.9	41.7	0.46
HL-23	(Local Control)		5.8	15.9	36.4	28.9	0.55

[1] Mean of three yield trials conducted at Hung Loc Research Center, Dong Nai, Vietnam in 1989-1992.
[2] Root dry matter content.

Table 5. Result of Advanced Yield trial at Agric. College #3, Bac Thai, north Vietnam.

Clones	Dry yield (t/ha)	Fresh yield (t/ha)	RDMC (%)	Starch (%)	HI
Rayong 60	11.0	28.6	38.7	25.8	0.55
Rayong 1	9.8	29.2	33.6	21.0	0.54
Vinh Phu (check)	9.1	25.8	35.4	23.3	0.57
CM5262-27	9.0	23.2	38.6	24.7	0.48
MKVC28-71-66	8.3	22.4	37.2	22.3	0.44
MKVC28-77-3	8.2	23.1	35.5	19.7	0.64
Rayong 3	7.3	20.7	35.4	24.9	0.55
MKVC28-71-67	7.2	20.3	35.5	20.3	0.65
CM5604-21	6.6	19.0	35.0	20.4	0.61
CM4231-32	6.6	20.6	32.0	19.4	0.63
CM6125-117	6.1	17.5	35.1	20.9	0.63
CM5257-33	6.1	17.2	35.8	24.3	0.73
CM4785-29	6.0	16.9	35.7	22.8	0.63
CM4054-40	5.8	16.5	35.1	19.3	0.59
CM6125-129	5.3	16.3	33.0	16.6	0.66
Hanatee	5.2	14.8	35.6	23.1	0.39
CM6125-125	4.9	15.8	31.2	15.0	0.64

Some of these advanced clones also gave very good results in a network of on-farm trials and on-farm evaluations. Especially Rayong 60 was found to be an outstanding cultivar **(Table 6 and 7).**

Table 6. Results of on-farm trials conducted by Hung Loc Research Center in south Vietnam, 1991/92.

Clone	Fresh root yield (t/ha) on the farm of								
	A	B	C	D	E	F	G	H	Mean
Rayong 3	12.3	12.5	13.8	14.2		13.2			13.2
Rayong 60		16.8			17.4		17.2	18.6	17.5
CM5257-33		10.5	12.1	12.1					11.6
CM6125-117	14.7	13.7	16.7	16.4	16.7	15.7			15.7
CM6125-125	17.1	16.2	19.6	18.6	20.0	17.8			18.2
CM6125-129	15.6	13.4	18.4	15.8	15.4	14.6			15.5
MKUC28-71-66	16.4	14.6				16.4			15.8
HL-23			12.6	13.7	12.3		18.0	15.3	14.4
HL-24	10.6		11.8	14.8	14.5	10.4	13.8	12.2	12.6
Gon		11.0				8.4	8.9		9.4

Table 7. Results of on-farm trials conducted by Agric. College #3 in north Vietnam in 1992.

Clones	Fresh root yield (t/ha) on the farm of						
	A	B	C	D	E	F	Mean
Rayong 60	16.3	17.0	15.2	19.4	-	-	16.9
CM5262-27	16.0	-	11.7	-	-	-	13.8
MKUC28-71-67	15.6	11.1	-	-	-	-	13.3
HL-19	14.3	-	13.7	-	7.7	8.4	11.0
CM4785-29	-	-	-	-	14.5	16.0	15.2
CM4231-32	-	-	-	-	11.0	13.5	12.2
Vinh Phu	15.0	14.8	9.5	9.5	9.5	10.7	12.8
Rayong 1	20.7	5.7	14.0	14.0	-	-	13.5

Based on these results, Rayong 60 was officially registered at the National Seed Board to be evaluated in a network of on-farm evaluation and varietal multiplication trials jointly managed by IAS, the Root and Tuber Crops Research Center and AC#3. It is expected that Rayong 60 will be the first new successful variety selected by the breeding program in Vietnam in collaboration with CIAT.

In addition, genetic material in the form of hybrid seeds from CIAT were first introduced to Hung Loc Center and AC#3 in 1989 and 1990, respectively, and on an annual basis after that. Evaluation and selection followed a scheme as shown in **Figure 1.**

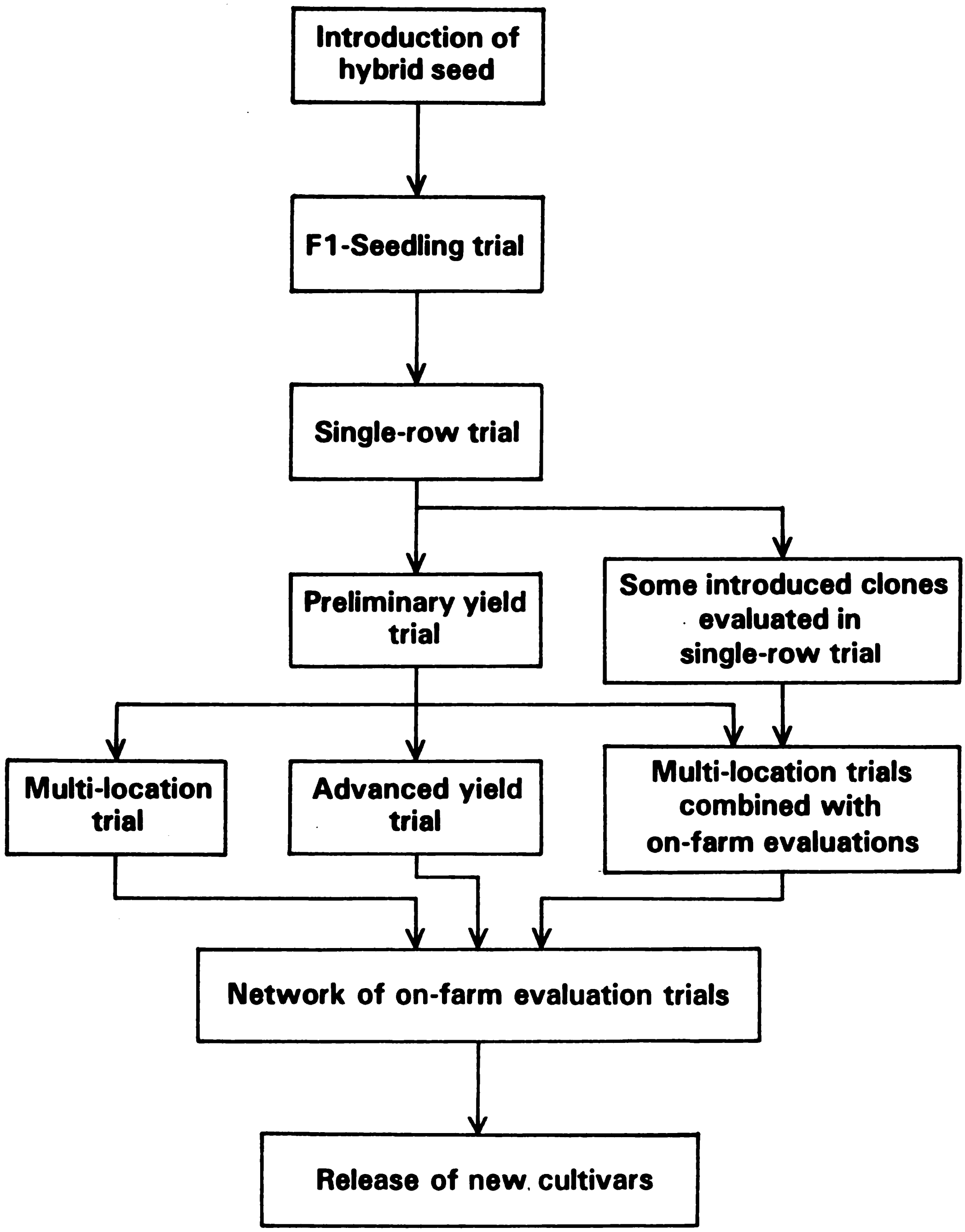

Figure 1. Schematic presentation of the evaluation and selection scheme of the CIAT cassava seed introductions.

Through this intensive selection at Hung Loc Center and at AC#3 very promising breeding lines were identified, as indicated in **Tables 8** and **9.**

Table 8. Result of an Advanced Yield trial at Hung Loc Research Center, based on selections from hybrid seeds introduced from CIAT/Colombia and the Thai-CIAT program in 1992/93.

Lines	Parents	Dry root yield (t/ha)	Fresh root yield (t/ha)	Root dry matter content (%)	Root starch content (%)	Total biomass (t/ha)	HI
SM1141-5	CG879-19	11.1	29.1	38.1	27.3	47.7	0.61
OMR32-02-3	CM681-2	10.5	29.4	35.6	23.8	50.7	0.58
Rayong 60	MCol1684xR1	10.1	26.4	38.2	27.4	43.3	0.61
SM1096-10	CM3435-5	9.7	25.4	38.0	27.1	42.3	0.60
SM902-5	CM507-37	9.6	25.5	37.7	26.7	45.5	0.56
SM1129-2	CM1491-5	9.5	24.7	38.3	27.7	53.7	0.46
OMR32-06-3	Rayong 90	9.4	26.0	36.1	24.7	41.9	0.62
SM948-11	CG5-79	9.0	25.7	35.2	23.2	46.0	0.56
SM1157-1	CM2902-36	8.1	22.4	36.3	24.7	32.9	0.68
OMR32-13-9	CMR25-32-5020	8.0	21.5	37.0	25.7	33.6	0.64
SM1095-7	CM3405-1	7.6	22.7	33.6	20.9	37.0	0.60
SM981-3	CM2563-5	7.4	20.7	35.8	24.0	41.4	0.50
SM981-2	CM2563-5	6.9	19.3	35.5	23.7	32.2	0.60
SM1135-8	CM3624-1	6.7	17.4	38.3	27.6	33.5	0.52
SM1157-3	CM2902-36	6.7	16.9	34.6	22.2	36.1	0.54

Table 9. Result of a Replicated Yield trial at Agric. College #3 in north Vietnam, based on selections from hybrid seeds introduced from CIAT/Colombia in 1989.

Lines	Parents	Dry root yield (t/ha)	Fresh root yield (t/ha)	RDMC (%)	Root starch content (%)	Total biomass (t/ha)	HI
SM1223-1	CM2174-7	12.82	38.5	33.3	20.8	65.03	0.59
SM1090-8	CM3299-4	10.59	26.3	40.3	29.3	47.26	0.56
SM1072-3	MCub18	10.35	36.2	28.6	14.4	66.86	0.54
SM1193-1	CG1420-1	8.91	29.8	29.9	15.1	54.16	0.54
SM1073-3	MCub32	8.27	22.8	36.3	24.8	44.20	0.51
SM1200-8	CM3299-4	8.14	22.7	35.9	24.6	41.23	0.54
Vinh Phu (Local cultivar)		6.54	19.2	34.1	22.7	36.30	0.50

*These six clones were selceted among 29 entries for the Advanced Yield trial.

These results suggest that a comprehensive cassava varietal improvement program based on CIAT hybrid seed material, will steadily develop in Vietnam.

Need For a Cassava Breeding Network and Cooperative Research

Cassava varietal improvement in Vietnam will not achieve much without the breeding materials from CIAT. The role of CIAT in providing genetic materials to nations like Vietnam with scarce genetic resources has already been emphasized. Therefore, cooperative research and the exchange of breeding materials among Asian nations under the coordination of CIAT will continue to play an important role in helping national programs achieve their objectives.

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ON-FARM RESEARCH AND TRANSFER OF TECHNOLOGY FOR CASSAVA PRODUCTION IN VIETNAM

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ABSTRACT

In Vietnam, extension activities are considered by the government as an urgent and long-term measure, that has a great influence on the production process of farmer commodity production. Among extension objectives, cassava production is given great importance in those areas where appropriate conditions for its development exist.

This paper presents an overview of the extension strategy, structure and organization in Vietnam, the linkage of national cassava research and extension organizations, and the objectives and methods of extension activities in Vietnam.

This paper also analyzes in detail the results of on-farm research and transfer of technology for cassava production conducted by the Hung Loc Agricultural Research Center. Among the initial achievements is the release of cassava varieties HL-20, HL-23 and HL-24, which are now grown in thousands of hectares every year. A cultural technique of intercropping cassava with mungbean, peanut and winged bean has obtained satisfactory results, contributing to increased farmer income and the maintainance of soil fertility.

Cassava germplasm introduced from the Thai-CIAT program is very promising, in particular Rayong 60. This variety is now released by MAFI for multi-locational field trials and dissemination in production fields. A research and extension network for cassava production in Vietnam has been established by linking the National Food Crops Program with the National Extension Program with the support of international organizations such as CIAT, CIP and IDRC. Through this network, new cassava varieties and advanced cultural techniques will be transferred to production fields very quickly.

INTRODUCTION

In the assessment and planning of agricultural and rural development of Vietnam up to the year 2000, food production will still be the most important and strongest production branch. The Vietnamese government has chosen a strategy of increasing rice and maize production, and at the same time of attaching great importance to the

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production of cassava, sweet potato and Irish potatoes "in those areas and in those seasons having appropriate conditions for their development" (Nguyen Cong Tan, 1993).

The cassava planting area in Vietnam during the coming years will not be increased, but will still range from 200,000 to 300,000 ha; however, cassava yields will increase by the adoption of new cassava varieties and more intensive cultural practices.

On-farm research and transfer of technology for cassava production are key factors for cassava development. They are an important bridge linking science with production.

Overview of Technology Transfer Strategy, Structure and Organization in Vietnam

In recent years, agricultural production in Vietnam has made greater progress than in previous periods. Farmers' households have become autonomous economic units, constituting a dynamic and strongly motivated force for developing the rural economy. Extension activities have received more attention and have become an effective means of technology transfer for increased production.

At the end of 1992, The Ministry of Agriculture and Food Industry (MAFI) established a National Extension Program and Extension Divisions in different ecological zones, linking extension organizations of Provincial Extension Centers, Institutes and Universities into a strongly organized system from the national down to the village level (Ngo The Dan, 1992).

In addition to the development of the national extension system, the government encourages the establishment of volunteer extension organizations by scientists, economists, business men and individuals (Nguyen Cong Tan, 1993).

The Vietnamese government considers that agricultural extension is an urgent and long-term measure, which has a great influence on the development of farmer commodity production and on rural reconstruction.

Extension objectives

1. To disseminate agricultural development strategies, policies and rural reconstruction.
2. To diffuse agricultural technical progress adapted to the ecological and economic conditions of farmer households.
3. To inform about prices and markets of agricultural products.
4. To diffuse experiences of good model farmers.
5. To develop new technologies for farmers.
6. To supply inputs (varieties, fertilizers, insecticides, fungicides, herbicides, production management ...) and outputs (preservation, processing, products consumption) in

accordance with farmers' needs.

Extension methods

1. Establish demonstration models.
2. Organize visits and exchange technical information with good farmers.
3. Organize technical training for farmers in the field.
4. Disseminate new technologies and new knowledge through leaflets, panels, hand books, newspaper, radio and television.
5. Promote competition, selection, recognition, praise and rewards for good model farmers.
6. Establish professional associations and good farmers clubs.

The extension methodology used by the Institute of Agricultural Science of South Vietnam (IAS) are summarized in the following 10 letters T (in Vietnamese):

1. Thu nghiem	Trials
2. Trinh dien	Demonstrations
3. Tap huan	Training
4. Trao doi	Exchange
5. Tham vieng	Farmer tours
6. Tham quan, hoi nghi dau bo	Farmer field days
7. Thong tin tuyen truyen	Information, propaganda
8. Thi dua	Competition
9. Tong ket khen thuong	Recognition, praise and reward
10. Thanh lap mang luoi nguoi nong dan gioi	Establish good farmers' network

Extension budget

The budget for extension activities comes from the following sources:

1. Government investment.
2. Investment of Agricultural Products Trade Companies.
3. Investment from extension activities.
4. International organizations, countries and non-governmental organizations (NGOs).

Linkage of Cassava Research and Extension Organizations in Vietnam

The organizational diagram for the linking of cassava research and extension activities in Vietnam is presented in **Figure 1**, while the research and technology transfer process for cassava production in Vietnam is depicted in **Figure 2**.

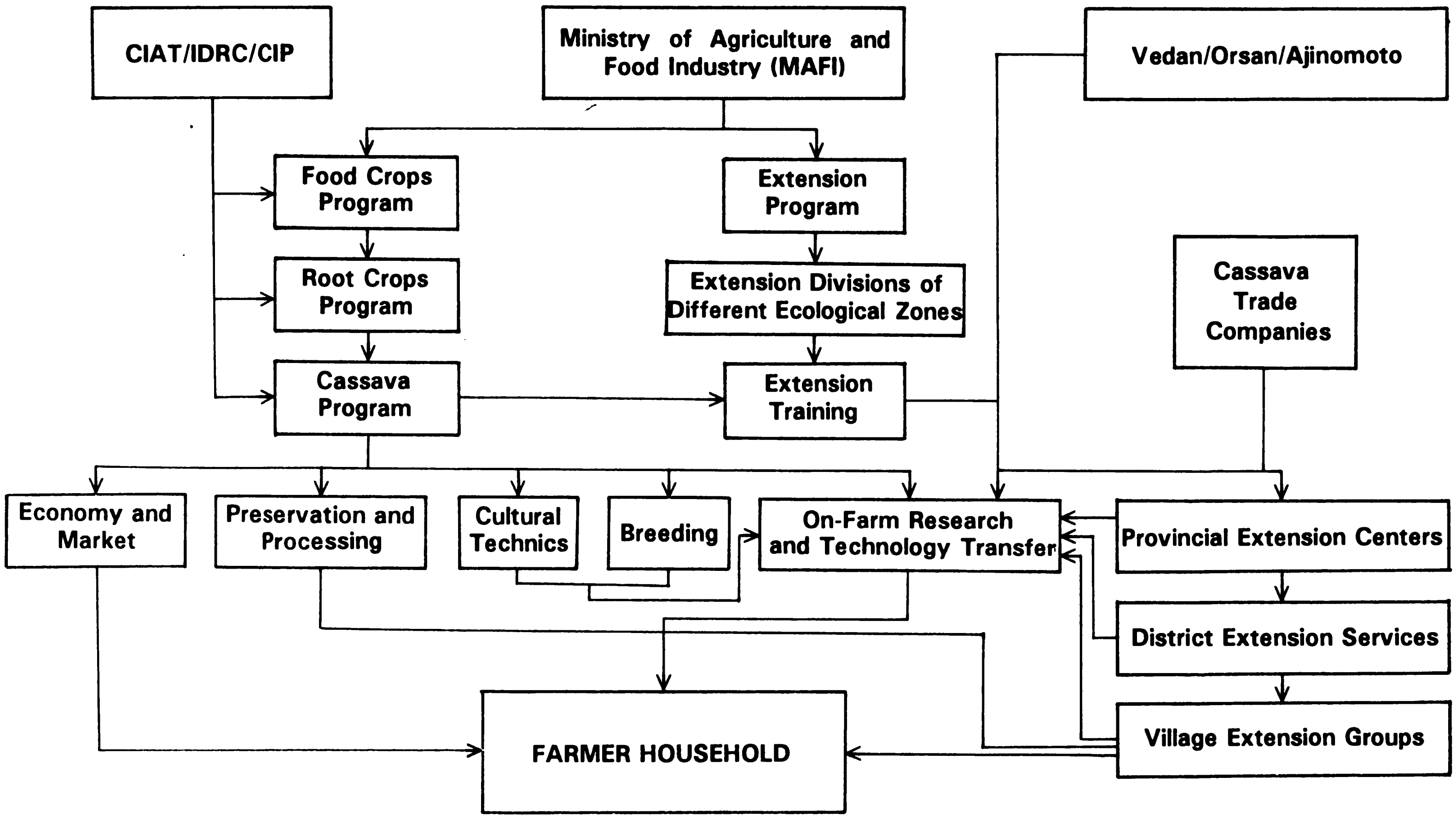
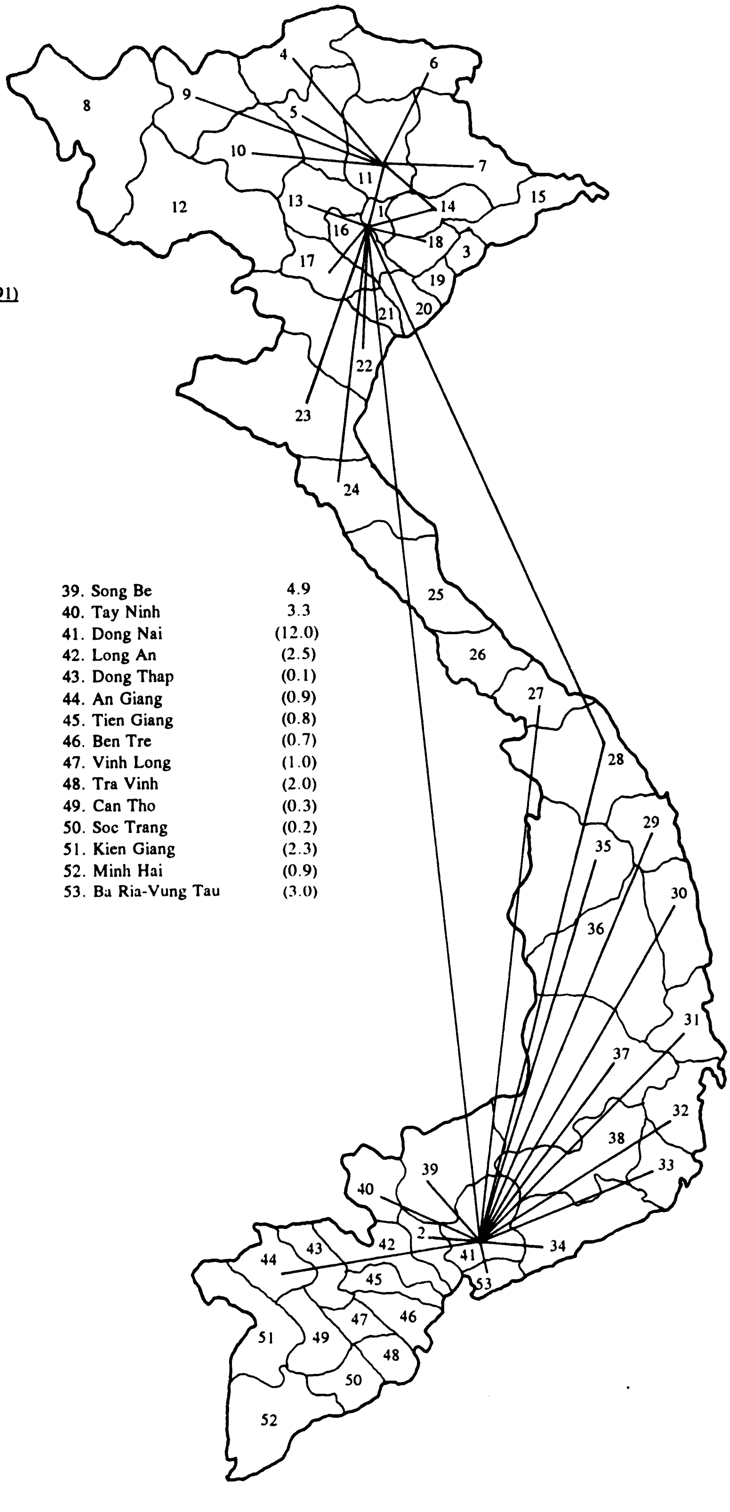


Figure 1. Coordination of cassava research and extension organizations in Vietnam.



Provinces	'000 ha (1991)
1. Ha Noi	-
2. Ho Chi Minh	0.7
3. Hai Phong	(0.3)
4. Ha Giang	(5.5)
5. Tuyen Quang	(7.0)
6. Cao Bang	1.9
7. Lang Son	3.8
8. Lai Chau	7.5
9. Lao Cai	4.5
10. Yen Bai	10.5
11. Bac Thai	4.9
12. Son La	12.7
13. Vinh Phu	12.5
14. Ha Bac	8.1
15. Quang Ninh	(3.3)
16. Ha Tay	4.3
17. Hoa Binh	8.7
18. Hai Hung	(0.3)
19. Thai Binh	(0.1)
20. Nam Ha	(0.5)
21. Ninh Binh	(1.6)
22. Thanh Hoa	14.4
23. Nghe An	11.8
24. Ha Tinh	2.8
25. Quang Binh	4.0
26. Quang Tri	3.5
27. Thua Thien-Hue	6.2
28. Quang Nam-Da Nang	17.5
29. Quang Ngai	12.0
30. Binh Dinh	10.9
31. Phu Yen	4.7
32. Khanh Hoa	8.2
33. Ninh Thuan	(2.8)
34. Binh Thuan	(3.5)
35. Kon Tum	(6.0)
36. Gia Lai	(8.0)
37. Dac Lac	4.8
38. Lam Dong	2.1
39. Song Be	4.9
40. Tay Ninh	3.3
41. Dong Nai	(12.0)
42. Long An	(2.5)
43. Dong Thap	(0.1)
44. An Giang	(0.9)
45. Tien Giang	(0.8)
46. Ben Tre	(0.7)
47. Vinh Long	(1.0)
48. Tra Vinh	(2.0)
49. Can Tho	(0.3)
50. Soc Trang	(0.2)
51. Kien Giang	(2.3)
52. Minh Hai	(0.9)
53. Ba Ria-Vung Tau	(3.0)

Figure 2. The research and technology transfer network for current cassava production in Vietnam.

On-Farm Research and Transfer of Technology for Cassava Production in South Vietnam: A Case Study of Hung Loc Agricultural Research Center.

During the past ten years (1980-1990), Hung Loc Agricultural Research Center has collected local cassava germplasm, and from this has selected and recommended three cassava cultivars: HL-20, HL-23 and HL-24. At the same time, the Center has studied mungbean, peanut and winged bean as intercrops with cassava to increase the farmers income and contribute to the maintenance of soil fertility in cassava fields. Since 1991 we have cooperated with CIAT to carry out preliminary on-farm trials of promising new cassava varieties and more intensive cultivation techniques for the major cassava producing areas of the Southeastern Region.

The strategy for on-farm research and transfer of technology for cassava production, used by the Hung Loc Center, is illustrated in **Figure 3.** The cassava research and development program in cropping systems is following the methodology for on-farm cropping systems research proposed by IRRI (Zandstra *et al.*,1981; Carangal, 1990) and the Agro-ecological Systems Analysis methods of Conway (1986).

1. Collection and Analysis of Basic Data of the Southeastern Region on Cassava Production and Marketing

The basic characteristics of climate and soils of the region are shown in **Figures 4** and **5.** The 12 leading districts for cassava production of the Southeastern Region are: Thong Nhat, Long Thanh and Xuan Loc districts of Dong Nai province; Thuan An, Ben Cat and Dong Phu districts of Song Be province; Hoa Thanh, Duong Minh Chau and Tan Bien districts of Tay Ninh province; and Chau Thanh, Xuyen Moc and Long Dat districts of Baria-Vung Tau province, as shown in **Figure 6.** Among these, Thong Nhat is the most important cassava producing district in terms of concentration of cassava production areas; in 1991, the area planted to cassava was 4650 hectares.

The results of 219 household surveys on cassava production in the Southeastern Region, conducted in 1990 (out of a total of 592 surveys conducted in south Vietnam - Pham Van Bien *et al.*, 1992), as well as 180 surveys on cultivation techniques and economics of root crops in the Southeastern Region, conducted in 1992 (out of a total of 420 surveys conducted in south Vietnam - Hoang Kim *et al.*, unpublished) showed that cassava soils in south Vietnam in general, and in the Southeastern Region in particular, are poor in nutrients, subject to severe erosion and they are poorly fertilized. In about 48% of the cassava growing area in the South Central Coast and the Southeastern Region, cassava is intercropped with maize, grain legumes and others crops **(Table 1).** The percentage of cassava farmers growing cassava in association with grain legumes in these regions is about 16%, but this could be further expanded. The most common cassava cultivars used are H-34 and Gon **(Table 2)** (Hoang Kim, 1992).

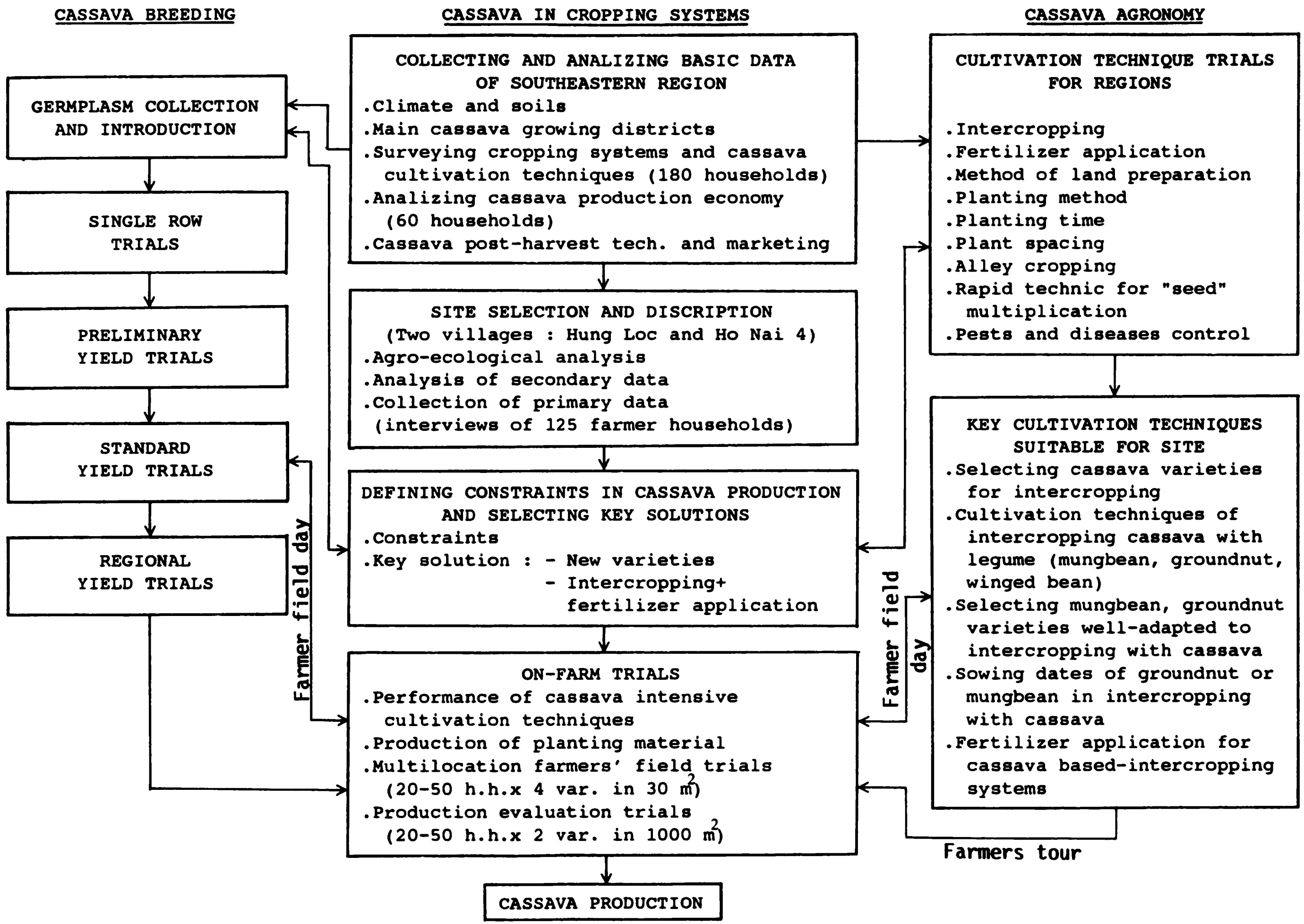


Figure. 3. Strategy for on-farm research and transfer of technology for cassava production in the Southeastern Region: A case study conducted by Hung Loc Agricultural Research Center.

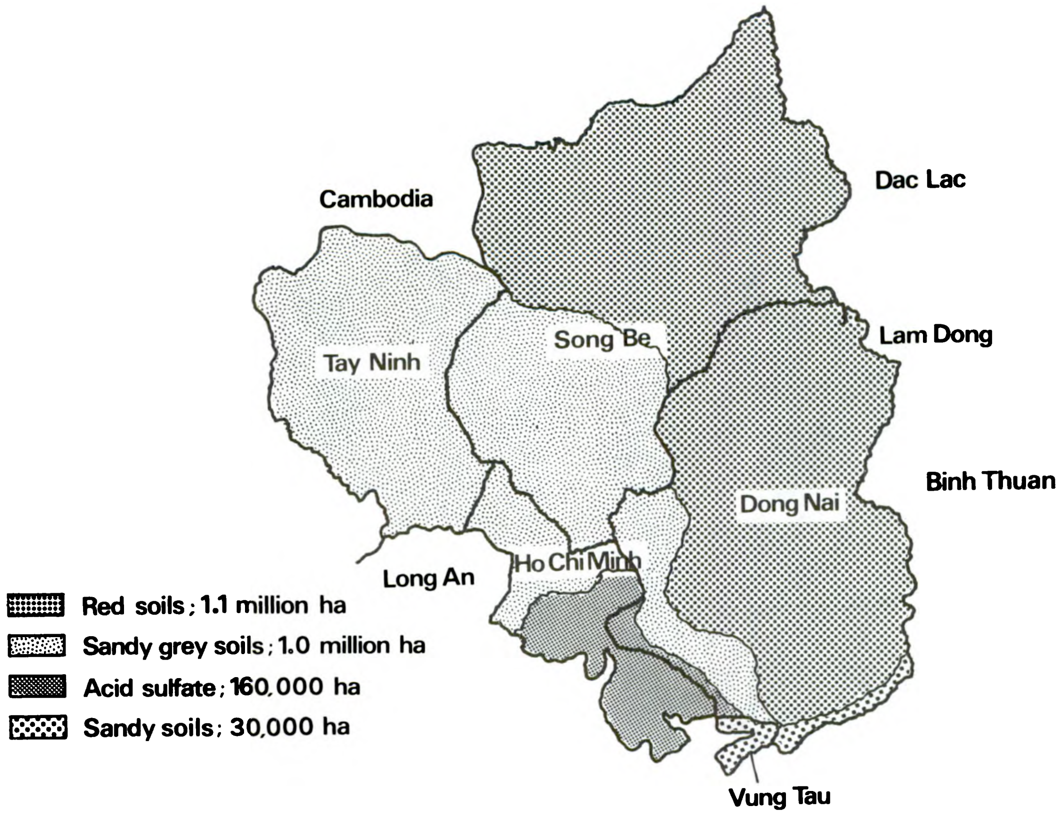
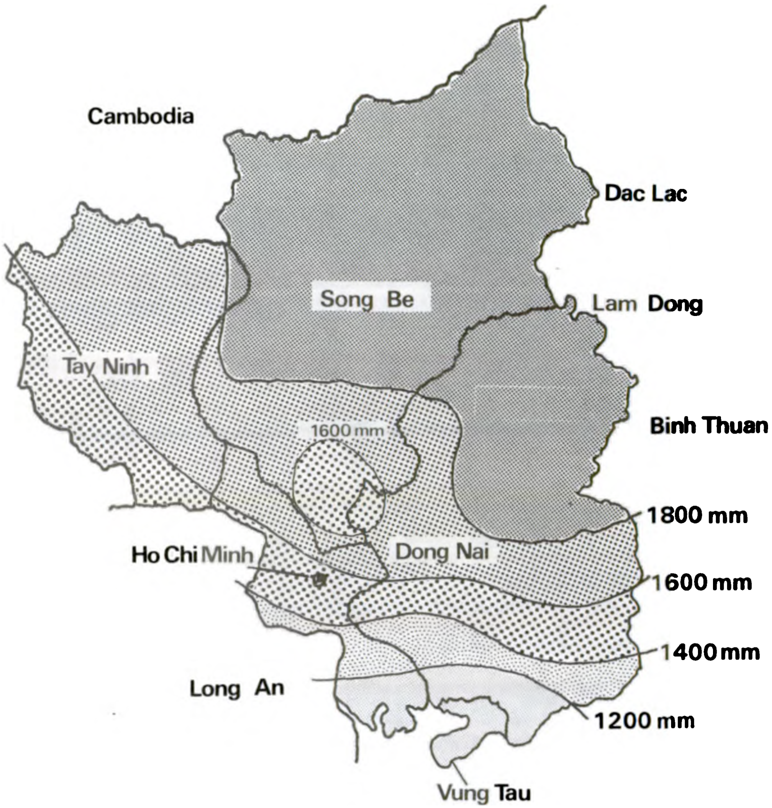


Figure 4. Distribution of soils in Song Be, Tay Ninh, Baria-Vung Tau provinces and Ho Chi Minh city of the Southeastern region of Vietnam.

Source : *Phan Lieu et al., 1992.*



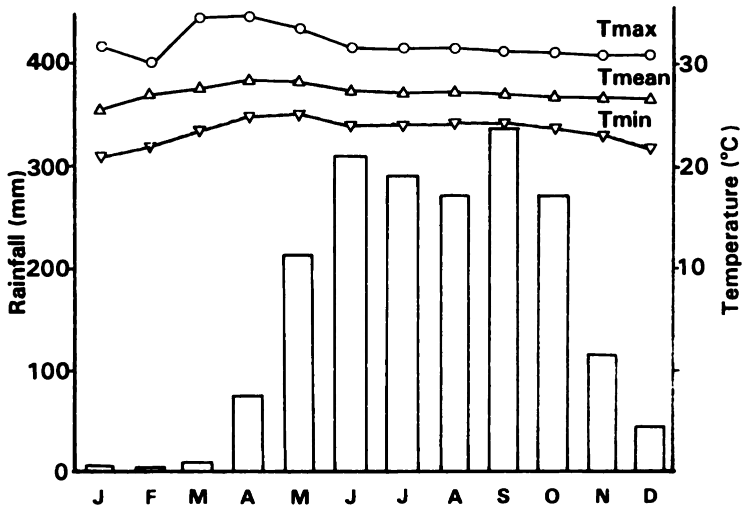


Figure 5. Isohytes for the mean annual rainfall in Song Be, Tay Ninh, Dong Nai and Baria-Vung Tau provinces and Ho Chi Minh city of the Southeastern region of Vietnam. At right are average rainfall distribution and temperature for Ho Chi Minh city.

Source: *Hoang Kim, 1992.*

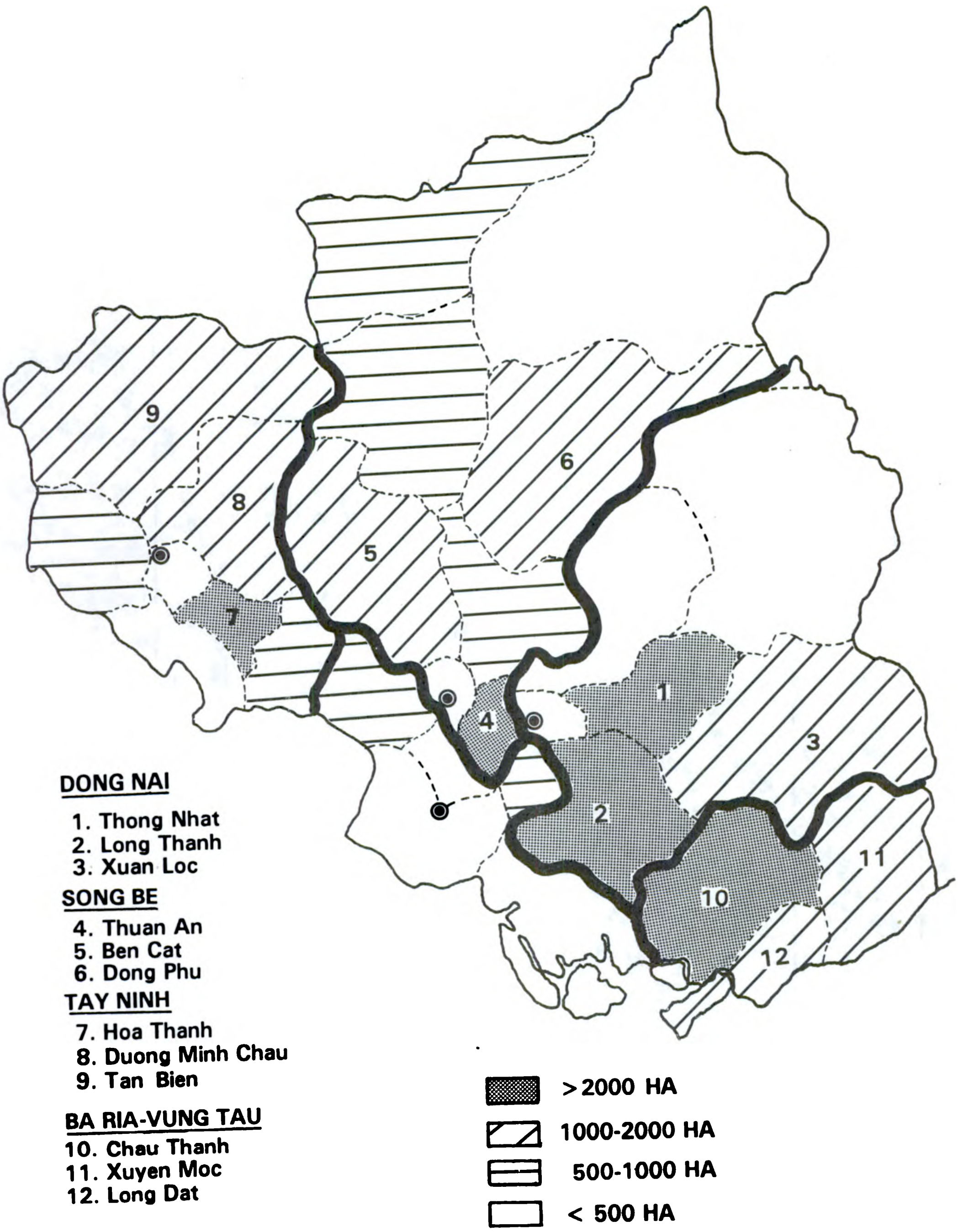


Figure 6. Cassava growing districts of the Southeastern region of Vietnam according to their production area in 1991.

Table 1. Survey results about cassava cropping systems used in various districts of the Southeastern and South Central Coastal Regions.

Province	District	No. of respondents	Cassava				No. of respondents growing cassava in association with			
			monoculture		intercropped					
			Area (ha)	%	Area (ha)	%	Maize	Grain legumes	Other	Total
Quang Nam-Da Nang	Thang Binh	21	0.81	100	0.00	0	0	0	0	0
	Hoa Vang	24	2.35	94	0.15	6	0	1	0	1
	Que Son	24	0.46	100	0.00	0	0	0	0	0
Quang Ngai-Binh Dinh	Son Tinh	22	2.07	100	0.00	0	0	0	0	0
	Phu My	24	4.84	100	0.00	0	0	0	0	0
	Phu Cat	24	4.30	98	0.10	2	0	1	0	1
Khanh Hoa	Van Ninh	17	5.17	96	0.23	4	0	0	1	1
	Dien Khanh	23	14.91	99	0.15	1	2	0	0	2
	Cam Ranh	23	14.20	97	0.40	3	0	0	4	4
Thuan Hai	Ham Tan	24	2.95	63	1.70	37	5	0	2	7
	Ham Thuan Nam	24	1.30	59	0.90	41	4	4	4	12
	Duc Linh	24	2.47	39	3.80	61	2	4	10	16
Dong Nai	Thong Nhat	22	4.70	42	6.40	58	11	0	4	15
	Long Thanh	24	0.50	9	5.10	91	10	6	5	21
Baria-Vung Tau	Xuyen Moc	24	1.00	10	8.50	90	17	0	4	21
Total		344	61.75	52	56.43	48	51	16	34	101

Source: Hoang Kim, 1992.

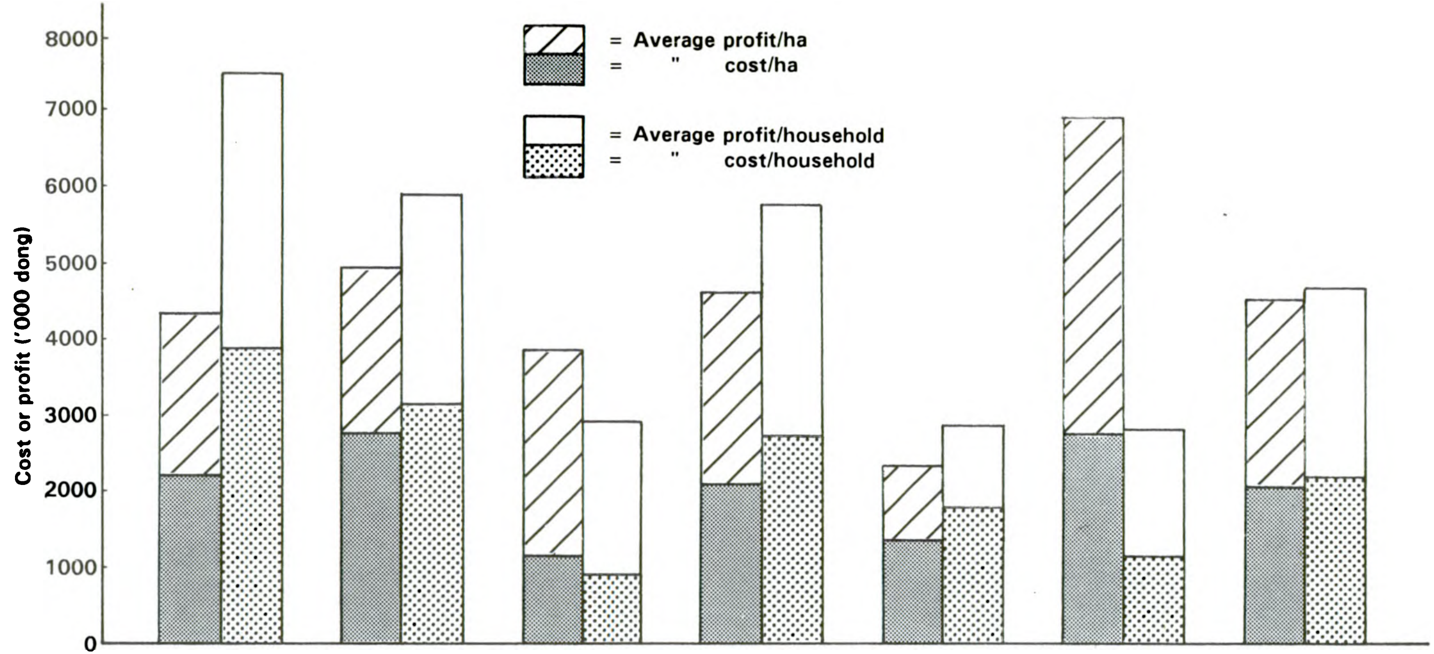
Table 2. Survey results about cassava cultivars and planting methods used in various districts of the Southeastern and South Central Coastal Region.

Province	District	No. of respondents	No. of respondents growing cassava cultivar					No. of respondents using planting method		
			H-34	Gon	HL-23	HL-24	Other	Ridge	No ridge	Other
Quang Nam-Da Nang	Thang Binh	21	9	6	0	5	1	21	0	0
	Hoa Vang	24	8	2	0	0	14	24	0	0
	Que Son	24	9	7	0	6	2	23	1	0
Quang Ngai-Binh Dinh	Son Tinh	22	12	4	0	6	0	7	15	0
	Phu My	24	24	0	0	0	0	3	21	0
	Phy Cat	24	24	0	0	0	0	6	18	0
Khanh Hoa	Van Ninh	17	10	3	0	0	4	1	16	0
	Dien Khanh	23	23	0	0	0	0	9	14	0
	Cam Ranh	23	23	0	0	0	0	10	12	1
Thuan Hai	Ham Tan	24	7	5	2	3	7	21	3	0
	Ham Thuan Nam	24	4	12	0	6	2	24	0	0
	Duc Linh	24	3	11	5	3	2	16	8	0
Dong Nai	Thong Nhat	22	0	2	8	10	2	0	22	0
	Long Thanh	24	0	4	5	3	12	15	9	0
Ba Ria-Vung Tau	Xuyen Moc	24	3	7	4	3	7	0	24	0
Total		344	159	63	24	45	53	180	163	1

Source: Hoang Kim, 1992.

An economic analysis of 60 cassava producing households in the Southeastern Region **(Figure 7)** shows the difference in average costs and profits of cassava production in various locations. The average cost effectiveness (net profit x 100/cost) in growing cassava was 119%, with the period from planting to harvest being 12 months (Tran The Thong *et al.*, 1992).

The economic efficiencies of processing into cassava starch, *bot khoai* (strip cassava), tapioca and vermicelli are shown in **Table 3.** The cost effectiveness of cassava starch production was higher than that of other products (Hoang Kim *et al.*, 1992). The fluctuations in the price of cassava fresh roots, dry chips and starch are shown in **Figure 8,** while the various market channels and the cost of cassava raw material and transport are shown in **Figures 9** and **10** and in **Table 4** (Tran The Thong *et al.*, 1992).



Province	DONG NAI	DONG NAI	DONG NAI	SONG BE	TAY NINH	HO CHI MINH	Average of
Village	XUAN LAP	HUNG LOC	TRA CO	AN PHU	NINH SON	LINH TRUNG	6 Zones
Kind of soils	Red yellow	Red yellow	Sandy grey	Sandy grey	Sandy grey	Sandy grey	
No.of respondents	10	10	10	10	10	10	
Average area (ha)	1.73	1.17	0.78	1.25	1.23	0.40	1.09
Cost effectiveness (%)	96	80	268	110	64	156	119

Figure 7. Economic efficiency of 60 households in growing cassava in the Southeastern region in 1991.

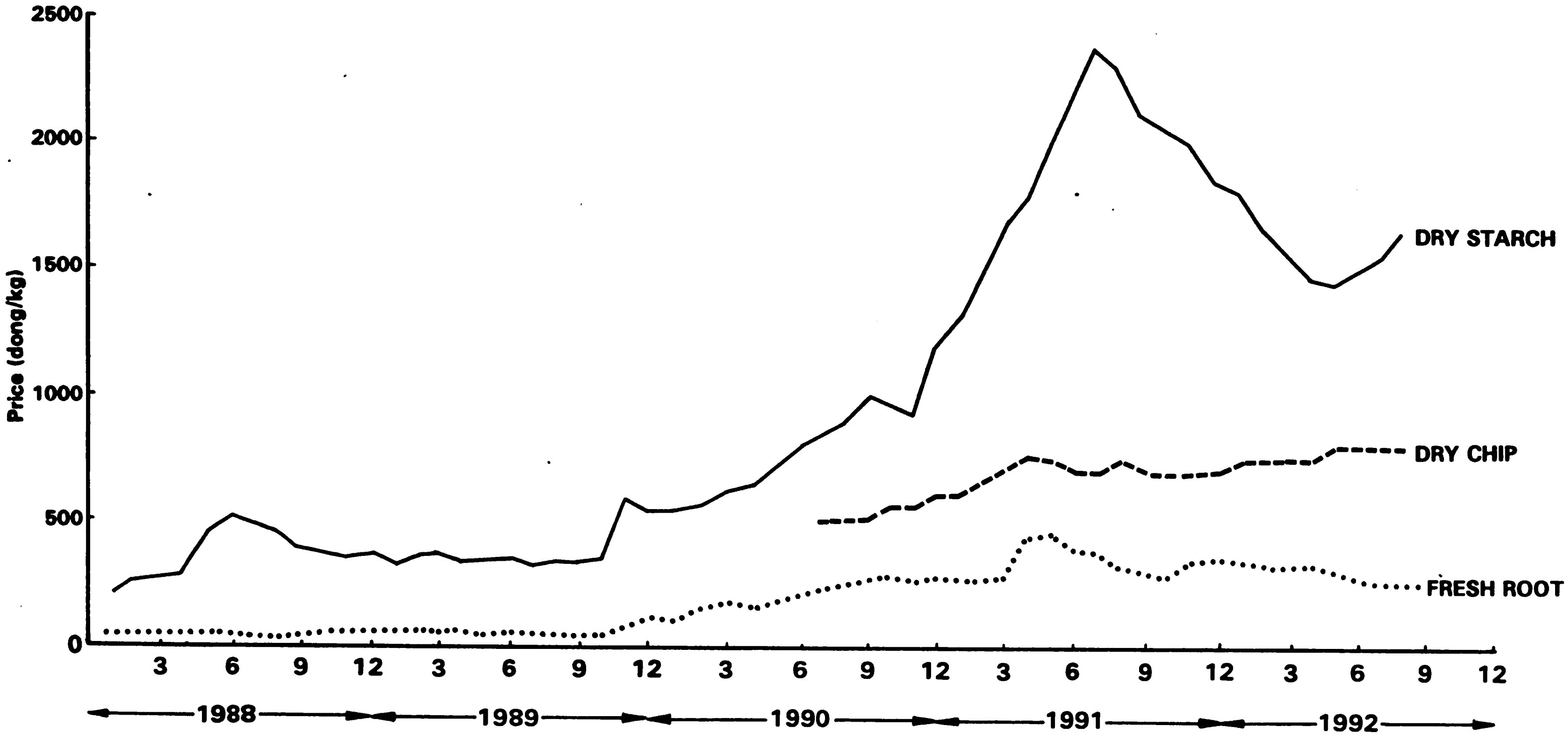


Figure 8. Price fluctuation of cassava dry starch, dry chips and fresh roots at Tra Co village (Dong Nai province) from 1988 to 1992.

Source: *Tran The Thong et al., 1992.*

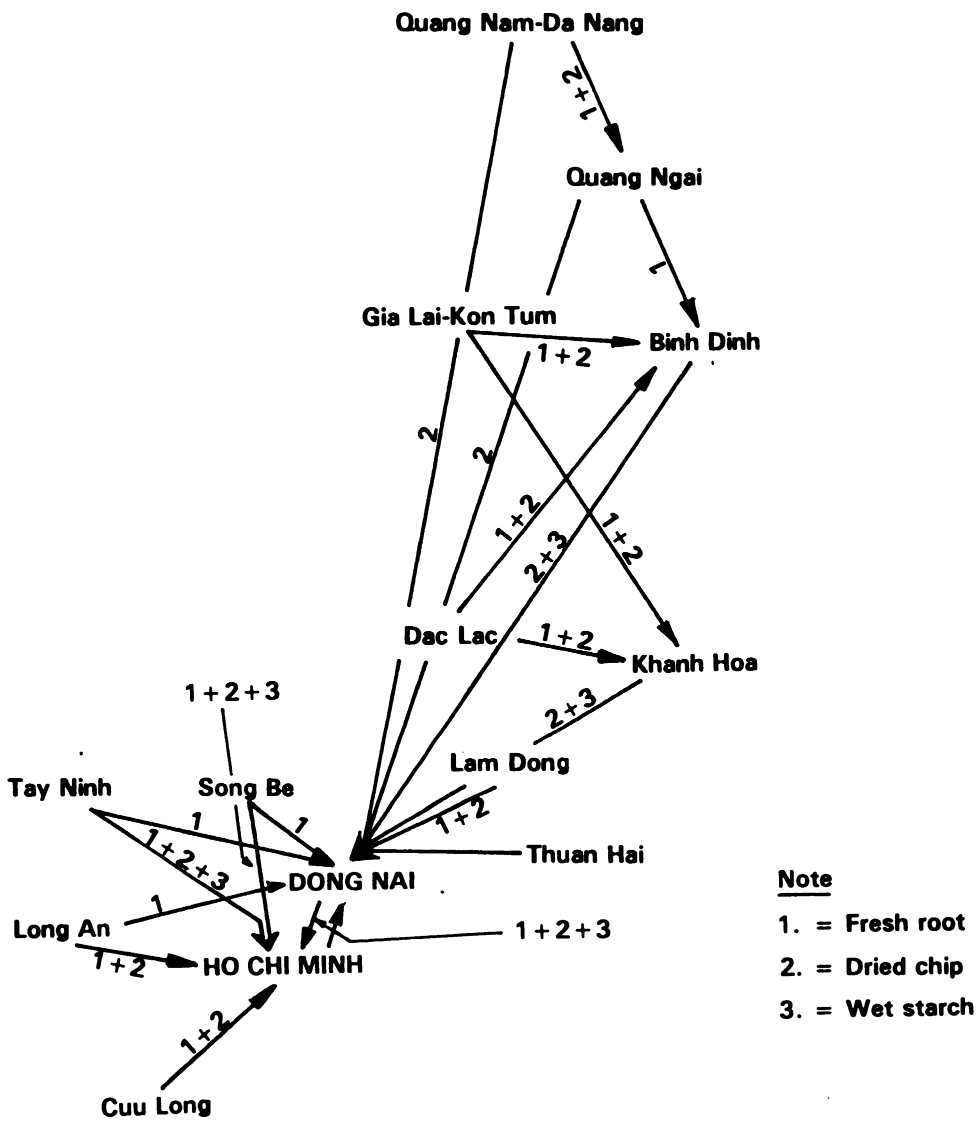


Figure 9. Distribution of various cassava raw materials in south Vietnam.

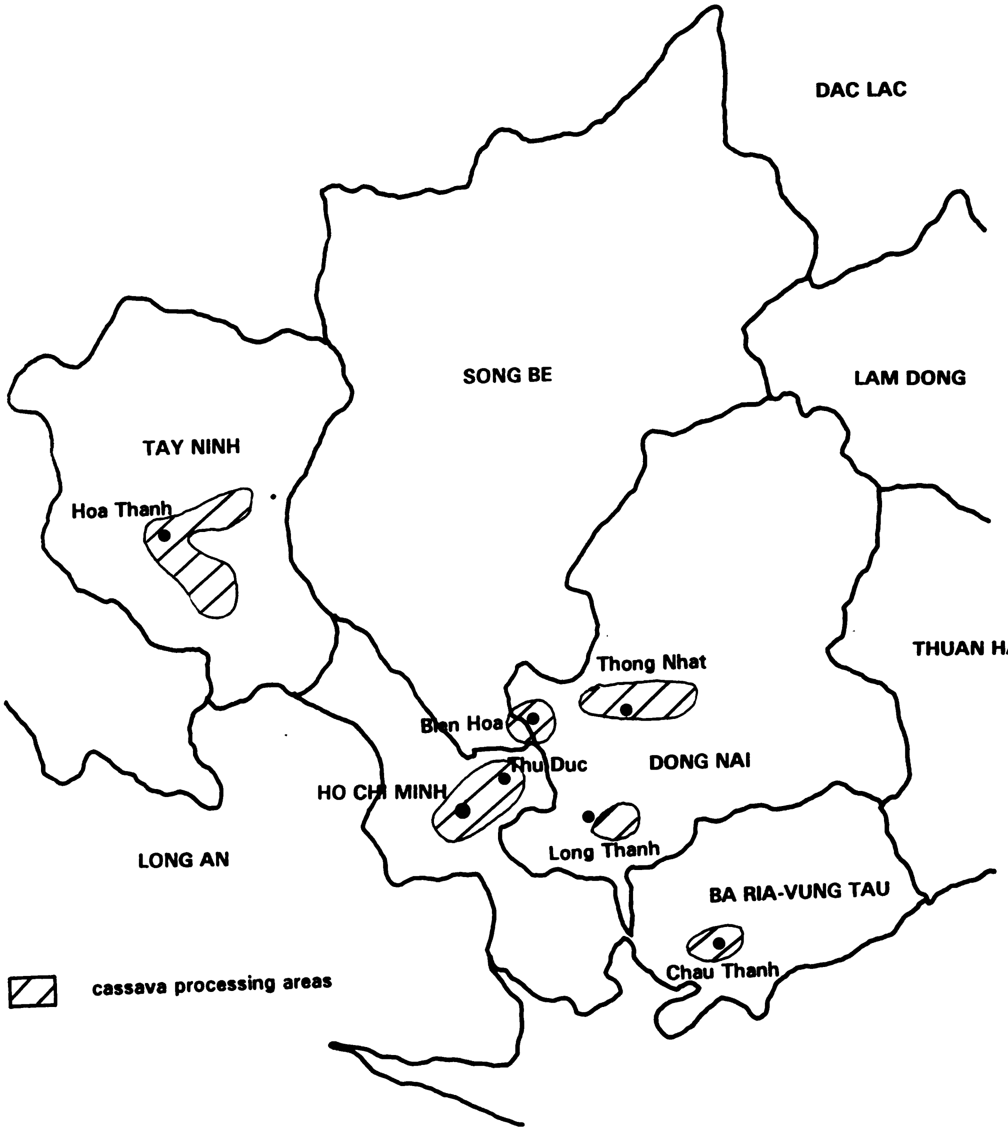


Figure 10. Cassava processing zones in the Southeastern region of Vietnam.

Table 3. Economic efficiency of cassava starch, cassava strips *(bot khoai)*, tapioca pearls and vermicelli processing in the Southeastern Region of Vietnam in July 1991.

Processed product or item	Starch	Cassava strips *(bot khoai)*	Tapioca pearls	Vermicelli [1] of cassava (1)	Vermicelli [1] of canna (2)	Vermicelli [1] No.8 (3)
Amount of raw material/shift (kg)	3,000	1,000	1,000	500	500	500
Average buying price/kg raw material (VND)[2]	350	1,400	1,400	1,400	1,400	750
Product recuperation ratio (%)	26	65	65	80	80	80
Products/shift (kg)	780	650	650	400	400	400
Total cost/kg of product (VND)	1,576	2,394	2,441	2,765	7,707	1,156
Raw material	1,346	2,154	2,154	2,333	7,375	937
Fuel	22	23	27	116	22	62
Package	29	14	14	20	25	5
Labor	100	100	100	200	200	200
Amortization	44	64	107	46	35	10
Other costs	34	39	39	50	50	10
Selling price of 1 kg of product (VND)	2,000	2,700	2,700	3,000	9,000	1,400
Profit per 1 kg of product (VND)	424	306	259	235	393	244
Profit for 1 processing shift ('000 VND)	330.7	198.9	168.3	98.7	146.6	102.5
Cost effectiveness (%)[3]	26.9	12.8	10.6	8.5	6.3	21.1

[1] (1) Vermicelli of cassava: 100% cassava (high quality wet starch)
(2) Vermicelli of edible canna: 70% edible canna + 30% cassava;
(3) Vermicelli No.8: 100% cassava (lower quality wet or dry starch)

[2] In Vietnamese dong; 1$ US = 9000 d.

[3] Cost effectiveness = net profit x 100/total costs

Source: Tran The Thong *et al.*, 1992.

Table 4. Marketing costs[1] of wet cassava starch from farm level in Hoai Nhon (Binh Dinh), Hoa Thanh (Tay Ninh), Ho Nai 4 (Dong Nai) and Thu Duc (Ho Chi Minh) to retailer level in Tan Binh (Ho Chi Minh city).

Price level and cost items	Dong/kg	%
I. From Hoai Nhon to Ho Nai 4 to Tan Binh		
Buying price (wet starch)	780	65.0
Loading cost	10	0.8
Transport cost (from Hoai Nhon to Ho Nai 4, about 639 km)	140	11.0
Business taxes, daily kiosk ticket, sanitation and other fees	30	2.5
Unloading cost	10	0.8
Decantation	40	3.3
Gross profit I	40	3.3
Loading cost	10	0.8
Transport cost (from Ho Nai 4 to Tan Binh, about 49 km)	32	2.6
Business taxes, daily kiosk ticket, sanitation and other fees	20	1.6
Gross profit II	88	7.3
Buying price by consumers in Tan Binh	1,200	100.0
II. From Hoai Nhon directly to Tan Binh		
Buying price (wet starch)	780	71.0
Loading cost	10	0.9
Transport cost (from Hoai Nhon to Tan Binh, about 688 km)	172	15.6
Business taxes, daily kiosk ticket, sanitation and other fees	30	2.7
Gross profit	108	9.8
Buying price by consumers in Tan Binh	1,100	100.0
III. From Hoa Thanh to Tan Binh		
Buying price (wet starch)	1,030	85.8
Loading cost	10	0.8
Transport cost (from Hoa Thanh to Tan Binh, about 100 km)	65	5.4
Business taxes, daily kiosk ticket, sanitation and other fees	22	1.8
Gross profit	73	6.1
Buying price by consumers in Tan Binh	1,200	100.0
IV. From Thu Duc to Tan Binh		
Buying price (wet starch)	1,070	89.1
Loading cost	10	0.8
Transport cost (from Thu Duc to Tan Binh, about 15 km)	32	2.6
Business taxes, daily kiosk ticket, sanitation and other fees	10	0.8
Gross profit	78	6.5
Buying price by consumers in Tan Binh	1,200	100.0

[1] Date: July 31, 1992; 1 US $ = 11,300 dong

Source: Tran The Thong *et al.*, 1992.

2. Site Selection and Cropping Systems Analysis of Two Villages: Hung Loc and Ho Nai 4.

Hung Loc village (representative of areas with reddish brown latosols) and Ho Nai 4 village (representative of areas with grey podzolic soils) were selected for more intensive research. Data was collected on soils, climate, number of people and workers in a family, and the present status of agricultural production was analyzed. Further interviews were conducted in 125 households. The analysis of these surveys **(Table 5)** indicates that among 90 households surveyed in Hung Loc village, 47.8% are only-crop growing households, 40% are crop-livestock integrated farming households, while 12% are crop-trading-secondary occupation households. The average cassava planting areas occupy 20.1% of the whole cultivated area. Among 30 households surveyed in the Ho Nai 4 community, 17.7% are only-crop growing households, 17.1% only-processing households and the remaining 65.8% are crop-livestock-trading or processing integrated households. The average cassava planting areas occupy 81.0% of the whole cultivated area.

Table 5. Cassava intercropping systems used in Hung Loc and Ho Nai 4 villages of Thong Nhat district of Dong Nai province in 1991/1992. Date from 90 respondents in Hung Loc and 35 in Ho Nai 4 villages.

Cropping systems	Hung Loc		Ho Nai 4	
	No. of respondents[1]	Area (ha)	No. of respondents[1]	Area (ha)
Cassava-based cropping systems	30	28.08	17	18.10
Cassava monoculture	2	3.95	14	16.90
Cassava + maize + mungbean	7	7.13	0	0.00
Cassava + mungbean	7	6.00	0	0.00
Cassava + maize	6	4.40	0	0.00
Cassava + cashew	5	3.70	3	1.20
Cassava + cashew + maize + mungbean	3	2.90	0	0.00
Other cropping systems	165	111.88	13	4.25
Total	195	139.96	30	22.35
% of cassava-based cropping systems	15.4	20.1	56.7	81.0

[1] Number of respondents using a particular cropping system; several respondents used 2-3 different cropping systems.

3. Defining Constraints in Cassava Production and Selecting Key Solutions.

Three major constraints to cassava production at Hung Loc and Ho Nai 4 communities were identified:

- Low price of cassava and unstability of the market
- Varietal degradation and mixture
- Lack of fertilizer supply

The following three key solutions are proposed:

- The use of new high-yielding, high-starch content varieties with 7-12 months growth cycles and a good plant type for intercropping (medium leafiness, late branching and lodging resistant).
- Growing cassava intercropped with mungbean, peanut and winged bean in order to increase farmers' incomes and improve soil fertility.
- Promoting increased cassava household processing and on-farm animal feeding.

4. Evaluation Trials of New Cassava Varieties and Cassava Intercropping Systems

From data of nine trials conducted during three years we can conclude that:

- The best cassava variety for growing either in monoculture or in association with grain legumes is Rayong 60. Other good varieties are HL-24, CM6125-125 and HL-23 **(Table 6).**
- The most suitable cultural practices for cassava grown in association with mungbean and winged bean is: cassava planted at 1.20 x 0.80 m intercropped with winged bean in the cassava rows and with two mungbean rows between cassava rows; this produced an increase in profit from 43-53% compared to cassava monoculture **(Table 6),** and the amount of mungbean green matter that could be incorporated into the soil was 7.2 to 8.3 t/ha **(Table 7)** (Hoang Kim, 1992).
- The cropping pattern of two peanut rows grown between cassava/winged bean rows resulted in an increase in profit from 42-85% compared to cassava monoculture **(Table 8),** and the amounts of peanut green matter to be incorporated in the soil was 6.6 to 12.5 t/ha **(Table 9)** (Hoang Kim, 1992).
- The best early, high-yielding mungbean variety, moderately resistant to Yellow Mosaic virus, with green glossy seeds and suitable for growing in both monoculture or in association with cassava is HL-89-E3 (IPB M79-9-82). This variety has been recognized by MAFI in 1992 (Nguyen Van Chuong and Hoang Kim, 1992).
- The best early, high-yielding, big seeded peanut varieties suitable for monoculture or intercropping with cassava are ICGS E56, Lampong and Giay **(Table 9).**

Table 6. Yield and economic efficiency of various cassava cropping systems with mungbean (M) and winged bean (W) on reddish brown latosols of Hung Loc (Dong Nai province) in 1991.

Treatment[1]	Yield (t/ha)			Total cost ('000d)[2]	Gross income ('000d)	Net profit ('000d)	% of sole crop	Cost effectiveness (%)[3]
	Cassava	Winged bean	Mung bean					
Cassava (Rayong 60)/W+M	31.1	0.43	0.86	3,544	14,841	11,297		319
Cassava (HL-24)/W+M	27.7	0.23	0.85	3,504	13,176	9,672		276
Cassava (CM6125-125) /W+M	31.9	0.34	0.71	3,544	14,398	10,854		306
Cassava (HL-23)/W+M	26.7	0.39	0.71	3,504	12,688	9,184		262
Cassava (Gon)/W+M	24.5	0.31	0.79	3,484	12,020	8,536	143.2	245
Cassava (Gon) + mungbean	24.3	-	0.82	3,260	11,375	8,115	136.1	249
Cassava (Gon) sole crop	24.7	-	-	3,684	8,645	5,961	100.0	222
CV (%)	13.2	8.7	3.2					
LSD (0.05)	1.6	0.1	0.05					

[1] Cropping pattern: cassava (spacing 1.2 x 0.8m) intercropped with winged bean (spacing 1.2 x 0.8 m x 2 seeds) in the row and intercropped with 2 mungbean rows (spacing 0.4 x 0.2 m x 2 seeds) between cassava rows.
[2] Prices at Hung Loc; November 1991:cassava (fresh roots) 350 d/kg; winged bean (dry seed) 2,200 d/kg; mungbean (dry seed) 3,500d/kg. 1 US $ = 9,700 dong
[3] Cost effectiveness = Net profit x 100/total cost

Source: Hoang Kim, 1992.

Table 7. Biological efficiency and biomass production in various cassava intercropping systems with mungbean (M) and winged bean (W) on a reddish brown latosol in Hung Loc (Dong Nai) in 1991.

Treatment	LER[1]	ATER[2]	Mungbean biomass yield (t FW/ha)	Amount of nutrients in mungbean biomass incorporated into the soil (kg/ha)[3]		
				N	P_2O_5	K_2O
Cassava (Rayong 60)/W+M			7.8 ab	29.7	7.0	31.5
Cassava (HL-24)/W+M			8.3 a	31.7	7.6	33.5
Cassava (CM6125-125)/W+M			7.2 c	27.5	6.6	29.1
Cassava (HL-23)/W+M			7.2 c	27.5	6.6	29.1
Cassava (Gon)/W+M	1.86	1.32	7.7 bc	29.4	7.0	31.1
Cassava (Gon)+mungbean	1.76	1.20	7.9 ab	30.1	7.2	31.1
Cassava (Gon) sole crop	1.00	1.00				
CV (%)			7.6			
LSD (0.05)			0.5			

[1] LER - Land equivalent ratio; mungbean yield (HL89-E3) monoculture: 1.05 t/ha; winged bean yield (Binh Minh) monoculture: 1.05 t/ha; winged bean yield (Binh Minh) monoculture: 2.44 t/ha; mungbean is harvested 2 months after sowing; cassava and winged bean are harvested 7 months after planting.

[2] ATER = Area-Time Equivalent ratio.

[3] Percent dry matter of mungbean biomass: 20.4 % ; concentrations of N, P and K are 1.91, 0.20 and 1.68%, respectively.

Source: Hoang Kim, 1992.

Table 8. Yield and economic efficiency evaluation of cropping patterns of maize (MZ), winged bean (W), mungbean (M) and peanut (P) intercropped with cassava at Hung Loc Center in Dong Nai province in 1987.

Treatments[1]	Yield (t/ha)					Gross income ('000d)	Total cost ('000d)	Profit[2] ('000d)	% of sole crop
	Cassava	Maize	Winged bean	Mung bean	Peanut				
Cassava sole crop	16.7 a					167	98.0	69.0	100
Cassava + MZ	14.3 b	2.40				251	125.0	125.2	181
Cassava + W	14.4 b		0.48			192	108.4	86.3	125
Cassava + P	14.5 b				0.57	248	127.8	120.2	174
Cassava + M	17.1 a			0.50		244	135.7	108.3	157
Cassava + W + MZ	13.4 b	2.10	0.37		0.54	266	141.8	124.2	180
Cassava + W + P	14.3 b		0.34			274	146.3	127.7	185
Cassava + W + M	15.3 ab		0.42	0.45		260	153.4	106.6	154
CV (%)	9.6								

[1] Cropping pattern: Cassava (with plant spacing 1.2x0.8m), intercropped with winged bean (with plant spacing 1.2x0.8 mx2 seeds) on the row between 2 cassava plants and intercropped with 1 maize row or 2 mungbean (or peanut) rows between cassava rows.

[2] Prices at Hung Loc market in 1987:

cassava = 10 d/kg

winged bean = 100 d/kg

maize = 45 d/kg

mungbean = 145 d/kg

peanut seed = 180 d/kg

Source : Hoang Kim *et al.,* 1987.

Table 9. Yield and economic efficiency evaluation of cropping patterns of cassava intercropped with peanut (P) and winged bean (W) on reddish brown latosol at Hung Loc Center, Dong Nai province in 1991.

Treatments[1]	Yield (t/ha)			Peanut biomass yield incorp. into soil (t/ha)	Gross income ('000d)	Total cost ('000d)	Profit[2] ('000d)	% of sole crop
	Cassava	Winged bean	Peanut					
Cassava sole crop	27.8 a	-	-	-	9,730	2,684	7,046	100
C + W + P (ICGS. E 56)	27.0 a	0.30 a	0.67 a	6.8 b	14,331	3,680	10,651	151
C + W + P (Lampong)	27.0 a	0.32 a	0.60 b	6.6 b	13,934	3,680	10,254	145
C + W + P (ICGV 87350)	25.9 a	0.24 b	0.54 c	12.5 a	12,995	3,680	9,315	132
C + W + P (ICGV 87281)	26.4 a	0.24 a	0.53 c	11.9 a	13,107	3,680	9,427	134
C + W + P (ICGV 86606)	26.8 a	0.21 b	0.60 b	11.9 a	13,622	3,680	9,942	141
Ç + W + P (ICGV 86600)	27.7 a	0.27 a	0.62 b	12.0 a	14,195	3,680	10,515	149
C + W + P (ICGV 86020)	26.1 b	0.28 a	0.54 c	11.5 a	13,153	3,680	9,473	134
C + W + P (GIAY)	26.9 b	0.25 a	0.59 b	7.0 b	13,682	3,680	10,002	142
C + P (GIAY)	27.2 ab	-	0.60 b	7.2 b	13,330	3,440	9,890	140
CV (%)	11.7	9.1	5.8	8.7				

[1] Cassava variety: KM-60
Winged bean variety: Binh Minh
Cropping pattern: cassava (spacing 1.2 x 0.8 m) intercropped with winged bean (spacing 1.2 x 0.8 m x 2 seeds) in the row and intercropped with 2 peanut rows (spacing 0.4 x 0.2 m x 2 seeds) between cassava rows.

[2] Prices at Hung Loc, Nov. 1991:
cassava (fresh roots) = 350 d/kg
winged bean (dry seed) = 2,200 d/kg
peanut (dry seed) = 6,300 d/kg

Source: Hoang Kim, 1992.

5. Regional Field Trials and Farmers' Field Trials

In 1991, a field day was organized for farmers and extension workers to harvest and evaluate cassava trials at Hung Loc Center. Farmers and extension workers discussed and then selected cassava varieties for further testing. The results of these regional trials and farmers' field trials indicate that Rayong 60 was the most promising variety, which should be promoted for general production **(Table 10).**

In 1992, there were 50 on-farm trials with four cassava varieties on each farmer's field, with each variety planted in 30 m^2 plots without replication; the farmers' cultural practices were used. There were also six trials on cassava intercropping with mungbean and peanut.

Rayong 60 is recognized as a good variety and was released by MAFI for regional field trials and dissemination in April, 1993. Its new name in Vietnam is KM 60 (Tran Ngoc Quyen *et al.*, 1993).

Table 10. Cassava yields (t/ha) in regional and on-farm trials coordinated by Hung Loc Agricultural Research Center, 1991/1992.

Treatment	Regional trials[1]				On-farm trials[2]						
	a	b	c	d	A	B	C	D	E	F	Av.
Rayong 1	15.0	18.6	19.0	36.5							22.3
Rayong 3					12.3	12.5	13.8	14.2		13.2	13.2
Rayong 60	17.2	18.6	29.5	37.4		16.8			17.4		22.8
CM5257-33				23.5	10.5	12.1	12.1		15.8		14.8
CM6125-117				28.3	14.7	13.7	16.7	16.4	16.7	17.8	17.8
CM6125-125				37.2	17.1	16.2	19.6	18.6	20.0	14.6	20.5
CM6125-129				37.3	15.6	13.4	18.4	15.8	15.4	16.4	18.9
MKUC28-71-66				28.3	16.4	14.6					19.7
HL-23	18.0	15.3	17.7	-	-		12.6	13.7	12.3		14.9
HL-24	13.8	12.2	21.2	26.1	10.5		11.8	14.8	14.5	10.4	15.0
Gon	8.9		14.3	31.3		11.0				8.4	14.8
H-34		13.9									13.9

[1] Extension Centers in:

a. Ho Chi Minh city

b. Khanh Hoa

c. Song Be

d. Tay Ninh

[2] A to F refer to different farmers

6. Establishment of Cassava Research and Extension Network in South Vietnam

In 1993, a cassava research and extension network was established in south Vietnam: 14 cassava variety field trials were conducted in different ecological zones, while 23 farmers' households carried out production evaluation trials on KM 60. Three training courses for cassava production have been organized with the participation of about 90 farmers. The demonstration and seed multiplication areas of new cassava varieties HL-20, HL-23, HL-24 and KM 60 at two villages, Hung Loc and Ho Nai 4, are 78 hectares.

DISCUSSION

Evaluating on-farm research and transfer of technology for cassava production in south Vietnam, we find that:

1. Its strong points are:
   - The goals, objectives and methods of research and extension for cassava production are suited to Vietnamese conditions.
   - Although the initial impact is still small, the results are reliable and promising.
   - The varieties HL-20, HL-23 and HL-24 are now being multiplied and produced widely.
   - A technical solution of cassava intercropping with food legumes obtained satisfactory preliminary results.
   - New cassava varieties introduced from the Thai-CIAT program, in particular Rayong 60, are further tested and multiplied for production.
2. Its weak points are:
   - The extension of cassava production technology is not receiving enough attention and is not well supported financially.
   - Research and extension results for cassava consist of only small-scale surveys and on-farm trials.
   - Cassava has a low coefficient of seed multiplication, a long growing period of 7-12 months, while its price is low and unstable; thus, technical improvements take a long time to be put into production.

We hope that with the organization of the National Root Crops Program and the effective support from CIAT, IDRC, CIP, etc. new cassava varieties and advanced technical practices will be adopted more extensively, in order to increase farmers' incomes and to improve the fertility of cassava soils.

CONCLUSIONS AND PROPOSALS

The following conclusions can be drawn:

1. In Vietnam, extension activities are considered by the government as an urgent and

long-term measure, which have a great influence on the development process of farmer commodity production and rural reconstruction. Among the extension objectives, cassava production is promoted in those areas and cropping seasons which have appropriate conditions for its development. Extension for cassava production is in great demand and is of high necessity.

3. On-farm research and transfer of technology for cassava production in Vietnam have obtained some initial results: The varieties HL-20, HL-23 and HL-24 are now grown in many thousands of hectares. The technical practice of cassava intercropping with mungbean, peanut and winged bean has given good results and has contributed to increased farmers' incomes and helped to maintain the productivity of cassava soils.
3. Cassava germplasm introduced from the Thai-CIAT program is very promising. In particular, Rayong 60 is now permitted by the Ministry of Agriculture and Food Industry of Vietnam for regional field trials and dissemination in production areas.
4. A research and extension network for cassava production is established by the linkage of the National Food Crops Program and the National Extension Program. With the effective support of international organizations such as CIAT, IDRC and CIP, new cassava varieties and advanced cultural technics will be put rapidly into production.

To improve future efficiency, the following points are proposed:

1. To further strengthen the cooperation with CIAT in the area of on-farm research and transfer of technology for cassava production in Vietnam.
2. To further reinforce and enlarge the research and extension network for cassava production in Vietnam, in particular to attach importance to good farmers' networks.
3. To exchange information on the establishment and management methods of extension projects at village, district and provincial levels.
4. To obtain experience and financial support from international organizations such as CIAT, IDRC, ACIAR, TARC etc.

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RECENT PROGRESS IN CASSAVA AGRONOMY RESEARCH IN THE PHILIPPINES

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ABSTRACT

In Leyte, the long-term fertility trial under coconut showed significant responses to fertilizers after the second cropping cycle. Highest yields were obtained in treatments with 90 kg/ha of P_2O_5 and 60 kg/ha of N and K_2O, while lowest yields were obtained in treatments without P application. In another trial there was a significant interaction between time-of-planting and age-at-harvest. When intercropping maize within cassava rows, the yield of cassava was not reduced if the fertilizer requirements of both crops were met and the population of maize was only half of that of the monocrop.

In an erosion control trial, large soil losses were observed in plots where vetiver or lemon grass had been planted as contour barriers, especially during the first year of establishment. Application of grass mulch continued to be the most effective treatment in reducing erosion, while it also resulted in the highest yield. During the fifth cropping cycle, it was observed that plots with complete fertilizer (60-60-60 kg/ha) application had the highest soil loss, while plots with grass mulch had again the lowest. Root yields were highest with the application of mulch and lowest in plots with lemon and vetiver grass barriers.

In Bohol, significant differences in yield due to fertilizer levels were observed in the second, third and fourth cropping cycles. The main response was to K and N application. No significant differences in yield were observed between the two cultivars. Stake length significantly affected the root yield of cassava in the first and second year, but not in the third year of cropping. A significant interaction was observed among stake length, position of planting and cultivar. In an intercropping trial, cassava yields were not significantly affected by interplanting of either soybean, mungbean, cowpea, peanut or pole sitao. However, cassava row spacing significantly affected the yields of cassava and intercrops.

In Negros Occidental the long-term fertility trial showed a significant yield response only to the application of N. There were significant differences among the two cultivars, but no significant interaction between fertilizer and cultivar. Crop residue incorporation or removal had still no significant effect on yield during the 3rd cropping cycle. An intercropping trial showed that cassava yields were significantly reduced by intercropping with all crops except

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[1] PRCRTC, Baybay, Leyte, Philippines.

[2] BES, Ubay, Bohol, Philippines.

[3] UPLBCA, La Carlotta City, Negros Occidental, Philippines.

soybean in the second and third year. Alley cropping with *Leucaena leucocephala, Gliricidia sepium* or *Crotalaria sp* markedly reduced cassava yields.

INTRODUCTION

Even though the cassava industry in the Philippines is not as well-developed compared with some other Asian countries, specifically Thailand, recently the government has given more support to cassava as a potentially important industrial crop. In fact, three groups of organizations, i.e. farmer cooperatives, government institutions and private or business sectors, are now actively supporting the cassava industry in Mindanao, the major cassava growing area of the Philippines.

Table 1. Production, area and yield of cassava in provinces with at least 1,000 ha for ten cropping years in the Philippines in 1981 and 1990.

Province	Area (ha)		Production (t)		Yield (t/ha)	
	1981	1990	1981	1990	1981	1990
Philippines	**199,956**	**213,773**	**1,680,409**	**1,853,979**	**8.40**	**8.67**
Lanao del Sur	32,000	32,192	491,781	650,235	15.37	20.20
Sulu	9,250	29,789	41,079	133,413	4.44	4.48
Camarines Sur	18,000	20,899	158,340	191,500	8.80	9.16
Basilan	18,100	17,591	260,168	195,770	14.37	11.13
Bohol	10,000	12,833	52,863	135,090	5.29	10.53
Leyte/Biliran	9,950	9,541	56,920	37,103	5.72	3.90
Southern Leyte	4,005	6,447	10,357	14,039	2.59	2.18
Negros Occidental	7,300	6,407	36,238	28,670	4.96	4.47
Albay	10,700	5,777	156,710	51,854	14.65	8.98
Surigao del Norte	11,500	4,641	46,798	19,218	4.07	4.14
Quezon	2,979	6,595	15,242	35,999	5.12	5.46
Western Samar	6,030	4,765	25,086	22,437	4.16	4.71
Misamis Oriental	5,700	4,133	40,967	36,739	7.19	8.93
Cebu	2,270	3,762	7,389	24,450	3.26	6.50
Bukidnon	4,400	3,589	35,409	38,069	8.05	10.61
Sorsogon	1,882	3,061	2,730	8,720	1.45	2.85
Northern Samar	4,118	3,383	7,275	5,523	1.77	1.63
Eeatern Samar	2,005	2,703	26,616	18,870	13.27	6.98
Siquijor	2,168	1,600	7,035	4,080	3.24	2.55
Iloilo	2,270	1,933	12,547	11,401	5.53	5.90
Negros Oriental	3,930	2,210	9,242	3,840	2.35	1.74
Zamboanga del Sur	2,600	1,683	22,042	11,704	8.48	6.95
Pagasinan	1,045	1,257	8,813	7,839	8.43	6.24
Agusan del Norte	1,230	1,467	3,708	7,995	3.01	5.45
Masbate	1,300	1,112	2,235	2,000	1.72	1.80
Subtotal	168,708	189,350	1,537,596	1,696,558		
Of total (%)	84.37	88.57	83.25	91.50		

Source: Bureau of Agricultural Statistics.
Compiled by: PRCRTC Database.

Cassava Production in the Philippines

During the past ten years (1981-1990) overall cassava production in the Philippines has not increased substantially. For example, **Table 1** shows that the area of 199,956 ha planted to cassava in 1981 has only increased to 213,773 ha in 1990, an increase of 9.4%. Yields increased only from 8.40 to 8.67 t/ha, or about 3.1%.

The major cassava growing area of the Philippines is located on Mindanao island, which accounts for 42% of the total acreage, followed by 26% in the Visayas islands (mainly the Central and Eastern part), and 18% in Luzon. Average cassava yields for each region are shown in **Table 2.** The average yield of 9.21 t/ha in Mindanao is considerably higher than those in Visayas (5.15 t/ha) and Luzon (5.74 t/ha). Cassava yields in the major cassava planting areas in Mindanao (specially the northern and northeastern part), as well as those in Visayas and Luzon are relatively low mainly due to low soil fertility. Thus, fertility maintenance or improvement was set as a major research objective.

During the past five years (1988-1993), cassava agronomy research placed major emphasis on soil fertility maintenance and erosion control. Developing better intercropping and cultural practices for cassava grown under coconut was another priority area of research.

RESEARCH RESULTS

Recent Experiments in Leyte

1. Cultural management under coconut

1) Long-term fertility maintenance: A long-term fertility trial under mature coconut trees, spaced at about 8x8m, showed that there were significant yield differences due to fertilizer application in the second and subsequent cropping cycles **(Table 3).**

Highest yields were generally obtained in the treatment with 60 kg N, 90 kg P_2O_5 and 60 kg K_2O/ha (F_8), while lowest yields were obtained in treatments without P application (F_1 and F_6), suggesting a deficiency of this nutrient **(Figure 1).** Soil analysis of the NPK check plots in 1990 indicated intermediate levels of 2.8% organic matter and 0.15 me K/100g, but a very low level of 1.7 ppm of Bray-II-extractable P. Thus, significant responses to P and N (sometimes) are in accordance with soil analyses results.

2) Time of planting and age-at-harvest: There was a significant interaction between time-of-planting and age-at-harvest **(Table 4).** Yields were low and decreased consistently when cassava planting was delayed from January to July. This was probably due to a rather long drought from February to June. The yield decline may also be due to a gradual buildup of pests or diseases in the field during subsequent plantings. Age-at-harvest between 9 and 12 months had no significant effect on yield, indicating

Table 2. Cassava yield (t/ha) in the various regions of the Philippines from 1981 to 1991.

Year	Region													
	Philip.	Car	Ilocos	Cag. Vly.	Cent'l Luzon	South Tag'g	Bicol	West Vis	Cent'l Vis	East Vis	West Mind	North Mind	South Mind	Cent'l Mind
1981	8.40	11.74	6.97	3.68	3.64	5.70	9.95	5.38	4.17	4.80	10.50	5.67	5.37	14.92
1982	7.52	11.27	6.43	4.23	3.86	5.86	9.20	4.56	3.64	4.11	10.44	5.69	5.65	11.90
1983	6.56	9.38	6.26	4.11	4.46	5.73	8.33	3.93	2.72	4.40	6.32	5.06	5.43	11.34
1984	7.40	9.15	6.40	3.23	6.17	5.82	7.96	4.40	4.41	3.98	6.28	4.75	5.49	17.35
1985	8.25	7.48	5.93	3.17	5.56	5.92	7.05	4.40	4.81	3.64	6.60	5.86	4.78	21.74
1986	8.16	7.70	6.26	3.29	6.13	6.08	7.16	4.38	7.44	3.40	6.97	6.91	6.58	17.56
1987	8.51	7.61	6.00	3.70	6.35	5.88	7.96	4.81	8.15	3.27	6.96	6.92	6.25	18.85
1988	8.60	8.30	5.61	3.66	6.20	6.47	8.92	5.48	7.82	3.83	6.78	6.78	6.14	19.25
1989	8.67	8.48	6.27	3.71	6.52	6.16	8.20	5.03	8.09	3.65	7.21	7.48	5.93	19.07
1990	8.67	8.57	5.94	3.26	6.28	6.16	8.19	5.13	8.21	3.65	6.77	7.63	5.86	19.18
1991	9.11	9.42	5.90	3.73	6.57	6.12	7.84	5.10	7.87	4.05	6.83	8.30	5.37	18.54

that Golden Yellow variety can be harvested already at 9 months.

2. Intercropping.

The first trial on within-row intercropping **(Table 5)** showed that intercropping cassava with maize did not reduce the yield of cassava if the maize was planted at half of its normal population and was harvested as green ears, but the yield of intercropped maize was reduced by about 30% if it was harvested for dry grain, especially when fertilizers were applied only according to the requirement of cassava. However, a succeeding trial showed no significant differences in yield among the treatments, although the intercropped cassava had a higher LER than the monocrop.

Table 3. Marktable root yield of cassava (cv Golden Yellow) grown under coconut as affected by different levels of N, P and K fertilizers during four cropping cycles in ViSCA, Philippines.

Treatment No.	$N-P_2O_5-K_2O$ (kg/ha)	Marketable root yield (t/ha) 1st year (1989/90)	2nd year (1990/91)	3rd year (1991/92)	4th year (1992/93)
F_1	0-0-0	6.50	4.05 cde	4.25 b	6.72 c
F_2	0-60-60	5.21	4.80 bcde	7.30 a	11.72 ab
F_3	30-60-60	3.30	4.05 cde	8.40 a	8.90 abc
F_4	60-60-60	5.80	3.32 de	8.65 a	9.27 abc
F_5	90-60-60	5.43	5.57 bcd	9.71 a	12.87 a
F_6	60-0-60	7.77	2.96 e	7.21 a	5.95 c
F_7	60-30-60	5.18	4.59 bcde	7.30 a	10.05 abc
F_8	60-90-60	6.40	7.95 a	9.87 a	13.22 a
F_9	60-60-0	4.22	5.06 bcde	7.67 a	8.27 bc
F_{10}	60-60-30	5.28	6.46 ab	9.10 a	9.65 abc
F_{11}	60-60-90	4.94	5.97 abc	9.70 a	12.92 a
F_{12}	90-90-90	5.06	3.99 cde	9.79 a	11.62 ab
CV (%)		29.9	28.5	23.2	26.9
F test: Global:		NS[1)]	**	**	**
N:		NS	*	NS	NS
P:		NS	**	NS	*
K:		NS	NS	NS	NS

[1)] NS = not significant
* = significant (P<0.05)
** = highly significant (P<0.01)
Mean seperation: DMRT (0.05)

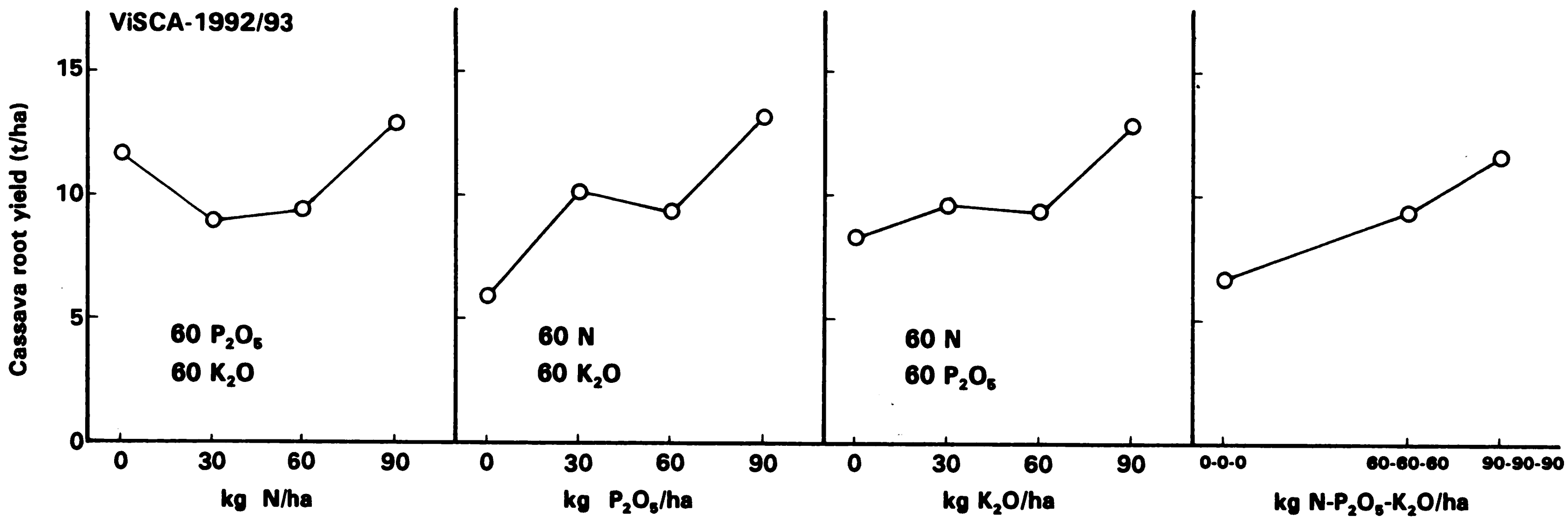


Figure 1. Response of cassava, cv Golden Yellow, to the annual application of various levels of N, P and K when grown under coconut palms at ViSCA, Baybay, Leyte, Philippines in 1992/93 (4th year).

Table 4. Marketable root yield (t/ha) of cassava as affected by time of planting and age at harvest in ViSCA, Leyte, Philippines in 1992/93.

Time of planting	Harvest time (MAP) 9	10	11	12	Avg.
January	11.3	9.1	9.9	13.3	10.9 a
March	9.7	9.5	10.7	11.8	10.4 a
May	7.2	6.8	6.8	5.6	6.6 a
July	5.6	4.7	3.7	5.0	4.7 b
Average	8.4 a	7.5 a	7.8 a	9.8 a	

Table 5. Grain yield of maize, root yield of cassava and the land equivalent ratio (LER) of different cropping systems in ViSCA, Philippines in 1992/93.

Cropping systems	Maize yield (dry grain) (t/ha)	Cassava yield (fresh roots) (t/ha)	LER[1)]
Cassava monoculture (cv GY)	-	17.1 a	1.0
Maize monoculture (cv VM2)	5.5 a	-	1.0
Maize monoculture (cv VM6)	5.0 a	-	1.0
GY + VM2 (2 plants/hill)	2.8 b	18.6 a	1.6
GY + VM6 (2 plants/hill)	2.7 b	16.6 a	1.5
GY + VM2 (1 plant/hill)	3.6 b	16.3 a	1.6
GY + VM6 (1 plant/hill)	3.2 b	19.3 a	1.8

[1)] $LER = \frac{\text{yield of cassava intercrop}}{\text{yield of cassava monocult.}} + \frac{\text{yield of maize intercrop}}{\text{yield of maize monocult.}}$

3. Cultural practices for erosion control

This experiment was conducted continuously for five cropping cycles (1988-1993) in a field near Baybay, Leyte, with about 25% slope, previously used for four years as a communal grazing area.

The treatments used and the results of five cropping cycles are shown in **Table 6.** The results of the first two cropping cycles have already been presented during the last Regional Cassava Workshop held in 1990 in Malang, Indonesia. The treatments used in the second year were further tested in the third year, while for the fourth and fifth years treatments 1, 3, and 5 were changed to conventional tillage (CT) with lemon grass barrier, CT with vetiver grass barrier and CT with *Crotalaria juncea* intercropping, respectively.

Table 6. Cassava yield and soil loss due to erosion during five cropping cycles of cassava grown under various cultural practices on 25% slope in Baybay, Leyte, Philippines.

Treatments[1]	Root yield (t/ha)[2]	Soil loss (t/ha)[2]
First cropping 1988–1989 (2153 mm rainfall)		
CT with clean culture	5.3 c	190 a
Strip tillage	2.6 d	10 f
MT with herbicide	1.6 d	21 ef
MT with underbrushing	1.3 d	3 f
CT with 60-60-60 fertilizer	9.2 a	114 d
CT with sweet potato intercrop	0.8 e	138 c
CT with *Gliricidia sepium* hedgerows	4.1 c	173 b
CT with dried grass mulch	7.5 b	31 e
CT with *Desmodium ovalifolium* intercrop	1.1 d	188 a
CT with underbrushing	9.2 a	113 d
CT with stone walls	3.5 a	65 e
Second cropping 1989–1990 (1673 mm rainfall)		
CT with *Desmodium ovalifolium* intercrop	4.0 c	6.2 d
CT with 60-60-60 fertilizer	33.1 a	37.3 a
CT with *Gliricidia sepium* hedgerows	15.7 b	31.6 b
CT with dried grass mulch	28.2 a	9.7 d
CT with *Cajanus cajan* hedgerows	19.1 b	15.4 c
Third cropping 1990–1991 (2526.5 mm rainfall)		
CT with *Desmodium ovalifolium* intercrop	5.3 e	0.7 c
CT with 60-60-60 fertilizer	16.4 b	7.9 ab
CT with *Gliricidia sepium* hedgerows	9.0 d	8.4 a
CT with dried grass mulch	19.5 a	6.1 b
CT with *Cajanus cajan* hedgerows	13.3 c	6.3 ab
Fourth cropping 1991–1992 (1867.2 mm rainfall)		
CT with lemon grass hedgerows	18.9 b	62.8 ab
CT with 60-60-60 fertilizer	26.0 a	52.7 b
CT with *Gliricidia sepium* hedgerows	18.9 b	70.8 a
CT with dried grass mulch	28.1 a	28.0 c
Ct with *Crotalaria juncea* intercrop	17.5 b	31.0 c
Fifth cropping 1992–1993 (2187.8 mm rainfall)		
CT with lemon grass hedgerows	12.7 d	21.7 c
CT with 60-60-60 fertilizer	25.6 b	39.8 a
CT with *Gliricidia sepium* hedgerows	13.1 d	20.7 c
CT with dried grass mulch	32.1 a	6.6 d
CT with *Crotalaria juncea* intercrop	17.8 c	30.3 b

[1] CT = conventional tillage ; MT = minimum tillage

[2] Mean seperation : DMRT (0.05)

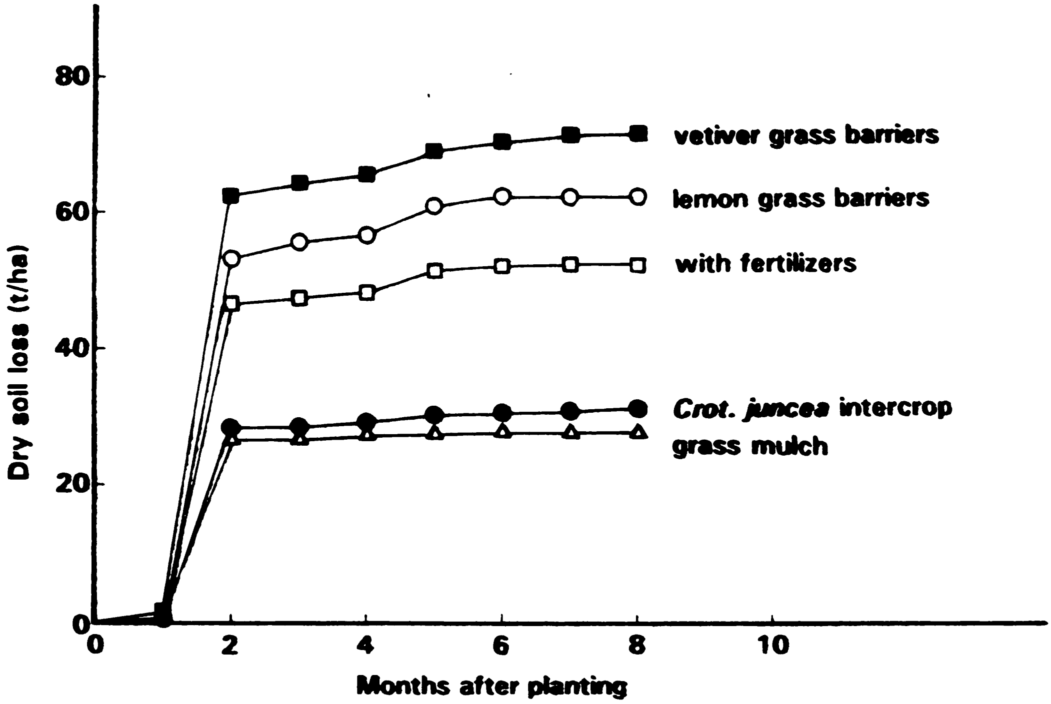
Soil loss due to erosion was high in the first cycle, but much lower in the second and subsequent cropping cycles, particularly in well-established treatments with sufficient ground cover, like CT with dried grass mulch. During these five years, the amount of dry soil loss ranged from as low as 0.7 t/ha in treatment CT with *D. ovalifolium* intercrop to as high as 190 t/ha in CT with clean culture. The marked increase in erosion in the fourth cycle is due to changes in some treatments, which increased the erodability of the soil through additional cultivation. In general, soil losses were low in those treatments where there was enough soil cover, such as in MT with underbrushing, CT with *Desmodium ovalifolium* intercrop and CT with application of dry grass mulch.

In the first two years highest cassava root yields were obtained in CT with fertilizer application, but starting from the third year highest yields were obtained where dry grass mulch was applied, even without fertilizers, indicating that the mulch not only protected the soil from erosion but also supplied nutrients to the cassava crop. Intercropping cassava with *Desmodium ovalifolium* was the most effective treatment to reduce erosion as the *Desmodium* produced a permanent and complete soil cover; however, cassava was unable to compete with the *Desmodium* for light, water and nutrients and cassava yields were seriously reduced. For that reason this treatment was changed after the third cropping cycle.

Figure 2 shows that during the fourth cropping cycle erosion was minimal during the first month after planting, but increased very markedly during the second month, after which the cassava canopy became well established, protecting the soil from further erosion losses. The recently planted vetiver and lemon grass barriers were not yet effective in reducing erosion; these treatments in fact caused the most serious soil losses. Intercropping with *Crotalaria juncea* or the application of dry grass as a mulch were the most effective treatments to reduce erosion. However, the intercropped *Crotalaria* competed severely with cassava, causing a marked yield reduction **(Table 6)**. Intercropping with *Crotalaria* could be an effective erosion control practice if the green manure were cut or pulled out at 1 1/2-2 months after planting to be used as a mulch and to prevent serious competition with cassava.

Recent Experiments in Bohol

1) Long-term fertility maintenance: Table 7 shows that differences in yield due to fertilizers were not significant in the first year, were significant in the second and highly significant in the third and fourth year **(Figure 3)**. In the 3rd and 4th cropping cycles, highly significant responses to N and K were observed. Generally, cassava yields decreased by about 50% in the second cropping cycle, but with fertilizer application



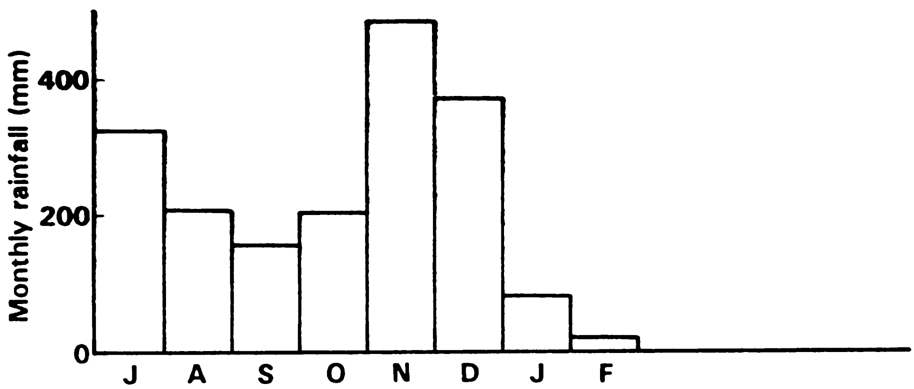


Figure 2. Effect of various management treatments on dry soil loss due to erosion in cassava planted on 25% slope in Baybay, Leyte, Philippines in 1991/92.

Table 7. Effect of different levels of applied N, P and K on cassava yield, averaged over two cultivars, during the first four years of a long-term fertility trial at the Bohol Experiment Station, Bohol, Philippines in 1989-1992.

$N-P_2O_5-K_2O$ (kg/ha)	Cassava root yield (t/ha) 1st year (1989/90)	2nd year (1990/91)	3rd year (1991/92)	4th year (1992/93)
0-0-0	25.4	11.8 bcd	10.1 c	7.5 f
0-60-60	29.6	10.8 cd	8.2 c	11.9 e
30-60-60	31.0	10.2 d	18.1 ab	17.3 cd
60-60-60	30.3	13.4 bcd	15.6 b	20.4 b
120-60-60	29.8	17.9 a	17.6 ab	22.4 ab
60-0-60	31.1	13.2 bcd	16.2 b	17.1 d
60-30-60	33.0	11.5 cd	18.0 ab	20.2 bc
60-120-60	31.5	13.5 bcd	17.4 ab	20.2 bc
60-60-0	32.6	12.3 bcd	8.2 c	6.8 f
60-60-30	28.1	15.1 ab	14.9 b	15.2 d
60-60-120	33.0	14.2 bc	19.6 a	22.2 ab
120-120-120	29.4	18.1 a	20.1 a	23.5 a
CV (%)	13.3	21.9	18.7	16.2
F-test: Global :	NS[1)]	*	**	**
N :	NS	*	*	**
P :	NS	NS	NS	NS
K :	NS	NS	**	**

[1)] NS = not significant
* = significant ($P<0.05$)
** = highly significant ($P<0.01$)
Mean seperation: DMRT (0.05)

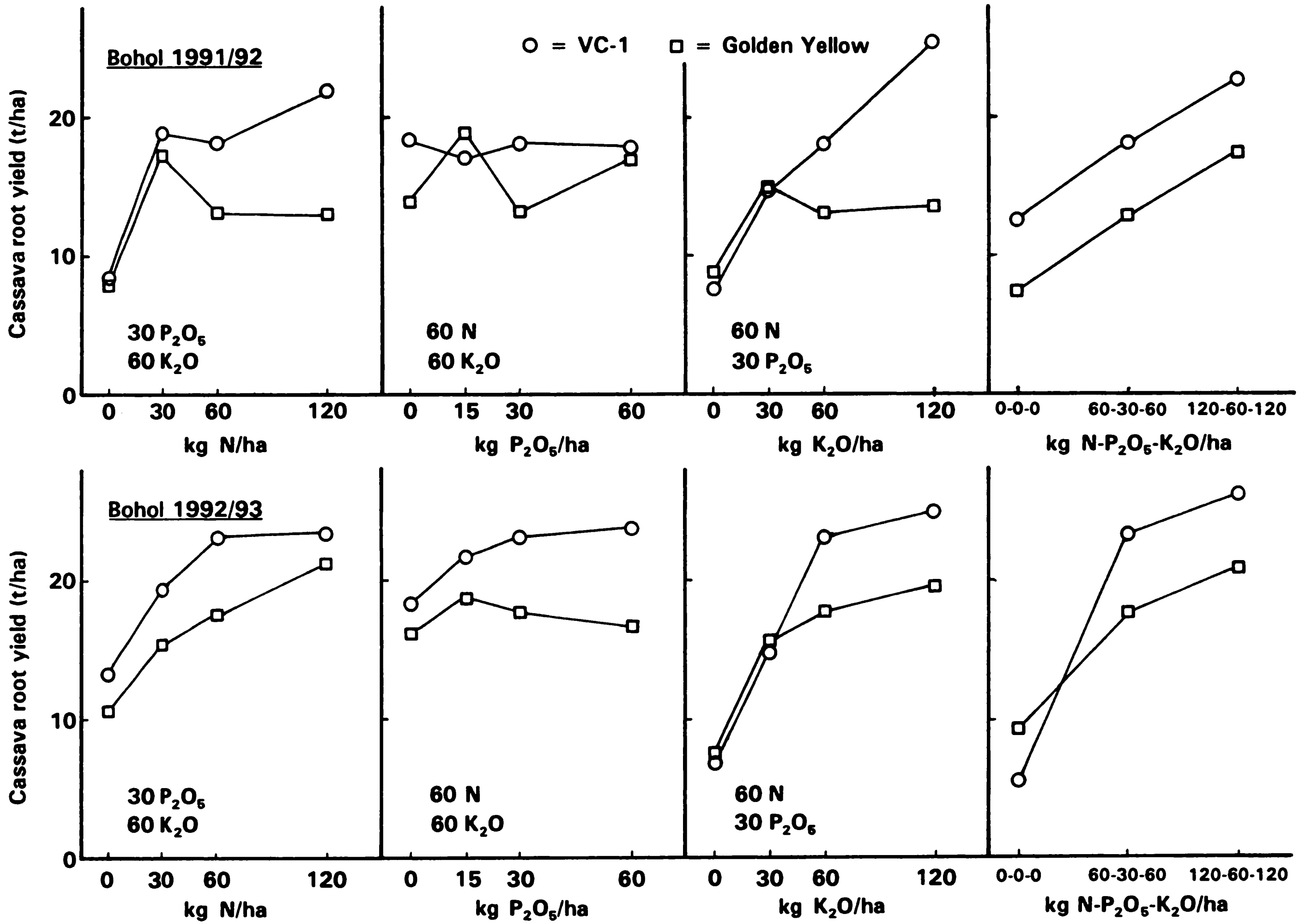


Figure 3. Response of two cassava cultivars to the annual application of various levels of N, P and K in the third and fourth years of cropping in Ubay, Bohol, Philippines.

yields increased again in the 3rd and 4th year. Significant differences in yield were observed between the two cultivars, with VC-1 generally being more responsive to fertilizer application than Golden Yellow.

2. **Stake length and planting position:** Stake lenght significantly affected the root yield of cassava in the first and second cropping cycle, but not in the third **(Table 8).** A significant interaction was observed between stake length, position of planting and the cultivar of cassava used. On average, stake length did not affect the yield of Golden Yellow, but short stakes significantly reduced the yield of VC-1. Vertical or inclined planting was better than horizontal planting for Golden Yellow, but horizontal planting was better for VC-1.

3. **Intercropping: Table 9** indicates that the yield of cassava was not significantly affected by intercropping treatments, but was significantly affected by cassava planting pattern, with the double-row system giving the highest yields. The yields of intercrops was also significantly affected by cassava row spacing, but were highest when cassava was planted in a square (1.0x1.0 m) arrangement.

Table 8. Effect of planting position and stake length on the root yield of two cassava cultivars during three cropping cycles in Bohol Experiment Station, Bohol, Philippines in 1989–1991.

	Root yield (t/ha)		
	1st year (1989/90)	2nd year (1990/91)	3rd year (1991/92)
Stake length (a)			
10 cm	14.27 b	4.81 b	23.20 a
15 cm	15.74 b	6.56 a	26.28 a
20 cm	18.21 a	7.39 a	23.22 a
Planting position (b)			
Horizontal	16.90 a	6.31 a	23.51 a
Inclined	15.06 a	5.78 a	24.87 a
Vertical	16.59 a	6.60 a	24.32 a
Variety (c)			
VC-1	12.32 b	4.49 b	24.54 a
Golden Yellow	20.05 a	7.97 a	23.93 a
CV a (%)	19.95	34.80	21.50
CV b (%)	23.86	28.37	24.03
CV c (%)	18.52	25.14	17.77

Table 9. Yields of cassava and intercrops (t/ha) as influenced by cassava planting arrangement at Bohol Experiment Station, Bohol, Philippines in 1991/92.

Cropping system	Cassava spacing (m)			
	1.0x1.0	1.7x0.59	(2.0+0.8)x0.71	Average
Cassava yield (t/ha)				
Cassava monocrop	12.75	14.47	14.58	13.93 a
Cassava+peanut	11.71	9.10	12.47	11.09 a
Cassava+mungbean	15.92	13.68	16.37	15.32 a
Cassava+soybean	17.40	15.92	16.60	16.64 a
Cassava+cowpea	13.83	14.86	14.91	14.53 a
Cassava+pole sitao	11.86	11.13	14.74	12.58 a
Average	13.91 ab	13.19 b	14.94 a	
CV (%)	16.72			
F-test: Cropping system NS; Spacing *; System x Spacing NS.				
Intercrop yield (t/ha)				
Cassava monocrop	-	-	-	-
Cassava+peanut	1.34	0.88	1.14	1.12 a
Cassava+mungbean	0.49	0.32	0.40	0.40 c
Cassava+soybean	0.47	0.29	0.17	0.31 c
Cassava+cowpea	0.93	0.92	0.89	0.91 b
Cassava+pole sitao	0.48	0.30	0.48	0.42 c
Average	0.74 a	0.54 b	0.62 ab	
CV (%)	31.07			
F-test: Cropping system**; Spacing *; System x Spacing NS.				

Recent Experiments in Negros Occidental

1) Long-term fertility maintenance: Table 10 presents results for three years (1989-1992) of the long-term fertility trial in La Granja Station in Negros Occidental. A significant yield response was observed only to the application of N. Of the two cultivars used, Lakan consistently gave higher yields than cv. Golden Yellow over all cropping cycles. There was no significant effect of crop residue removal or incorporation on yield, even in the third cycle.

Table 10. Effect of different levels of applied N, P and K on the root yield of cassava, averaged over two cultivars and two residue management treatments, grown at UPLB La Granja, Negros Occidental, Philippines in 1989–1992.

Treatments $N-P_2O_5-K_2O$ (kg/ha)	1st year (1989/90)	2nd year (1990/91)	3rd year (1991/92)
0-0-0	29.60 b	3.43 e	12.98 d
0-100-100	31.32 b	6.01 d	13.08 d
100-0-100	38.87 a	10.71 ab	22.19 bc
100-100-0	38.54 a	11.11 a	23.85 ab
50-100-100	38.53 a	8.80 c	21.27 bc
100-50-100	41.29 a	11.43 a	20.08 c
100-100-50	40.24 a	8.00 bc	25.41 a
50-50-50	37.49 a	9.16 d	22.13 bc
100-100-100	40.05 a	9.94 abc	21.60 bc
CV (%)	12.88	25.56	20.56
F-test: Global:	**[1)]	**	**
N:	**	**	**
P:	NS	NS	NS
K:	NS	*(neg)	NS

[1)] NS = not significant
* = significant (P<0.05)
** = highly significant (P<0.01)
Mean seperation:DMRT (0.05)

2) Intercropping: As shown in **Table 11,** yields of cassava planted with legumes, whether intercropped, alley-cropped or undercropped, were very much reduced compared with the monocrop. This result was consistently observed in four cropping cycles, which indicates that cassava is very sensitive to competition for light, water or nutrients when planted with either intercrops, alley-crops or with a permanent legume soil cover.

CONCLUSION

There has been a slight increase in cassava planted areas and yield in Mindanao due to the recent promotion of the crop.

In Leyte, cassava under coconut showed mainly a response to P and sometimes to N, while there was still no response to K after four years of continuous cropping.

Table 11. Effect of intercropping,undercropping and alley cropping with various legumes on the yield of cassava grown in La Granja Research Station,La Carlota City,Negros Occidental of the Philippines in 1989–1993.

Cropping system[1)]	Cassava root yield(t/ha)			
	1st year (1989/90)	2nd year (1990/91)	3rd year (1991/92)	4th year (1992/93)
Cassava monoculture	32.8 a	10.50 a	25.16 a	26.38 a
IC with mungbean	22.3 bc	6.33 bc	18.06 bc	13.04 e
IC with peanut	21.1 bcd	4.69 de	17.92 bc	18.00 cd
IC with cowpea	21.3 bcd	6.90 bd	18.90 bc	20.74 bc
IC with pigeon pea	14.4 e	5.13 cde	17.27 c	17.54 cd
IC with bush sitao	22.9 b	6.52 bcd	19.06 bc	17.42 d
IC with soybean	22.5 bc	8.16 ab	21.55 ab	17.84 cd
AC with pigeon pea	18.9 d	5.45 cde	13.42 d	16.75 d
AC with *Leucaena leucocephala*	19.6 cd	3.73 e	11.81 d	19.36 cd
AC with *Gliricidia sepium*	21.6 bcd	4.68 de	12.48 d	18.32 d
AC with *Crotalaria anagyroides*	22.1 bc	7.78 bc	11.14 d	17.37 d
UC with *Stylosanthes guianensis*	19.0 d	5.10 cde	18.08 bc	22.70 b
CV (%)	9.0	23.5	15.25	26.33

[1)] IC = intercropped
AC = alley cropped
UC = undercropped
Mean seperation: DMRT (0.05)

Application of mulch of dry grass resulted in low levels of soil loss due to erosion, while the cassava root yield was high.

In Bohol, cassava responded very well to K and N application, while in Negros Occidental significant yield responses were observed only to N application.

In intercropping trials, cassava yields in Bohol were not affected by any of the legume intercrops, while cassava yields were markedly reduced by intercropping or alley cropping with legume crops in Negros Occidental.

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RECENT PROGRESS IN CASSAVA VARIETAL IMPROVEMENT IN THE PHILIPPINES

Algerico M. Mariscal and Jose L. Bacusmo[1]

ABSTRACT

The report covers varietal improvement for the period 1990-1993. Not much progress was made in the 1990/91 season due to the occurence of a super typhoon that damaged standing field trials. In recent years, however, progress in selection was made in terms of high yield and dry matter content and good plant type.

The cassava germplasm bank of PRCRTC has currently a total of 270 accessions, including 30 varieties introduced through tissue culture from Thailand. From this germplasm a polycross nursery and hybridization block were established to incorporate desirable genes into the local cultivars.

Since 1991 about 3659 new genotypes have been evaluated by PRCRTC. From these evaluations and screenings two varieties of CIAT origin were released by the Philippines Seedboard. These were CM4014-3 (PSB Cv-9) named VC-4 and MCol 1684 (PSB Cv-10) named VC-5. CM4014-3 is a cross of CM728-3 x CM681-2 of the 1984 CIAT introduced population. This variety had an average yield of 32.9 t/ha and is recommended throughout the country. It has a medium HCN and high starch content which is good for processing. MCol 1684 is a CIAT clone introduced in 1979. This is the first variety intended for regional release in Mindanao. It has had an average yield of 44.8 t/ha for the last 10 years. This variety has high HCN and medium starch contents and is good for starch processing.

Preliminary and General Yield Trials with cassava materials from CIAT/Colombia and the Thai-CIAT program resulted in the identification of outstanding clones that are high yielding, have high dry matter content and good plant type. In the General Yield Trial, about 40% of the Thai-CIAT materials had yields of 30-40 t/ha after 9 months and about 10% had yields of 50-65 t/ha. In the General Yield Trial about 45% of entries from CIAT/Colombia had yields of 20-30 t/ha after 10 months and about 36% produced 30-40 t/ha. This population has also high dry matter content. Germplasm selection focuses also on starch content and plant type aside from resistance to mites and scale insects.

Promotional yield trials with the recommended cassava varieties were conducted in farmer's fields and farmers made their own selection of desired varieties.

Gradually the distribution system of recommended cassava varieties have gained momentum. Lakan and Golden Yellow, both Philippines Seedboard varieties, are already widely

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used by farmers in Samar, Leyte and northern Mindanao for human food, starch production and feeds. MCol 1684 is planted in almost 2000 ha in Lanao del Sur, specifically for starch processing.

The other recommended varieties, VC-1, VC-2 and VC-3, are already in the fields of some farmer cooperators. With the joint effort of the local government and the private sector it is expected that rapid diffusion of recommended cassava varieties will be attained through the establishment of cassava nurseries and demonstration farms in strategic areas where cassava is an important crop.

INTRODUCTION

Cassava varietal improvement in the Philippines started in the 1960s at the Institute of Plant Breeding (IPB) at Los Banos, Laguna (Bacusmo and Bader, 1992). However, activities consisted mainly of variety trials of a few local and introduced varieties (Mariscal, 1987). It was only when the Philippine Root Crop Research and Training Center (PRCRTC) was established in 1977 at ViSCA, Baybay, Leyte, that a more organized and relatively well supported cassava breeding program started. The breeding program was further enhanced when PRCRTC established a strong linkage with CIAT in 1982 in which the latter provide improved breeding populations for the national program. This collaboration resulted in the release of several cassava varieties with parental origin from CIAT.

In spite of the release of new cassava varieties, the yield of cassava is still not very high, as indicated by the low national average yield of 9.2 t/ha (BAS, 1992). This is probably due to market uncertainty and low government support to the cassava industry in areas other than Mindanao.

Improving cassava yields is a challenge, but the possibility of success is high, considering the wide variability of materials received from CIAT. Progress in selection, however, in the 1990/91 season was slow because of natural calamities that affected the trials, resulting in unreliable results.

The acquisition of a better experimental area by PRCRTC in 1992 has resulted in a more reliable evaluation and the selection of a greater number of clones. Recent results also indicate improvements in the selection for resistance to pests and diseases.

Breeding Objectives

The breeding objectives for cassava in the Philippines have not changed since 1987 and aim to satisfy the needs of the cassava farmers which grow cassava in diverse agroclimatic conditions, as well as processors which utilize the storage roots in a variety of ways.

The breeding objectives are as follows:

1. High yield
2. High dry matter and starch content
3. Early harvestability
4. Resistance to pests and diseases
5. Tolerance to environmental stresses
6. Good plant type (root formation, root shape and branching habit).

Although the HCN level of cassava is not correlated with yield, the root HCN content will also be considered. Low HCN varieties are identified and selected for farmers who use cassava as a staple food. High HCN varieties, on the other hand, are preferred by starch millers. Those having low HCN and high dry matter and starch contents are considered dual purpose varieties (for table use and processing).

RECENT DEVELOPMENTS (1991–93)

Germplasm Development

The basis of a cassava improvement program is a germplasm collection with wide genetic variability; thus PRCRTC maintains and upgrades the genetic stock of cassava in the country. To date PRCRTC maintains in the field a germplasm collection containing 270 accessions of which 23 are elite materials selected from Advanced Yield Trials and 30 are clones introduced in the form of tissue culture materials from Thailand **(Table 1)**.

Table 1. Cassava germplasm at PRCRTC, ViSCA, Baybay, Leyte, Philippiness.

Source	# of accessions
Local	86
Foreign	131
New accessions from the Thai-CIAT program (tissue culture)	30
New elite clones	23
Total	270

Varietal Release

The 1991-1993 Regional Yield Trials have resulted in the release of two new cassava varieties by the Philippine Seedboard. The two varieties of CIAT origin are CM4014-3, released as PSB Cv-9 (VC-4), and MCol 1684 locally known as PSB Cv-10 (VC-5). The latter is the first variety which is released specifically for regional recommendation in Mindanao. **Tables 2, 3** and **4** show the performance of these cultivars in the Regional Trials. The following are the morphological descriptions of these two new varieties:

Table 2. Total fresh root yield (t/ha) of accessions in the cassava Regional Trials, 1990–1993.[1)]

ENTRY	1990/91		1991/92						1992/93		MEAN
	BES	ViSCA	BES	USM	UPLB	AES	LANAO	ViSCA	BES	UPLB	
1. CM4012-11	24.3	22.2	35.0	33.4	24.0	-	-	35.6	38.2	31.3	30.5
2. CM4014-3*	24.2	31.3	31.9	44.2	16.0	25.9	42.7	39.2	42.4	16.8	32.9
3. CM4050-1	24.5	30.2	28.3	26.2	19.6	-	40.3	35.3	40.1	22.8	29.6
4. CM4066-1	20.4	20.5	25.4	17.4	-	-	38.9	38.3	30.1	-	27.3
5. MCol 1684	19.1	29.1	29.9	25.1	-	-	41.5	40.8	33.3	-	31.2
6. G41r-1b	-	32.1	-	33.6	23.6	15.3	-	32.8	-	29.4	27.8
7. CM3422-1	-	27.8	-	30.7	28.0	27.7	-	22.9	-	18.0	25.9
8. CM3419-2a	-	33.4	-	36.2	18.8	20.6	-	33.3	-	21.4	27.4
9. CM3384-2	-	17.7	-	-	17.9	-	-	-	-	19.4	18.3
10. CM43283-4	-	25.0	-	-	26.8	14.7	-	28.8	-	28.8	24.8
11. VC-3 (check)	14.4	28.3	22.1	-	-	-	-	18.6	-	-	20.7
12. UPL Cv-5 (check)	22.1	29.3	31.4	-	-	19.1	-	38.3	30.3	-	28.9
C.V. (%)	26.8	28.7	11.8	32.3	23.2	29.1	-	21.3	13.1	22.2	

[1)] Average of 3 to 4 replications/trial; entries with more than 30% missing plants are not included.

Table 3. Characteristics of VC-4 (CM 4014-3) and VC-5 (MCol 1684).

Parameters	VC-4	VC-5
1. Average yield (t/ha)	32.9	28.9
2. Dry matter content (%)	33.8	30.6
3. Starch content (%)	22.9	20.0
4. HCN content	Medium	High
5. Reaction to pest and diseases:		
a. white peach scale insect	HR	HR
b. red spider mite	MR	MR
c. CBB	MR	MR

1) Based on 10 Regional Trials conducted in 6 locations during 1990-1993.
Source: PRCRTC, 1993.

Table 4. Characteristics of MCol 1684 and the check variety, Hawaiian 5, evaluated in Regional Trials in Mindanao, Philippines.

Parameters	MCol 1684 (VC-5)	Hawaiian 5 (check)
1. Average yield (t/ha)	44.8	40.4
2. Dry matter content (%)	33.6	31.2
3. Starch content (%)	20.3	20.3
4. HCN content	High	High,
5. Reaction to pests and diseases:		
a. red spider mite	MR	MR
b. CBB	MR	MR

[1)] Based on 7 trials in Mindanao (Univ. South. Mindanao and Lanao del Sur). during the period 1983-1993.
Source: PRCRTC, 1993.

1. VC-4 (CM4014-3) Moderately branching; light purple unexpanded leaves, green petioles, silver green stem, white root skin and white flesh. It has medium HCN and high starch contents. This cultivar is recommended for production of starch and animal feed. It is resistant to lodging and moderately resistant to red spider mites and CBB. The clone was selected from the cross CM728-3 x CM681-2, which was introduced in 1984.

2. VC-5 (MCol 1684) Moderately branching; light green unopened leaves, light purple petioles, silver green stem, white root skin and yellow flesh. This variety was released as the first regional cassava variety for Mindanao. It is recommended solely for starch processing due to its high HCN and dry matter content. This clone was introduced by CIAT to the Philippines in 1979. The variety consistently shows good performance in western Mindanao especially in Malabang, Lanao del Sur, where a starch factory operates.

Promising Selections

Since 1991, 11,084 hybrid seeds have been introduced to PRCRTC, comprising 147 crosses **(Table 5).** A total of 3,659 hybrid seedlings have been evaluated. Most of these seedlings came from seed introductions from the CIAT/Colombia and Thai-CIAT programs. A summary of the number of genotypes at different testing stages is shown in **Table 6.** From the results of the Preliminary Yield Trial of Thai-CIAT materials, 35% of the population had a yield range of 30 to 40 t/ha and 25% between 40 to 50 t/ha **(Figure 1).** The check variety Lakan produced a yield of only 25 t/ha. In a subsequent

Table 5. Number of cassava hybrid seeds supplied by CIAT to PRCRTC, ViSCA, Baybay, Leyte, from 1991 to 1993.

Date	No. of seeds	No. of crosses	Source
January 1991	4,079	89	CIAT/Colombia
January 1991	2,794	44	CIAT/Colombia
March 1993	1,850	29	CIAT/Colombia
June 1993	2,361	35	Thai-CIAT
Total	11,084	197	

Table 6. Number of entries of cassava evaluated at various stages of selection by PRCRTC, ViSCA, Baybay, Leyte, from 1991 to 1993.

Selection stage	Year			Total
	1990/91	1991/92	1992/93	
	No. of entries			
F_1 Seedling Trial	1,200	807	1,652	3,659
Single-Row Trial	133	761	315	1,209
Preliminary Yield Trial	46	117	86	249
General Yield Trial	28	52	27	107
Advance Yield Trial	16	13	12	38
Regional Trial	12	12	12	12
On-Farm Trial	-	-	4	4
Varietal Release	-	-	2	2
Promotional Trial	2	4	4	4

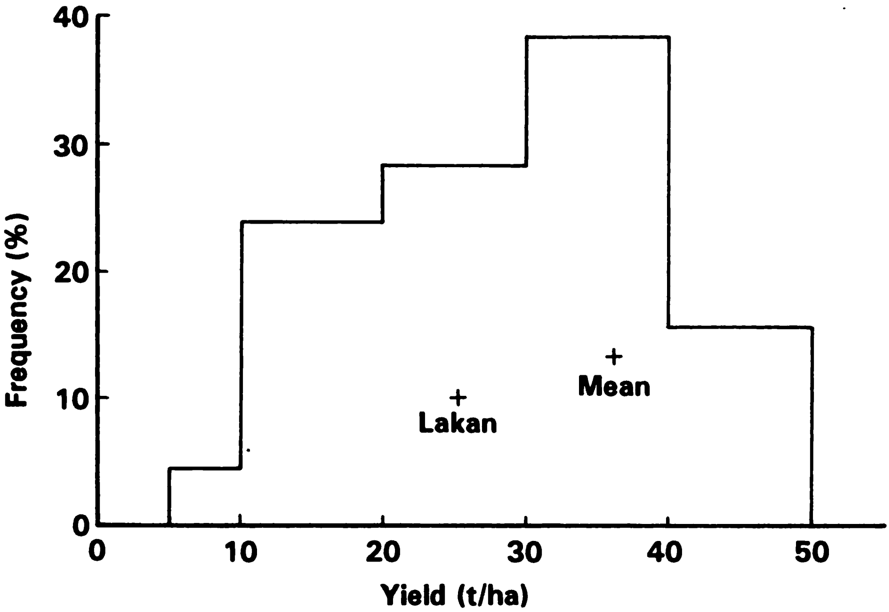

Figure 1. Frequency distribution of fresh root yield in the Preliminary Yield Trial of cassava hybrids from the Thai-CIAT program (1991/92).

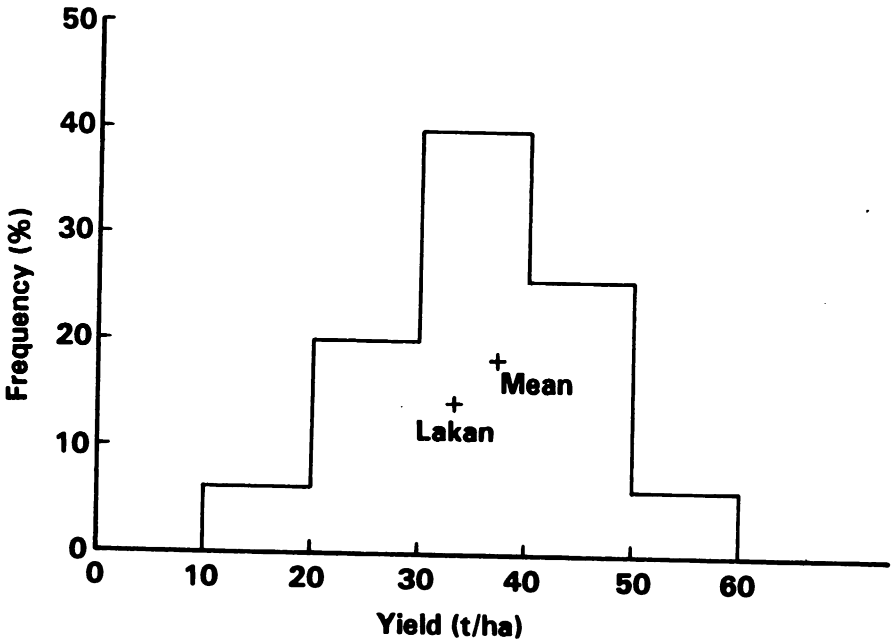

Figure 2. Frequency distribution of fresh root yield in the General Yield Trial of cassava hybrids from the Thai-CIAT program (1992/93).

General Yield Trial, further progress in selection was attained: 40% of the entries had a yield range of 30 to 40 t/ha after 9 months, 25% produced 40 to 50 t/ha, while 10% had a yield of 50 to 65 t/ha **(Figure 2).** Results of selected cassava hybrids in the General Yield Trial with Thai-CIAT materials are presented in **Table 7.** It can be observed that as far as yield and dry matter are concerned, there was a considerable improvement compared with the check variety Lakan. The average yield of all entries was 36.7 t/ha, while Lakan produced only 31.4 t/ha. On the other hand, the dry matter content of Lakan is comparable to the average dry matter content of the test population. The majority of these selections have good plant type and root shape.

The results of the Preliminary Yield Trial with CIAT/Colombia material during the 1991/92 season **(Figure 3)** shows that 40% of the population had a yield range of 10 to 20 t/ha, 30% produced 20 to 30 t/ha, 18% yielded 30 to 40 t/ha and 5% had 40 to 50 t/ha. In subsequent testing in the General Yield Trial, 45% of the population had a yield of 20 to 30 t/ha and 36% produced 30 to 40 t/ha **(Figure 4).** The performance of

Table 7. Summary data of the performance of promising cassava hybrids from the Thai–CIAT program selected in the General Yield Trial (1992/93).

Clones	Fresh root yield (t/ha)	DM content (%)	Harvest index	Plant type[1)]	HCN content[2)]
1. MT 15-34	42.5	32.3	0.49	4	5
2. MT 12-44	65.0	31.2	0.61	5	8
3. MT 6-7	41.8	30.2	0.50	5	6
4. MT 14-48	46.0	31.1	0.58	5	8
5. MT 4-111	42.6	31.0	0.54	5	7
6. MT 4-52	44.4	31.9	0.57	4	6
7. MT 3-16	40.1	30.5	0.45	4	4
8. MT 2-123	36.9	30.0	0.59	4	6
9. MT 9-12	57.1	30.6	0.54	4	6
10. MT 10-12	46.7	28.8	0.71	5	8
11. MT 16-6	60.8	29.4	0.61	5	4
12. MT 4-251	48.7	33.6	0.63	5	4
13. MT 16-53	26.4	34.4	0.50	4	8
14. MT 15-32	38.6	33.1	0.62	4	5
15. Lakan (check)	31.4	30.6	0.54	5	4
16. VC-1 (check)	54.1	29.4	0.64	3	5
Average of 38 entries	36.7	30.7	0.52		

[1)] Based on rating scale: 1 = poor plant type; 5 = good plant type

[2)] Based on picrate test: 1 = low, 9 = high

Source : PRCRTC, 1993.

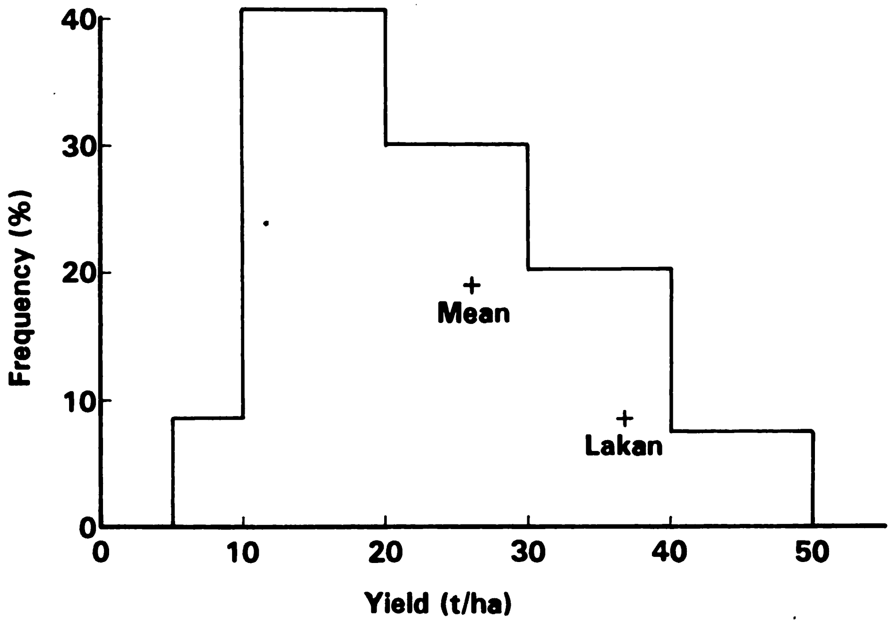

Figure 3. Frequency distribution of fresh root yield in the Preliminary Yield Trial of cassava hybrids from CIAT/Colombia (1991/92).

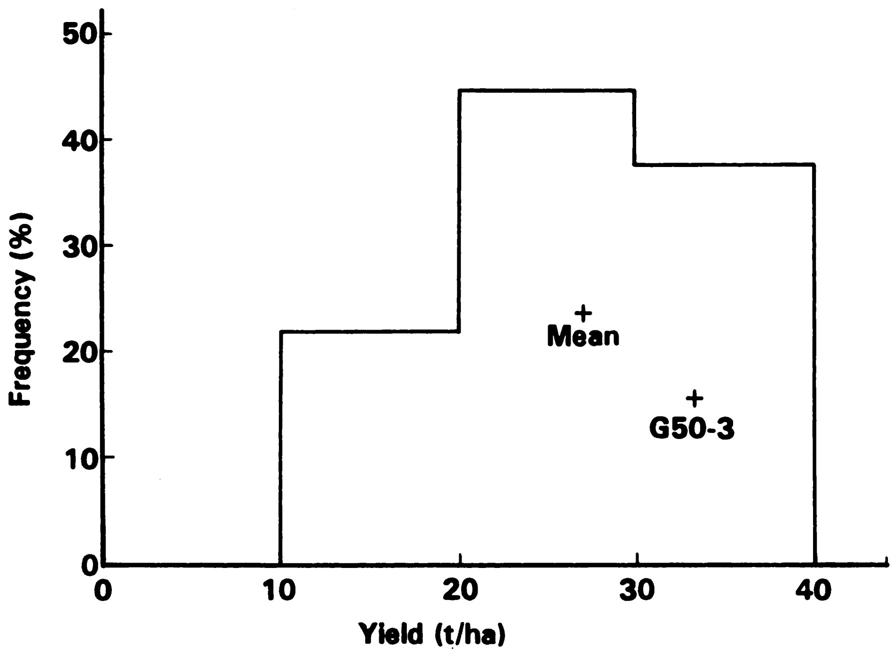

Figure 4. Frequency distribution of fresh root yield in the General Yield Trial of cassava hybrids from CIAT/Colombia (1992/93).

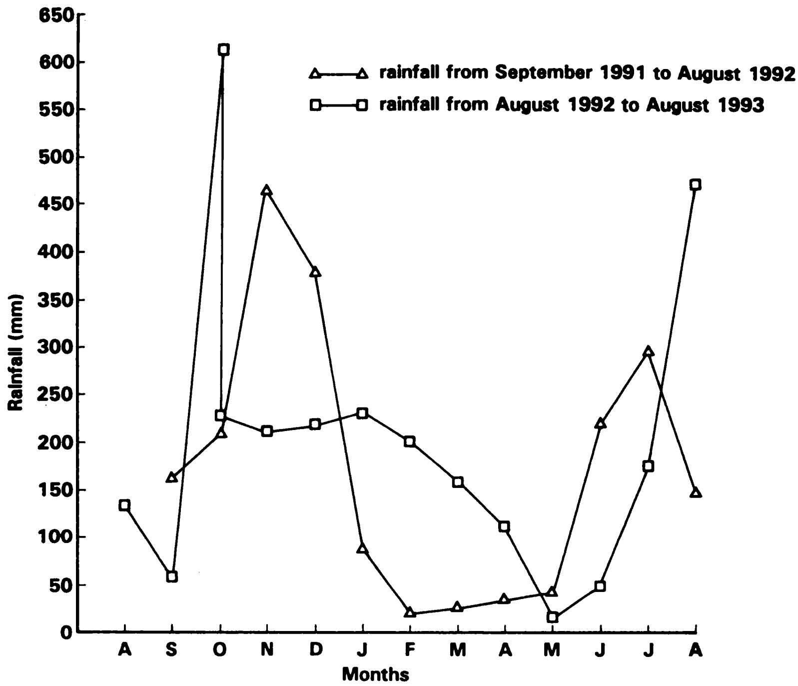

Figure 5. Rainfall distribution at PRCRTC during two crop years, 1991-1993.

Table 8. Summary data of the formance of promising cassava hybrids from CIAT/Colombia in the General and Advanced Yield Trials (1991–1993).[1]

Clones	Root yield (t/ha)		Dry matter (%)		Harvest index		HCN content [2]
	General	Advanced	General	Advanced	General	Advanced	
1. Rayong 1	37.8	34.1	22.3	30.1	0.55	0.49	7
2. SM512-7	29.6	21.5	23.2	28.8	0.56	0.52	7
3. SM557-8	24.8	29.4	23.5	36.2	0.56	0.58	7
4. SM560-1	27.3	36.9	25.0	33.4	0.46	0.46	6
5. SM554-3	35.4	45.8	22.6	31.6	0.57	0.60	6
6. SM557-7	29.2	36.3	22.5	31.4	0.50	0.54	6
7. SM563-1	21.9	18.8	23.3	32.7	0.52	0.43	4
8. SM466-6	26.6	33.9	22.9	32.2	0.49	0.49	7
9. SM566-1	25.1	40.1	22.0	31.0	0.65	0.68	6
10. MCol 1684	31.2	27.0	23.2	29.6	0.56	0.56	8
11. G 50-3 (check)	35.4	39.5	21.1	28.4	0.57	0.58	7
12. VC-1 (check)	-	38.7	-	32.2	-	0.65	6
Mean	29.5	33.5	22.9	31.5	0.54	0.55	

[1] General Yield Trial: planted Sept. 25, 1991; harvested Aug. 8, 1992;
Advanced Yield Trial: planted Aug. 25, 1992; harvested July 15, 1993.

[2] Based on picrate test: 1 = low, 9 = high

Source : PRCRTC, 1993.

selected cassava hybrids from CIAT/Colombia in the General and Advanced Yield Trials is presented in **Table 8.** It is interesting to note that the root yield levels in the General and Advanced Yield Trials were quite similar, but that the dry matter contents were very distinct. The average dry matter content in the General Yield Trial was only 22.9%, compared to 31.5% in the Advanced Yield Trial. The probable reason for this is the rainfall distribution during the 1991-1993 evaluation periods **(Figure 5).** In the General Yield Trial, which was conducted during the 1991/92 cropping season, not much rainfall occurred from the 5th up to the 7th month after planting, but during the 8th and 9th month rainfall was heavy. The starch in the roots may have been translocated to the tops for new leaf formation during the recovery of the plants after the drought stress. In the Advanced Yield Trial, conducted during the 1992/93 cropping season, rainfall was low during the 9th month and moderate before the harvest; this might have resulted in the high dry matter content in the Advanced Yield Trial compared to that in the General Yield Trial. The total rainfall for crop seasons 1991/92 and 1992/93 were 2093 and 2807 mm, respectively.

Table 9. Summary data of the performance of selected tissue culture-derived cassava clones from the Thai-CIAT program in the Preliminary Yield Trial at PRCRTC in 1992/93.

Clones	Fresh root yield (t/ha)	Dry matter content (%)	Harvest index	Spider mite resistance[1)]	HCN content[2)]
1. CM3299-4	56.1	33.3	0.71	3	6
2. Rayong 1	47.2	31.3	0.59	4	6
3. CM4054-40	35.0	32.2	0.71	3	7
4. CG1355-2	42.2	33.3	0.49	3	5
5. MCol 2215	49.4	36.9	0.62	3	4
6. CM2772-3	41.9	34.7	0.62	4	6
7. CM3372-4	48.9	31.6	0.59	2	5
8. Rayong 60	56.4	32.7	0.69	3	8
9. CM4231-32	60.8	33.4	0.66	4	3
10. CM2166-6	40.0	29.2	0.64	2	5
11. CM3306-4	50.5	36.1	0.64	4	5
12. MCol 1505	40.6	33.7	0.55	3	6
13. MMal 2	38.9	31.0	0.62	3	7
14. CMR28-67-76	52.2	34.2	0.62	2	6
15. CMR29-56-101	48.9	32.1	0.67	2	6
16. Lakan (check)	42.6	35.6	0.58	3	5

[1)] Based on rating scale: 1 = highly resistant; 9 = highly susceptible

[2)] Based on picrate test: 1 = low, 9 = high

Source : PRCRTC, 1993.

The Preliminary Yield Trial, consisting of materials introduced as tissue culture from Thailand, indicate a number of promising clones **(Table 9).** Clones like Rayong 1 and Rayong 60 as well as other selections outyielded the local check Lakan. These materials generally produced high yield, dry matter content and harvest index as well as good plant type.

Utilization of CIAT Germplasm

Aside from screening and field evaluation of hybrid seed materials introduced from CIAT, the center utilized elite clones for hybridization work in order to improve the local cultivars. Hybridization blocks were established and selected parents of local and foreign origins were planted for subsequent crossing. Open-pollinated seeds in the germplasm collections were also collected for screening and evaluation. Thousands of open-pollinated seeds are now ready for evaluation.

From the hybrid population developed in 1984, thirteen selected clones have been tested for three cropping seasons from 1991 to 1993. The performance of these hybrids is presented in **Table 10.** The majority of these hybrids outperformed the check variety VC-2; however, no hybrids outyielded the other check variety Lakan. As far as dry matter is concerned, some progress was observed, but again few hybrids had dry matter contents higher than the check variety Lakan; examples of these are CMP 77-5 and CMP 21-6.

Because of the potential of these locally developed hybrids, five entries were included in this year's cassava Regional Yield Trial. These are CMP 21-15, CMP 62-15, CMP 21-6, MOP 26-1 and CMP 32-10.

Breeding of cassava for resistance to scale insects and mites has resulted in the identification of resistant parents and progenies. MOP 24-2 F_1 progenies from open pollinated seeds generated 18 promising clones that are resistant to red spider mites. These had a yield range of 0.4 to 4.8 kg/plant in the Single-Row Trial. Twelve promising selections have entered into the Preliminary Yield Trial. The performance of these selections is presented in **Table 11.** From controlled pollination among promising parents (G50-3, MOP 24-2, CMR77-15, VC-2, UPL Cv-4, PR-C 350 and Golden Yellow), 183 F_1 progenies were identified to have moderate to high resistance to mites. Subsequent selection resulted in 65 resistant clones that will be further tested in a Single-Row Trial.

Distribution of Planting Materials

The increase of cassava production in the southern part of the Philippines (Mindanao), was brought about by the joint efforts of the government, the private sector, financial institutions, technical assistance and the marketing of dried chips for export. In effect,

Table 10. Performance of locally-developed cassava hybrids in the Advanced Yield Trial during three cropping seasons (1991–1993) at PRCRTC, ViSCA, Baybay, Leyte, Philippines.

Clones	Parents	Fresh root yield (t/ha)	Dry matter content (%)	Harvest index	HCN content[1]
1. CMP 17-11	CMC40 x PR-C60a	18.6	32.5	0.43	7
2. MOP 26-1	CM305-38	33.0	31.8	0.45	5
3. CMP 25-11	MCol 1684 x CMC40	21.3	30.8	0.45	6
4. CMP 21-6	VC-1 x PR-C60a	34.0	34.6	0.56	6
5. CMP 62-15	CMC40 x BdSC	34.1	32.5	0.48	7
6. CMP 17-10	CMC40 x PR-C60a	19.2	32.7	0.40	7
7. CMP 40-6	PRC-67 x CM305-38	35.1	34.2	0.53	3
8. CMP 77-5	MCol 1684 X SIP 242	27.4	35.2	0.46	5
9. CMP 25-1	MCol 1684 X CMC40	25.2	32.7	0.51	5
10. CMP 60-4	CMC40 X CM305-38	28.8	30.7	0.48	4
11. MOP 24-2	CMC84	27.6	29.3	0.48	4
12. CMP 21-13	VC-1 X PR-C60a	25.6	28.4	0.43	6
13. CMP 21-15	VC-1 X PR-C60a	42.6	31.4	0.60	4
14. VC-1 (check)		24.5	29.3	0.42	4
15. Lakan (check)		44.8	34.5	0.62	4
Mean		29.3	32.0		

[1] Based on picrate test : 1 = low, 9 = high

Source : PRCRTC, 1993

Table 11. Fresh root yield, harvest index and spider mite resistance rating of selected MOP 24-2 F1 progenies evaluated in the Single-Row Trial at PRCRTC, Baybay, Leyte in 1992.[1)]

Progeny	Fresh root yield (kg/plant)	Harvest index	Spider mite resistance	
			Rating	Reaction[2)]
1. MOP 24-2-4	4.68	0.63	2.4	R
2. MOP 24-2-12	2.43	0.59	2.2	R
3. MOP 24-2-13	3.20	0.45	2.2	R
4. MOP 24-2-19	3.08	0.52	2.1	R
5. MOP 24-2-21	2.38	0.50	2.3	R
6. MOP 24-2-28	4.83	0.57	2.2	R
7. MOP 24-2-30	2.42	0.57	2.0	R
8. MOP 24-2-34	3.73	0.60	2.3	R
9. MOP 24-2-40	4.03	0.54	2.5	R
10. MOP 24-2-46	2.82	0.48	2.6	R
11. MOP 24-2-6	2.30	0.46	2.4	R
12. MOP 24-2-52	3.93	0.61	2.7	R

[1)] Average of 15 plants/entry

[2)] Based on rating scale: 1 = highly resistant, 9 = highly susceptible.

Source: PRCRTC, 1993.

the need for planting material became a problem. To date the Land Bank of the Philippines has financed the cassava production in about 2,000 hectares through farmer cooperatives, and the common variety planted is Golden Yellow, which was promoted by PRCRTC as one of its recommended cultivars. To facilitate the rapid distribution and adoption of newly-released cassava varieties, promotional trials were established in important cassava growing areas.

Promotional Trials

These trials were conducted in areas where cassava is a dominant crop. This was a joint effort between CIAT and PRCRTC, and entries were limited to recommended varieties only. In one of the PRCRTC sites in Samar, farmers selected VC-2 as the best variety for that area and farmers immediately expanded their cassava fields using this selected variety. At another site in Leyte the trial is still going-on and farmers are eager to see the results.

In large industrial plantations, like Matling Agro-Industrial Corporation in Malabang, Lanao del Sur, and the Aznar Cassava Equatorial Mill in Leyte, PRCRTC will provide new cassava varieties for testing and evaluation in their respective locations. The companies take charge of operating and field expenses and they themselves select the best varieties for their purpose. In Matling our center provided ten varieties in 1991, which they tested **(Table 12)**; from this they selected CMR32-10 and CM4014-3 (the newly released variety VC-4). MCol 1684, the other new variety approved for Mindanao, is already widely used in their plantation; approximately 2,000 hectares are planted to MCol 1684 in Malabang.

At the Aznar Cassava Mill in Kananga, Leyte, the new varieties were planted in a trial located adjacent to farms of a farmers' cooperative, which had a marketing agreement with the starch mill. Farmers then selected the best variety out of the pool of varieties tested. To date around 400 hectares are ready for planting the varieties that they selected, namely Lakan, VC-1 and VC-2.

Table 12. Results of a Variety Trial conducted at Malting Agro-Industrial Corporation, Malabang, Lanao del Sur in 1991/92.

Variety	Fresh root yield (t/ha)	Starch content (%)
1. CMP 21-15	31.7	20.3
2. CMP 32-10	44.1	19.7
3. CM4014-3	42.7	22.0
4. CM4050-1	40.3	21.0
5. CM4054-3	38.9	19.0
6. CM4066-1	38.2	21.7
7. G 50-3	53.7	18.7
8. VC-1	32.5	18.3
9. Rayong 60	41.2	20.3
10. MCol 1684	41.5	20.3
11. Hawaiian 4	31.6	18.3
12. Hawaiian 5 (check)	39.8	20.3
Mean	39.7	20.0

Source : MICC, 1992.

Establishment of Model Farms and Nurseries

To further facilitate variety distribution, PRCRTC initiated the establishment of model farms by farmers' cooperatives in Mindanao where most cassava production is located. This model farm will be a showcase of the recommended varieties plus the necessary cultural management practices. This will also be the source of planting material for the farmers in those cooperatives.

Aside from the model farm, each cooperative will have cassava nurseries of the new varieties, which will be used as the source of planting material. These seed-systems have triggered a positive response from cassava farmers. This way the distribution of new cassava varieties will be greatly accelerated.

PRIORTIES

The potential of cassava in the Philippines' economy rest mainly on domestic demand. In recent years, a large number of cassava plantations have been established in northern Mindanao in order to cater to the export market in Europe. The quota allocation in the EEC of 145,000 metric tons of dried chips is so small that it can be met by only one exporter. But due to this massive increase in cassava plantations in Mindanao, the price of cassava chips for export has dropped drastically from P2.50/kg in the early part of the year to P1.40/kg recently. With the current low price farmers no longer have any enthusiasm for planting cassava.

Thus, in line with the Medium-Term Philippine Development Plan, priorities should be geared towards domestic utilization of cassava in industry. As such, PRCRTC shall need to take some bold steps in the effective transfer of mature cassava technologies to cassava farmers. This will become a component of the national development plan called "Philippine 2000".

In response to these priorities, the Department of Science and Technology (DOST) and the Philippine Council for Agricultural Resources Research and Development (PCARRD), have launched a program of Cassava Technology Transfer in Agusan del Norte in Mindanao and in Camotes Island in the Visayas. These will be spearheaded by PRCRTC.

Considering these new developments, the objectives in cassava breeding will continue as before, but more emphasis will be placed on the identification of varieties that will suit the needs of industry, mainly for the production of animal feed, flour and starch.

This team approach between government technocrats, non-governmental organizations and the industrial sector will facilitate the more effective transfer of technology.

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CASSAVA TECHNOLOGY TRANSFER IN THE PHILIPPINES

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ABSTRACT

After several years of conducting research in cassava, the Philippine Root Crop Research and Training Center (PRCRTC) developed technologies that may raise the crop's potential and help uplift the welfare of Filipino farmers, processors and consumers. To fully tap this potential, PRCRTC, in cooperation with the national agricultural extension service, conducted extension activities to transfer the technologies to the intended users, i.e. small or large-scale producers, processors, entrepreneurs and other interested individuals or groups.

The technology transfer is being done through training, publications, exhibits, radio broadcasts and pilot commercialization projects. These activities gained momentum only recently, but substantial progress can already be observed. These include the people's increasing awareness of the cassava technologies, spread of the PRCRTC-recommended varieties in some parts of the country and the eight operational village-scale cassava processing projects in the Visayas and Mindanao regions.

While conducting the different technology transfer activities, PRCRTC learned important lessons that led to the implementation of the Integrated Root Crop Extension Program. A case study on the establishment of a cassava processing project following an integrated approach is presented. Problems on cassava technology transfer and some suggestions for improvement are also discussed.

INTRODUCTION

Cassava is a good source of carbohydrates. It thrives under marginal conditions and requires only minimum inputs. These are among the reasons why almost all of the small farmers in the Philippines plant cassava in their farms. They use it either as food or as animal feed.

This association with small farmers, however, gave cassava a low status. Thus, even if the crop has other uses aside from food or feed, it did not gain the attention of the country's development planners. More focus was given to major crops like rice and maize.

The importance of cassava and other root crops gained recognition among the national development planners when a calamity hit the Philippines in the early 1970s.

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Rice and corn became scarce and it was root crops that saved thousands of Filipinos from starvation.

This development led to the establishment of a national root crop research center based at the Visayas State College of Agriculture (ViSCA) in 1975. A national stature was accorded to the center on March 21, 1977 when the country's president converted it into the Philippine Root Crop Research and Training Center (PRCRTC) with a mandate to spearhead the development of the root crop industry in the country, particularly for the benefit of the rural poor.

The cassava research and development program in the Philippines thus gained impetus with the establishment of PRCRTC. After several years, the Center developed a number of cassava production, processing and utilization technologies that may raise the status of the crop from being a poor man's food to an important industrial crop, and thus help uplift the welfare of the Filipino farmers, processors and consumers.

Within the framework of its mandate, PRCRTC assumes the responsibility not only of generating root crop technologies but also of transferring these technologies to the intended users, i.e. small or large-scale producers, processors, entrepreneurs and other interested individuals or groups. To accelerate the technology transfer process, PRCRTC linked with the national agricultural extension service.

This paper presents PRCRTC's past and present cassava technology transfer activities, the problems encountered and some suggestions for improvement.

OVERVIEW OF THE NATIONAL AGRICULTURAL EXTENSION SERVICE

The Agricultural Extension Service in the Philippines aims to promote rural development through the introduction of appropriate technologies that can help rural people improve their productivity and income. It actually started during the 19th century with the introduction of modern farms by the Spaniards. The farms were made experimental stations for the government and at the same time demonstration centers for farmers. During the American regime, extension services were improved with the establishment of the Bureau of Agriculture (Balagapo, 1992).

Since then, the bureau, which underwent several reorganizations and renamings, has provided extension services related to crops and livestock. In 1984, when it became the Ministry of Agriculture and Food (MAF), it was made responsible for the formulation of policies and goals for promoting the production of agricultural crops, livestock, poultry and fisheries through the implementation of appropriate programs and projects as well as the provision of suitable services for administration, research, regulatory requirements and extension (Balagapo, 1992).

In 1987, MAF was renamed to Department of Agriculture (DA) but with the same functions as MAF. The extension services were then coordinated by one of its bureaus the Bureau of Agricultural Extension (BAEX).

BAEX had national, regional, provincial and municipal offices that coordinated the different extension-related activities. It also had an extensive network of field technicians or extension workers, who were in charge of transfering to the rural people technologies developed by the DA's technical bureaus, research centers(RCs) and state colleges/universities (SCUs).

On November 10, 1991, the country's president enacted the Republic Act No. 7160, otherwise known as the local government code (LGC). This code seeks to promote and strengthen local governance (BAR, 1992) and one of its provisions is the devolution of DA's functions relative to extension services and on-site research to the local governmental units (LGUs) -- the barangay, the municipality and the province (Balagapo, 1992).

With this new structure, those DA's extension workers and field researchers doing provincial functions were absorbed by the provincial government and came under the governor, while those performing municipal functions were absorbed by the municipal government and came under the mayor. This new development implies that research centers like PRCRTC, which plan to do extension projects have to coordinate not only with DA but also with the local governmental units.

PRCRTC'S LINKAGE WITH THE NATIONAL EXTENSION SERVICE

PRCRTC's linkage with MAF, which at the time was in charge of coordinating the delivery of agricultural extension services, started a few years after the establishment of the Center. For cassava, early collaborative activities of PRCRTC and MAF included the national cooperative variety trials, testing varieties for location specificity and pilot cassava processing projects in some villages in Region 8 (Eastern Visayas) (Bernardo, 1986; PRCRTC 1985, 1986). For the last activity, ViSCA worked collaboratively with MAF Region 8 in helping entrepreneurs establish village-level cassava processing plants. MAF's role was more on supervision and coordination of cassava production by some farmers who were organized as a group to ensure continuity of raw-material supply. PRCRTC-ViSCA provided technical help and supervision in product processing, while both agencies extended assistance in establishing market outlets (Bernardo, 1986).

In the following years, PRCRTC and MAF continued to devise ways to strengthen their linkage. To convey the available technologies to the greatest number of people and to get valuable feedback on problems still besetting the root crop industry, MAF and ViSCA conducted periodic consultation meetings with researchers, extension workers and farmers, starting in 1986. The objectives of these meetings included the identification of field problems and research needs, technologies ready for field adaptation/verification, and location-specific technologies and recommendations on different commodities for dissemination to farmers.

With the recent implementation of the local government code, PRCRTC has strengthened its linkage not only with DA but also with the LGUs, which are now given the function of coordinating the delivery of agricultural extension services to the rural people.

Also, with its current efforts to promote commercialization of cassava products, PRCRTC has strengthened its linkages with other development-oriented organizations (i.e. the Department of Trade and Industry, the Department of Science and Technology, the Land Bank of the Philippines and other possible financing institutions, non-government organizations, etc.); the cassava market sector; and farmers' organizations. These linkages are intended to pool resources and minimize duplication of efforts.

CASSAVA TECHNOLOGY TRANSFER ACTIVITIES OF PRCRTC

The first decade of PRCRTC's existence was focused more on technology generation. Technology transfer gained momentum only recently, although some activities like training, publications and planting material distribution were started during the first half of the 1980s.

An overview of the different technology transfer activities conducted by PRCRTC is presented here. These activities apply not only to cassava but also to other root crops.

Training

Training courses have been conducted by PRCRTC to improve the clientele's capability to use the technologies, and to provide extension workers with technical knowledge that they can use to help farmers. Earlier training covered only production technologies. Later, the Center received feedback about the peoples' need for technologies that can transform their cassava into more marketable forms.

In 1987, PRCRTC started to receive several requests for training on cassava processing technologies. These requests continued to increase each year, so the number of training courses conducted by PRCRTC from 1987 to 1992 also increased **(Figure 1)**. The topics included in the training also widened, covering the whole area of root crop production, processing and utilization.

The increase in the number of cassava training activities conducted implied that people's awareness of cassava technologies have been increasing. However, evaluation of the PRCRTC training activities revealed that many of the trainees were not able to use the technologies they had learned during the training. Among the reasons cited were the lack of capital to start a project using root crop technologies and the lack of follow-up technical support by PRCRTC-ViSCA or the sponsoring agency (Campilan, 1989).

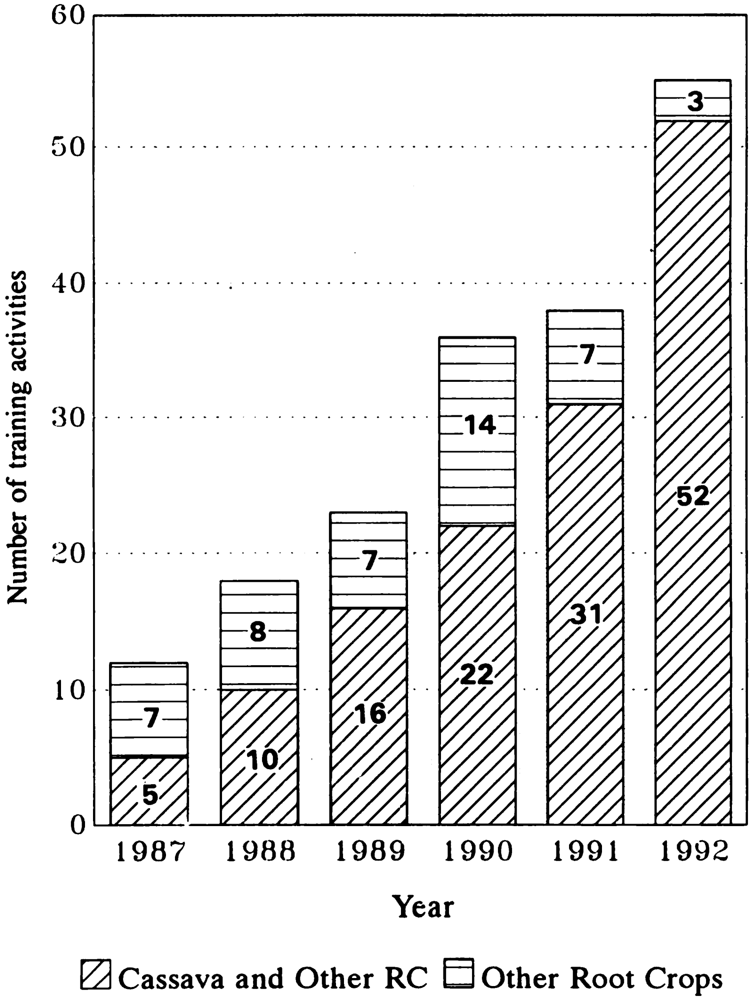

Figure 1. Number of training activities conducted by PRCRTC in 1987-1992.

These weaknesses of the training programs are noted and are now considered in the planning of future extension activities.

Exhibits, Publications and Radio Broadcasts

To further promote the available cassava technologies, PRCRTC participated in technology fairs/exhibits sponsored by ViSCA and other agencies (i.e. DOST, DA, DTI, etc.). It also produced publications and aired cassava information through the ViSCA radio, DYAC.

This year, PRCRTC, in cooperation with the Technology Livelihood Resource Center (TLRC) started to tap television as another medium for root crop technology promotion. The centers' technologies and ongoing commercialization projects have been featured in one of the top television channels in the country.

The tangible result of these promotional activities is the increasing requests for information materials, training and technical assistance on cassava.

Distribution of planting material

A few years after its establishment, PRCRTC started distributing planting material of improved cassava varieties to farmers and other interested people. This was done during training activities, exhibits and visits to the Center.

PRCRTC, DA and the other collaborating agencies/SCUs also distributed planting material to typhoon victims, and more recently, to the victims of the Mt. Pinatubo eruption as part of the rehabilitation efforts.

The above activities resulted in the spread of the recommended cassava varieties in some areas of the Philippines. For instance, MCol 1684, which was introduced by PRCRTC to Malabang, Lanao del Sur, is now replacing the traditional cassava varieties grown for starch by small farmers and large plantations. Also, Golden Yellow, the first cassava variety recommended by PRCRTC, is now the most widely grown variety, both for food and starch in Bohol, Negros, Surigao del Norte, Bicol and other cassava growing areas in the country. New cassava varieties are also starting to penetrate the small farms in other parts of the Philipines.

The above system of planting material distribution, however, is generally considered informal. One important drawback is that documentation of the volume of planting material distributed and the assessment of the extent of adoption and diffusion of the recommended varieties and their cultural management requirements were not part of the efforts. Thus, although PRCRTC has a general idea on the distribution of the improved cassava varieties in some areas, it lacks hard data on the actual distribution and performance of the varieties nation wide.

Another problem encountered by PRCRTC in relation to planting material distribution is that the Center lacks propagation areas. Thus, it can hardly cope with the increasing requests for planting material of the recommended varieties.

Recently, the development of a more systematic distribution system of root crop planting material has become part of the objectives of the newly implemented root crop seed systems project. PRCRTC, DA and the LGUs are starting to establish root crop nurseries in strategic areas. The Center is also trying to come up with a system to document and monitor planting material distribution and to access the varieties' actual performance in the farmers' fields.

Action/pilot projects

With the development of the root crop processing and utilization technologies, pilot project activities were given focus by the Center. These activities aimed to assess the technologies' performance in the field and to identify modifications that need to be made on the technologies, identify factors affecting technology adoption, and determine extension approaches that can be used to effectively transfer the technologies to the target users.

For the period 1985-1992, PRCRTC-ViSCA, in cooperation with DA, DTI, DOST and later with the concerned LGUs, had initiated 17 pilot cassava projects. Thirteen of these were in the Eastern Visayas Region, one in Western Visayas and three in Mindanao. Only the project in Negros (Region 6) concentrated on the distribution of planting material (cassava and sweet potato) to assist the sugarcane plantation workers when the sugar industry was in recession in the middle of the 1980s. The rest of the projects were on casssava processing, either into feeds (1 project), chips for feeds and flour (2 projects), flour and food products (7 projects), bakery products (2 projects) and non-bakery products (4 projects).

Of the 17 projects, 8 are currently operating, 3 have off-and-on operation, 4 were terminated and 2 have started later than scheduled.

Most of the pilot projects that stopped or that operated on an off-and-on basis were those that were established earlier through the Training and Visit method. Among the problems encountered were lack of capital to sustain operation, lack of entrepreneurial skills of the cooperators, weak leadership in the cooperating groups, lack of market outlets for the products, and lack of follow-up support when the project funding ended (Gundaya, 1991).

On the other hand, most of the projects that are still continuing on until now are those that were established using the integrated approach. Among the factors contributing to the success of these projects are: strong leadership and organizational capabilities of the cooperating groups, people's participation in the planning and implementation of the project, interagency and multidisciplinary support, and the incorporation of market development and group build-up components in the pilot activities.

Integrated Root Crop Extension Program

The lessons learned from the past extension activities led PRCRTC to implement the Extension Program (IRCRP). The program was started in 1992 and it is directed towards the promotion of root crop technologies that will lead to the establishment of economically viable, ecologically sound and sustainable livelihood projects. It is also geared towards empowerment of the clienteles to increase their capability in project management.

The integrated approach used in the program is pursued within the framework of multidisciplinary staffing and interagency cooperation aimed at enhancing complementarity of efforts and resources **(Figure 2).** It also places emphasis on clienteles' participation in all aspects of project planning, implementation and monitoring.

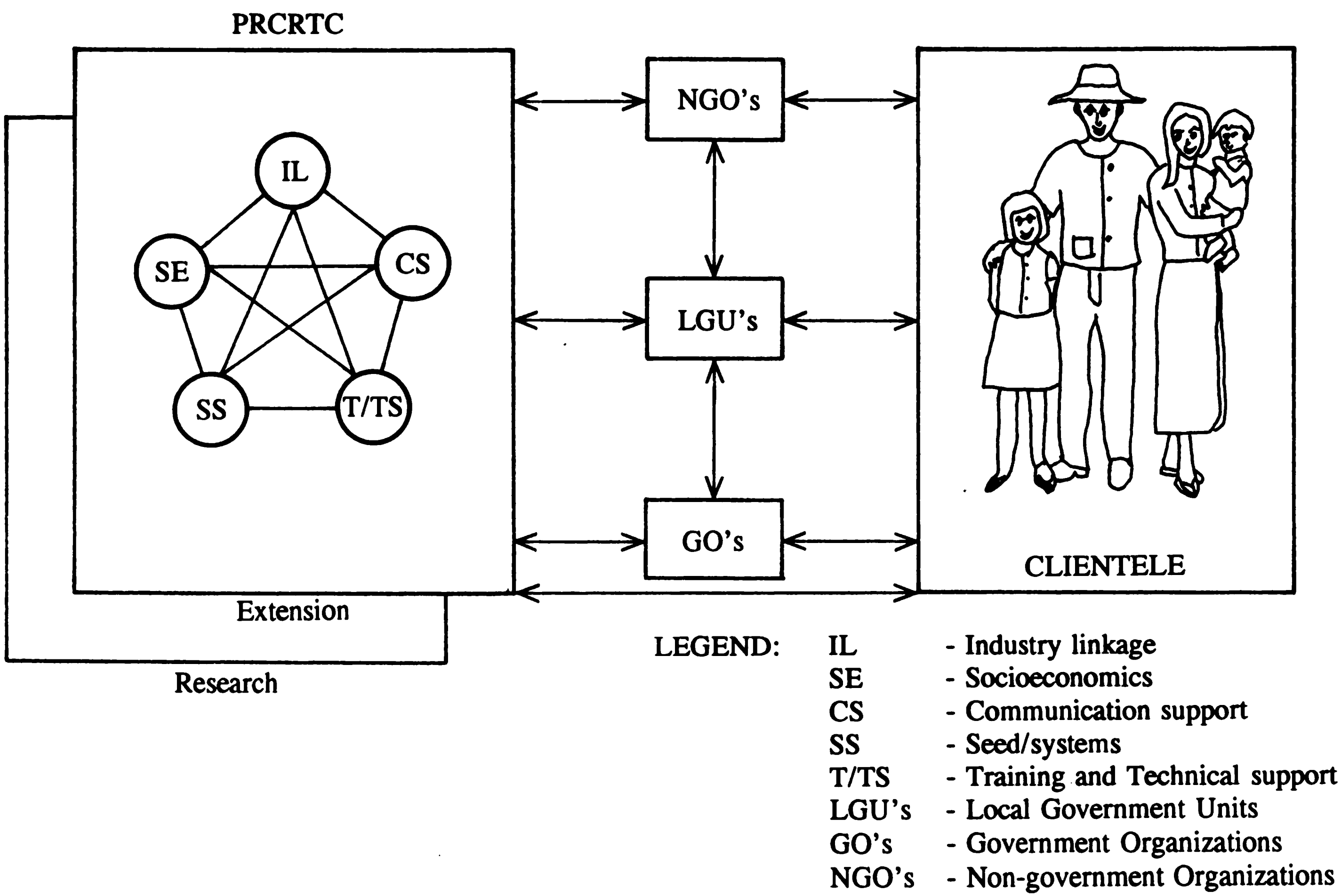

Figure 2. Conceptual framework of integrated root crop extension program.

In consideration of the multi-faceted factors affecting the success of extension projects, the program has the following components: (1) socioeconomics, (2) training (technical and organizational build-up) and technical support, (3) communication support (development, production and distribution of communication support and promotional materials), (4) seed systems components (development of mechanisms for effective distribution of root crop seed pieces), and (5) industry linkage/market development.

One project established using the IRCSP strategy is the cassava processing project in Surigao del Norte.

THE CASSAVA PROCESSING PROJECT IN SAN FRANCISCO, SURIGAO DEL NORTE

Background

The province of Surigao del Norte has fertile soils which are very suitable for agriculture. However, this province is always visited by typhoons such that the important crops raised by the farmers (i.e. rice, maize, coconut and fruit trees) are often destroyed. The crops that always survive after strong typhoons are root crops, particularly cassava, which is by nature a hardy crop. Most, if not all of the farmers in the province plant cassava as a food source, especially during times when rice and corn are really scarce.

Although cassava is already recognized by many commercial processors as an important agro-industrial crop, many people still consider it as a poor man's crop. This is because many of the farmers in Surigao del Norte are not yet properly linked to the cassava market. Thus, their use of cassava is limited only to direct home consumption (i.e. food and animal feed). There might be those that are aware of the demand for cassava as raw material for starch processing, but they are located far from the starch mills. Cassava, being a highly perishable crop, cannot easily be transported over long distances, especially by farmers with limited resources. These are among the reasons why many of the people in the province live below the poverty level. They could not regularly grow the important food and cash crops because of the typhoons that often visit their region. They do have cassava that can thrive under adverse conditions, but they cannot get additional income from it.

The Department of Trade and Industry (DTI) in Surigao del Norte has been aware of this situation. Having heard about the different cassava technologies developed by PRCRTC-ViSCA, DTI contacted the Center to assess the possibility of putting up a cassava project in the area that could expand the market of the crop. To attain complementation of efforts and resources, PRCRTC and DTI decided to involve the DA and the LGU of Surigao. Thus, the cassava processing project in San Francisco, Surigao del Norte, is a joint undertaking of PRCRTC-ViSCA, DTI, DA, the local government unit of

Surigao del Norte and a farmers' cooperative in San Francisco known as the Anao-aon-Ipil Farmers Multipurpose Cooperative (AIFAMUCO). The project was started in January, 1992. Its main objective is to establish a viable cassava processing project that will benefit the small farmers in the area.

Project Establishment

Site and cooperator selection

DTI, DA and the Surigao LGU assessed the cassava-growing areas of Surigao del Norte. They selected San Francisco as one of the project sites, because it is one of the province's top cassava-growing municipalities; it is near Surigao City, thus marketing of cassava products is not much of a problem; and a strong farmers' cooperative (AIFAMUCO), which was interested to participate in the project, existed in the area.

In–depth study of the pilot area

After selecting possible pilot sites, DTI contacted PRCRTC for technical assistance. A multidisciplinary team from PRCRTC-ViSCA (composed of a socio-economist, extension/communication specialist, cassava production specialist, an engineer and a food scientist) visited San Francisco and conducted an in-depth study of the area considering the following: (1) social network among farming/processing households, (2) relationship between cassava traders and farmers, (3) market mechanisms (i.e. pricing, trend, power-play, supply, etc.) of the cassava trade, (4) other possible vertical/backward/ forward linkages, (5) strengths/weaknesses of groups and social decisions, (6) users of root crop products (bakeries, city markets, etc.) and their corresponding market relationships, and (7) linkages with other support agencies which will be part of the local management groups to assist in supporting/monitoring the project. These data were gathered through surveys; consultations with various sectors (local government officials, farmers, processors, traders, bakeries, city market buyers, local traders); intensive market observation; and informal/key informant interviews.

Definition of roles of the participating organizations

Using the results of the in-depth study as basis, plans for project implementation were laid out. Agreements on the role of the participating organizations (DA, DTI, LGU, AIFAMUCO and PRCRTC-ViSCA) were made through a series of consultation meetings.

As agreed during the meetings, AIFAMUCO would operate the pilot project, while DTI would assist AIFAMUCO in market development and in acquiring the needed processing machines through its common service facilities (CSF) program. AIFAMUCO would pay DTI for the machines on a soft loan basis.

PRCRTC-ViSCA, on the other hand, was assigned to make the equipment and provide the needed technical assistance. DA in cooperation with the PRCRTC production specialist would assist AIFAMUCO in cassava production aspects, especially in the establishment of a cassava nursery, while the LGU would provide whatever support the coordinating agencies needed.

Input–sourcing

Since the processing equipment was already provided by DTI, AIFAMUCO had only to look for the operating capital for the project. It was secured by AIFAMUCO from the Land Bank of the Philippines (LBP).

Technology Introduction

The technology: As agreed during the consultation meetings, the project would be concerned with the processing of cassava into dried chips and flour. The steps in processing dried chips are: (1) washing the cassava roots, (2) peeling (in case the chips are intended for flour; if for feeds, peeling is not necessary); (3) chipping, and (4) drying. To produce flour, the dried chips are ground and then sieved. The machines needed for a village-level processing of these products include: root crop washer, pedal-operated chipper, modified tapahan dryer (for use during rainy season), attrition grinder and flour finisher.

Machine fabrication and installation: PRCRTC built all the machines except the grinder which was ordered from the Almeda Cottage Industry in Manila. The machines were installed in August 1992 at the processing site provided for by AIFAMUCO.

Technical trainings: To teach the cooperators about the cassava technologies which they would use for their project, PRCRTC conducted a series of training activities on cassava production and processing into chips and flour. The training was done at the project site and was attended not only by the AIFAMUCO members but also by the staff of DTI, DA and LGU, who were assigned to closely monitor the operations of AIFAMUCO.

Institutional development: AIFAMUCO was already a strong cooperative with business experience (rice milling and trading). Thus, there was not much problem as to its organizational and entrepreneurial capabilities. DTI and PRCRTC-ViSCA gave the group only some suggestions on product promotion.

Processing try–outs: To enable the cooperators to familiarize themselves with machine operations and to practice processing the desired qualities of chips and flour, they were made to conduct processing try-outs. These gave them the necessary basis for choosing what operational scheme to follow. The try-outs also led to the modification of some machines as suggested by the cooperators.

Nursery establishment: To be assured of a steady supply of planting material of the recommended cassava varieties, the participating organizations agreed to establish a nursery in the area. As agreed, DA and PRCRTC-ViSCA supported AIFAMUCO in the establishment of the nursery, which is currently managed by the latter.

Operational Scheme Identification

After testing the set-up and after consultation with its members, AIFAMUCO decided to adopt the centralized processing scheme. The cooperative bought fresh roots from its farmer-members, then hired some of its members to process the roots into dried chips and flour. Drying was not a problem particularly during sunny days because AIFAMUCO, being engaged in rice trading, had a drying area for rice. Marketing of the processed products was assigned to the cooperative's marketing manager.

Market Development

DTI and ViSCA assisted AIFAMUCO in establishing markets for chips by linking the cooperative with different chip buyers like the chips exporting firms and the ViSCA Feedmill, which utilizes cassava as corn substitute in the formulation of animal feeds.

To help develop markets for flour, PRCRTC-ViSCA conducted bakers training activities and developed some promotional materials like posters and radio plugs.

Monitoring

To monitor the progress of the project, DTI assigned one of its staff to regularly visit the cooperators. Feedback are passed to the supporting agencies concerned. The PRCRTC-ViSCA team also conducts periodic visits to the site.

Project Status

During the first half of 1993, the project was able to sell more than 10 tons of dried chips for feed to the ViSCA Feedmill. In the second half, it stopped processing chips when the ViSCA feedmill was overstocked and it stopped buying chips for feeds. AIFAMUCO did not sell chips to the other buyers (exporters) because the price was too low.

AIFAMUCO also is not yet selling flour to bakeries because the AIFAMUCO processors are still stabilizing the quality of their product. Flour quality testing is currently conducted by AIFAMUCO in cooperation with two interested bakery owners in Surigao City.

While waiting for the market of flour to be established, the AIFAMUCO decided to process their cassava into food products like cassava chicharon (cacharon) from flour, and chippy and fried chips from fresh roots. They requested PRCRTC-ViSCA to train them in the processing of these products.

AIFAMUCO's cassava food products had already been launched during the Food and Technology Fair held in Surigao City in September 1993. At present, AIFAMUCO is already selling these products in San Francisco and Surigao City. Packaging improvement is currently done in preparation for their planned market expansion.

To help AIFAMUCO promote the food products, PRCRTC-ViSCA produced some plugs and posters. Linkage with the Surigao-based Philippine Information Agency (PIA) is also established through DTI and the LGU.

Constraints

The major constraint that the project faces now is the market for chips and flour. With the current problem on the international chips market, the buying price of chips in the Philippines decreased to as low as three cents ($0.03) per kilo. With this price, cassava production is not profitable anymore for AIFAMUCO or any other cassava farmers.

Market development for flour is continuing. Most of the bakers still have to be convinced that cassava flour can be used in the preparation of bakery products. The others, although already convinced, have still to be taught how to use cassava flour. These entail several bakers training activities and the use of promotional materials like posters, plugs and others. Funds for product promotion, however, are limited so that it cannot support extensive promotional activities. This is the reason why the pace of cassava market development is slow.

Cassava flour has a chance to penetrate the market if it can be sold at a lower price than wheat flour. This implies that AIFAMUCO has to maximize its flour production level to reduce overhead cost. But then the level of production depends on flour demand. Thus, for AIFAMUCO to earn from its flour processing venture, there is a need to speed up market development.

On the side of the supporting agencies, one major constraint is the limited financial support of extension projects. PRCRTC, for instance, could not even hire a research assistant to closely monitor, document and facilitate the different project activities due to limited funds.

Towards a More Effective Cassava Technology Transfer

The experiences gained from the different extension activities of PRCRTC strongly suggest that the most important factor affecting farmers adoption of cassava technologies in the Philippines is market. Farmers would be encouraged to use technologies that can improve the yield of their crop if they had markets for their produce.

With the recent problem on the international market for cassava, the technology transfer activities in the Philippines should be geared towards increasing local utilization of the crop. The PRCRTC already has several processing technologies that can be used to diversity products from cassava, thus widening its range of utilizations and markets. But the transfer of these technologies to the farmers and other users becomes a little more complicated because the development workers now have to work towards the transfer not just of one technology but of several related technologies such as high yielding varieties, improved production practices, processing and utilization technologies. The transfer of each of these technologies needs different approaches and methods.

The case of the cassava processing project in Surigao del Norte has illustrated the possibility of using an integrated approach to effect better technology transfer. The project may be progressing at a slow pace, but the experiences gained from this project provides the different participating organizations an understanding of the importance of integrating their efforts toward better implementation of a particular development project. The involvement of a multidisciplinary staff led to the identification of important factors that need to be given attention to make the project viable. Also, the clienteles' participation right at the start of project implementation made them understand the nature of the project, the problems that can possibly be encountered and the possible solutions they are going to take.

The involvement of a strong cooperative also contributed to the initial success of project implementation. The members' experience in business enabled them to look for an alternative profitable cassava processing activity while waiting for the market for chips and flour to be established.

As of now, it is still too early to determine whether the Surigao project will be really sustained or not. But to increase the possibility that the project and other future cassava projects will succeed, the following improvements in the technology transfer efforts are suggested:

1. Strengthening of research, extension and users linkages to ensure that the technologies developed will be what the users need.
2. Increasing people's participation in the planning and implementation of cassava projects.
3. Continuous mobilization of multidisciplinary efforts to make sure that the different factors affecting success of the projects will be properly considered.
4. Establishment of closer coordination among organizations which are planning to put up cassava projects to minimize the establishment of too many small projects which will just lead to market competition later on.

5. Enhancement of local government's capability to handle development projects including cassava.
6. Tapping of existing farmers' federations as project operators to minimize time and effort spent in organizing new groups.
7. Consideration of other projects that may be linked with cassava projects to solve marketing problems for cassava products. For instance, increasing local utilization of cassava could possibly be done through the establishment of cassava-based feedmill projects, which should be linked with animal raising projects.

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RECENT PROGRESS IN CASSAVA VARIETAL IMPROVEMENT AND AGRONOMY RESEARCH IN MALAYSIA

S.L. Tan and S. K. Chan[1]

ABSTRACT

A total of four sets of seeds (totalling 5526 seeds) were recieved from CIAT during the period 1990-1993. One set (comprising 1100 hybrid seeds) originated from the Thai-CIAT program in Rayong. Evaluation and selection of seedling clones has progressed satisfactorily, and culminated in the release on August 9, 1992 of an early clone (CM3906-31) named MM 92. This cultivar is capable of yielding 30 t/ha of fresh roots on drained peat after six months, and up to 40 t/ha on mineral soils. Starch content, however, was low at 20%.

Agronomic research included studies on the effect of spacing and fertilizer rates on the yield of Perintis (released in 1988) and MM 92 grown on peat. A long-term fertility trial on peat has now completed its ninth cropping cycle. The most significant response has been to lime applications. On mineral soils, an erosion control study over two seasons of cropping showed that natural grass or citronella contour barrier strips were most effective in reducing erosion, although statistically there were no significant differences in soil loss due to the different tillage and cropping treatments.

Physiological studies on the effect of water stress (in excess and in short supply) were carried out in lysimeters and large containers, respectively. Cassava was able to withstand flooding (at 3 1/2 months) up to 3-4 days. Drought at 4 months seemed to increase the cyanide content in the root pith of the edible variety Medan. Conversely, moisture stress lasting three weeks in an 8-month crop appeared to produce the same effect in both Perintis and Medan.

INTRODUCTION

Due to an earlier policy decision in MARDI, the bulk of cassava varietal improvement work has been carried out on peat soils. At the end of 1992, during the research program review of the Division of Horticulture of MARDI, it was agreed that the cassava research program should not restrict itself only to peat (where the technical capability for large-scale production is still being developed on a long-term basis), but should also address itself to other soils, including rehabilitated ex tin-mining land.

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VARIETAL IMPROVEMENT

1. Seedling and Clonal Evaluation and Selection

A total of 5526 seeds were introduced from CIAT over the period April 1990 to June 1993. Of these,1100 seeds were from the Thai-CIAT program in Rayong, Thailand, while the rest were from CIAT headquarters in Colombia. As may be seen from **Table 1**, the batch from the Thai-CIAT program has yielded a higher percentage of selected seedling clones than the batches from CIAT/Colombia.

Table 1. Summary of seed introductions over the period April 1990 to June 1993.

Year of introduction	Seed batch	No. of seeds	Germination No. of seedlings	Germination %	Seedlings selected No.	Seedlings selected %
Apr. 1990	CIAT 9 (Thai-CIAT)	1,100	237	21.5	59	24.9
Feb. 1991	CIAT 10 (CIAT/Col)	1,271	716	56.3	102	14.2
Jan. 1992	CIAT 11 "	2,079	1,170	56.3	169	14.4
Feb. 1993	CIAT 12 "	1,076				

The stage of evaluation for each of the seed batches at the time of writing this report is as follows:

CIAT 12 seed batch : Seeds being germinated in polybags, prior to Seedling Evaluation

CIAT 11 seed batch : Selected seedling clones in Single-row Evaluations

CIAT 10 seed batch : 19 clones selected from 95 in Preliminary Yield Trial

CIAT 9(TH) seed batch : 18 clones selected from 59 in Preliminary Yield Trial

Selection criteria used to short-list seedlings for further evaluation are high fresh root yield, moderate to high root starch content (estimated by specific gravity method) and high harvest index. Check varieties used in Single-row and Preliminary Yield Trials may include Black Twig, Perintis and/or MM 92.

2. Yield Trials

CIAT 8(THAI-CIAT) seed batch: Of the 54 clones of *CIAT 8(TH)* evaluated against Black Twig and Perintis in Single-row Trials, 12 were selected (22%) for Preliminary Yield Testing. The criteria for selection were high fresh root yield, high starch yield and high harvest index.

A Preliminary Yield Trial of the 12 selected clones was established in September 1991 at Jalan Kebun Peat Station, using Perintis, Black Twig and MM 92 as checks. Although no significant differences were detected among the clones for fresh root yield (due probably to only two replications and the high coefficient of variation), OMR06-17

Table 2. Results of Preliminary Yield Trial using selected clones from CIAT 8 (TH) seed batch at Jalan Kebun Peat Station in 1991/92.

Clone	Fresh root yield (t/ha)	Harvest index	Root starch content (%)
OMR06-17	47.4 a	0.66 cd	23.4 bc
OMR06-4	40.4 a	0.78 a	17.2 fg
OMR06-21	33.7 a	0.69 abcd	24.9 ab
OMR06-64	29.9 a	0.64 cd	26.8 a
OMR06-46	28.7 a	0.75 ab	23.0 bcd
OMR08-18	25.0 a	0.64 cd	26.7 a
OMR06-12	23.3 a	0.65 cd	21.6 cd
OMR06-48	22.4 a	0.73 abc	24.9 ab
OMR30-37	22.3 a	0.62 d	24.7 ab
OMR06-25	18.4 a	0.61 d	22.7 bcd
OMR08-5	18.1 a	0.60 d	25.8 a
OMR30-11	17.5 a	0.74 abc	25.9 a
Perintis	36.9 a	0.78 a	18.9 ef
MM 92	33.2 a	0.69 abcd	15.8 g
Black Twig	27.8 a	0.55 bcd	20.8 de
CV (%)	43.0	6.1	4.4

Note: Values in the same column bearing the same letter are not significantly different from one another according to the DMR test at $P \leq 0.05$

and OMR06-4 were higher yielding than Perintis by 28 and 10%, respectively **(Table 2).** Eight clones produced significantly higher starch content.

CIAT 7 seed batch: All three Preliminary and Advanced Yield Trials on *CIAT 7* clones (including two local accessions, Sabah 1 and Tapah) have been completed. Of the total of 41 clones tested, none were outstanding in yield at six months after planting when compared to MM 92. At 12 months, SM814-22 had a root yield equivalent to that of Perintis and 85% higher than that of Black Twig; however, its starch content was only 21.8% as compared to Black Twig's 25.0% **(Table 3).**

CIAT 6 seed batch: Two of the 11 clones (CM6587-13 and CM6545-7) from this seed batch showed promise over the two checks, Black Twig and Perintis, at 6 months after planting. CM6587-13 produced a fresh root yield equivalent to 43 t/ha, which, although not significantly different from that of Perintis, was 26% higher **(Table 4).** The root yields of both clones were significantly higher than that of Black Twig (which had

Table 3. Yield performance after 12 months of top three clones from three Advanced Yield Trials on CIAT 7 seed batch at Jalan Kebun Peat Station.

Clone	Fresh root yield (t/ha)	Harvest index	Root starch content (%)
Trial 1			
SM967-2	31.0 b	0.48 cd	23.0 a
SM873-13	28.7 b	0.57 b	22.0 ab
CM6914-8	28.7 b	0.51 bcd	21.0 b
Black Twig	21.5 b	0.55 bc	22.0 ab
Perintis	48.0 a	0.69 a	21.3 ab
Mean (5 clones)	27.5	0.54	21.9
CV (%)	40.3	8.0	5.1
Trial 2			
SM814-22	74.4 a	0.73 a	21.8 b
SM814-23	60.6 b	0.68 ab	22.8 b
SM814-18	56.4 b	0.61 b	25.9 a
Black Twig	40.2 c	0.44 c	25.0 a
Perintis	69.2 ab	0.64 b	22.0 b
MM 92	59.5 b	0.62 b	20.8 b
Mean (20 clones)	50.2	0.54	23.8
CV (%)	17.1	10.1	5.4
Trial 3			
SM836-19	35.8 a	0.66 cde	21.9 b
SM987-13	34.0 a	0.72 bc	23.7 ab
SM967-1	31.7 a	0.63 de	23.6 ab
Black Twig	35.1 a	0.62 e	23.0 ab
Perintis	37.8 a	0.80 a	19.6 c
MM 92	30.6 a	0.70 bcd	17.8 c
Mean (12 clones)	28.7	0.66	22.4
CV (%)	34.1	6.7	5.8

Note: Values in the same column bearing the same letter are not significantly different from one another according to the DMR test at $P \leq 0.05$

a yield of only 29 t/ha). The starch yields of the two clones were more than 18% higher than that of Black Twig and more than 21% higher than that of Perintis.

Table 4. Yield performance of selected clones from CIAT 6 seed batch in comparison with Black Twig and Perintis at 6 and 12 months after planting in an Advanced Yield Trial at Jalan Kebun Peat Station.

Clone	Harvest at 6 months			Harvest at 12 months		
	Root yield (t/ha)	Starch content (%)	Starch yield (t/ha)	Root yield (t/ha)	Starch content (%)	Starch yield (t/ha)
CM6587-13	43.2 a	20.0 b	8.57 a	56.0 a	20.4 a	11.44 a
CM6545-7	34.3 ab	23.1 a	7.90 ab	49.3 a	21.3 a	10.60 a
CM5925-7	32.1 b	21.7 ab	6.96 ab	53.1 a	21.5 a	11.45 a
Black Twig	29.2 b	22.7 a	6.67 ab	43.6 a	17.1 b	9.56 a
Perintis	34.2 ab	18.7 c	6.44 ab	56.0 a	22.7 a	9.88 a
Mean[1)]	31.2	21.8	6.79	45.5	21.3	9.72
CV (%)	18.4	6.3	20.5	23.1	6.4	25.0

[1)]= Mean of 11 clones.

Note: Values in the same column bearing the same letter are not significantly different from one another according to the DMR test at $P \leq 0.05$

At 12 months, none of the clones significantly outyielded Perintis in fresh root yield nor Black Twig in starch yield. Nevertheless, the starch yields of CM5925-7 and CM6587-13 were both 15% higher than that of Black Twig **(Table 4).**

3. Meristem Introductions

The batch of meristem cultures introduced in 1990 has undergone Single-row Evaluation. Promising clones include MKUL28-77-3 and Rayong 3 for high yield as well as moderately high starch content, while CMR28-67-76, Rayong 1, Hanatee and CMR27-27-3 had high yield.

4. Regional Trial on Short-listed Clones

A Regional Trial was carried out at Pontian Peat Station on 11 short-listed clones (mainly from *CIAT 6* and *CIAT 7* seed batches) over two seasons. Harvesting was carried out after six months. In both seasons, none of the clones were significantly higher yielding than Perintis (although SM814-22 was marginally better). Unfortunately, the clones with high starch content (Sabah 1, Tapah, CM6757-3 and CM6663-3) had lower fresh root yields than Perintis **(Table 5).**

Table 5. Yield performance of 11 selected clones harvested after six months in two seasons of testing in a Regional Trial at Pontian Peat Station.

Clone	Root yield (t/ha)		Harvest index		Starch content (%)	
	1st[1)]	2nd	1st	2nd	1st	2nd
SM814-22	30.4 a	24.6 a	0.67 a	0.65 a	20.0 c	19.5 def
SM814-23	30.0 a	21.6 a	0.59 abc	0.56 bc	23.1 abc	19.7 cdef
CM6652-32	27.3 ab	22.6 a	0.64 ab	0.56 bc	21.5 c	19.0 f
CM6587-13	25.1 ab	16.0 b	0.62 abc	0.58 ab	24.0 abc	20.6 bce
CM6663-3	24.1 ab	16.0 b	0.54 bc	0.54 bcd	24.2 abc	21.4 ab
CM6545-7	22.2 bc	16.0 b	0.50 cd	0.44 e	24.0 abc	21.1 abc
CM6757-3	21.4 bc	17.2 b	0.57 abc	0.52 bcd	25.0 ab	21.6 a
Sabah 1	16.7 cd	14.8 b	0.41 de	0.48 de	24.9 ab	22.5 a
Tapah	14.5 d	11.9 c	0.36 e	0.35 f	25.9 a	21.5 ab
Perintis	29.4 a	24.4 a	0.62 abc	0.65 a	22.5 bc	19.1 ef
MM 92	22.6 bc	17.1 b	0.51 cd	0.51 cde	22.3 bc	20.4 bcde
Black Twig	17.2 cd	10.8 c	0.34 e	0.30 f	22.3 bc	21.2 ab
Mean	23.4	17.8	0.53	0.51	23.5	20.6
CV (%)	17.8	13.2	14.1	10.0	7.5	4.7

[1)] Refers to season of testing

Note: Values in the same column bearing the same letter are not significantly different from one another according to the LSD test at $P \leq 0.05$

5. Commercial Planting and Release of Early Cassava Clone MM 92

A one-hectare block of CM3906-31, a promising early cassava clone, was planted in July 1991 at the peat station in Pontian. A technology package for manual cultivation of cassava on peat, using all available components, was tested. The harvest was carried out in January 1992. Data were collected on fresh root yield (sampled areas as well as total), root starch content and harvest index (from sampled areas) **(Table 6)**, and costs and returns of production were calculated **(Table 7)**.

Subsequently, six ha of CM3906-31 were multiplied, and the clone was released as cultivar MM 92 (*Manihot* MARDI 1992) on 9 August 1992 by the Director General of MARDI. Requests for the new cultivar have been encouraging, and to date 57,900 cuttings have been supplied (maximum of 2,000 cuttings per request).

AGRONOMY

1. Effect of Spacing and Fertilizer Rate on Variety Perintis

An earlier trial on mineral soil at Serdang using Perintis showed slight evidence of a quadratic response to planting density (significant at $P \leq 0.10$), while a trial at Pontian, testing the effect of four rates of fertilizer, did not show a significant linear or quadratic effect for the fertilizer levels **(Table 8)**.

Table 6. Yield data from one–hectare planting of early clone CM3906–31 (MM 92) planted on drained peat and harvested after six months in Pontian Peat Station.

Economics traits	
Fresh root yield (t/ha)	
Estimated*	32.5
Actual	29.5
Starch content (%)*	18.16
Dry matter content (%)*	23.5
Harvest index	0.78

* = Estimated from 10 sampling areas.

Table. 7 Costs and returns of production of early clone MM 92 planted on one hectare of drained peat at Pontian Peat Station, managed manually and harvested after six months.

Item	Total man-hours	Cost (RM)[1)]
Costs		
Land preparation (rototilling to 30 cm depth)		45
Liming		
3 t/ha dolomitic lime		150
Application	20	80
Planting	48	90
Fertilizer application		
680 kg 12:6:22:3 fertilizer		523
818 kg sulphate of ammonia		295
Application	24	49
Weed control		
4 litres alaclor		90
Application	16	32
Manual weeding	70	150
2.7 litres paraquat		30
Application	24	48
Harvesting	104	400
Collection of stems for replanting and clearing area	72	144
Total	378	2126
Returns		
Total root yield (t)	25.9	
Starch content (%)	18.2	
Price roots/t at 18% starch content (RM)	85.50	
Gross returns (RM)	2,522.25	
Total costs (RM)	2,126.00	
Net returns/ha (RM)	396.25	

[1)] RM 1.00 = US$ 0.38

Table 8. Mean fresh root yields of Perintis at various fertilizer treatments on peat soil in Pontian Peat Station.

Application rates (kg/ha)	Equivalence in $N:P_2O_5:K_2O$	Root yield (t/ha)
0 NPK Blue[1] + 0 S/A[2]	0:0:0	59.3
340 NPK Blue + 288 S/A	100:40:58	58.8
680 NPK Blue + 576 S/A	200:80:116	66.8
1,020 NPK Blue	300:120:173	65.1

[1] Formulation of 12:12:17:2

[2] Sulfate of ammonia (with 20.6% N)

Subsequently, a set of trials was laid out on peat soil at Jalan Kebun and Pontian stations, to test for possible interactions of spacing with fertility level. The trials had nine factorial combinations of three spacings with three fertilizer rates. The spacings were 1.0x1.0 m, 0.75x0.75 m and 0.6x0.6 m. The fertilizer rates were 250 kg/ha of NPK Blue (12:12:17:2) plus 153 kg/ha of urea (equivalent to 100 kg N, 30 kg P_2O_5 and 42.5 kg

Table 9. Fresh root yields and starch contents of Perintis planted on peat at different spacings and fertilizer levels at Jalan Kebun and Pontian Peat Stations.

Treatments	Root yield (t/ha)		Starch content (%)	
	J. Kebun	Pontian	J. Kebun	Pontian
S_1F_1	115.2	16.9	29.6	23.3
S_1F_2	143.8	19.1	28.6	23.1
S_1F_3	147.9	11.9	30.1	24.6
S_2F_1	147.4	22.7	29.2	24.0
S_2F_2	137.4	24.8	30.6	24.0
S_2F_3	142.8	25.6	29.1	23.9
S_3F_1	124.8	31.7	29.9	22.8
S_3F_2	144.3	28.7	30.4	22.7
S_3F_3	129.7	28.6	29.0	24.0
Mean	137.8	23.3	29.6	23.6

Note: S_1 = 1.00x1.00 m F_1 = 100-30-42.5 (N-P_2O_5-K_2O in kg/ha)
S_2 = 0.75x0.75 m F_2 = 200-60-85 "
S_3 = 0.60x0.60 m F_3 = 300-90-127.5 "

K_2O/ha), and double or triple these rates. Statistical analysis did not show significant differences in yield between spacings or between fertilizer rates at Jalan Kebun. There was also no significant interaction. However, the yields of Perintis were unusually high in all the treatments, while starch contents were also high **(Table 9)**.

At Pontian, where the yield level was much lower, there was a yield improvement at the closest planting distance of 0.6 x 0.6 m **(Table 10)**, but there was no response to fertilizer rate. Thus, with a clone like Perintis with small plant stature (2 meters compared to Black Twig's 3 meters) and proportionally less top growth compared to root yield, a lower rate of fertilizer is sufficient to raise a good crop. While there was no advantage in increasing the plant population per hectare by closer spacing on a soil with high inherent fertility, on a less fertile soil yields may be increased by planting closer.

Table 10. Effect of spacing on fresh root yield of Perintis at Pontian Peat Station.

Spacing	Root yield (t/ha)
S_3 (0.60x0.60m)	29.7 a
S_2 (0.75x0.75 m)	24.3 b
S_1 (1.00x1.00 m)	16.0 c

Note: Values bearing different letters are significantly different from one another according to the DMR test at $P \leq 0.05$

2. Effect of Fertilizer Rate and Cutting Length on Yield of Early Cassava Clone MM 92

The objectives of the trial were:

(a) to determine the effect of cutting length on the performance and yield of early cassava clone MM 92

(b) to determine whether the rate and cost of fertilizers may be reduced in the planting of an early clone

The trial was carried out at the Pontian Peat Station over two seasons, with harvests conducted at six months after planting. Analyses of the data over two seasons showed that 20 cm cuttings produced higher yields than 60 cm cuttings in MM 92, but 60 cm cuttings resulted in higher root starch content **(Table 11).** With respect to fertilizer rate, half the normal rate for cassava on peat produced higher yields (fresh and dry root as well as starch) than the full rate. Thus, fertilizer costs (as given in Table 7) may be reduced by half, cutting down production costs by RM409 to RM1,717. Net profit would then be RM805.25/ha (or about US$306/ha).

3. Erosion Control in Cassava Cultivation

The objective of the study was to evaluate several soil tillage and crop management practices for erosion control in cassava cultivation on mineral soils. In the second-season trial, no significant difference between the treatments in the yield of cassava was found **(Table 12).** Nevertheless, the normal tillage treatment of once disc plowing followed by twice harrowing resulted in the highest yield, as was also the case in the first season. The trial also provided data on soil losses due to erosion by weighing the sediments collected in plastic-covered channels at the bottom of each plot.

As may be seen in **Figure 1**, soil losses were generally high in the first four months of casava growth, and were especially high during the second and third months after planting. There were no significant differences in soil losses as a result of the various cultural treatments (partially due to the use of only two replications), but it could be observed that the three treatments with vegetation between cassava, such as intercropping with citronella, groundnut or natural grass strips, resulted in the lower levels of soil loss.

Table 11. Effect of cutting length and fertilizer rate on the yield of early clone MM 92 (data over two seasons) planted at Pontian Peat Station and harvested after six months.

Cutting length (cm) -Fertilizer rate[1)]	Root yield (t/ha)	Harvest index	Starch content (%)
20-1[1)]	33.8 ab	0.48 c	19.5 b
20-0.5	37.9 a	0.57 b	20.0 ab
20-0	33.1 abc	0.70 a	19.4 b
60-1	28.9 c	0.43 d	20.9 ab
60-0.5	34.1 ab	0.50 c	20.6 ab
60-1	32.8 bc	0.61 b	21.2 a
Mean	33.4	0.55	20.3
CV (%)	14.1	8.6	7.9

[1)]1 = full rate of fertilizer: 250 N : 43 P_2O_5 : 160 K_2O in kg/ha

Note: Values within a column bearing the same letter are not significantly different from one another according to the DMR test at $P \leq 0.05$

Table 12. Effect of tillage and cropping treatments on the yield of cassava planted on 6–11% slope at MARDI, Serdang, Selangor, Malaysia.

Treatment	Cassava root yield (t/ha)		
	1988/89	1990	Cumulative
Normal tillage (1 disc-plowing+2 harrowings)	36.3 a	29.2 a	65.5
High tillage (1 disc-plowing+ 2 rototillings)	27.6 bc	26.0 a	53.6
Zero tillage with subsoiling	30.3 ab	24.9 a	55.2
Intercropping with citronella grass	30.1 ab	24.8 a	54.9
Reduced tillage (1 disc-plowing)	28.1 bc	24.3 a	52.4
Strip tillage with natural grass as live barrier	31.4 ab	24.2 a	55.6
Intercropping with groundnut	31.5 ab	23.8 a	55.3
Normal tillage without fertilizers	26.4 bc	21.9 a	48.3
Zero tillage with chemical weed conttrol	22.9 c	19.6 a	42.5

Note: Values within a column bearing the same letter are not significantly different from one another according to the LSD test at $P \leq 0.05$

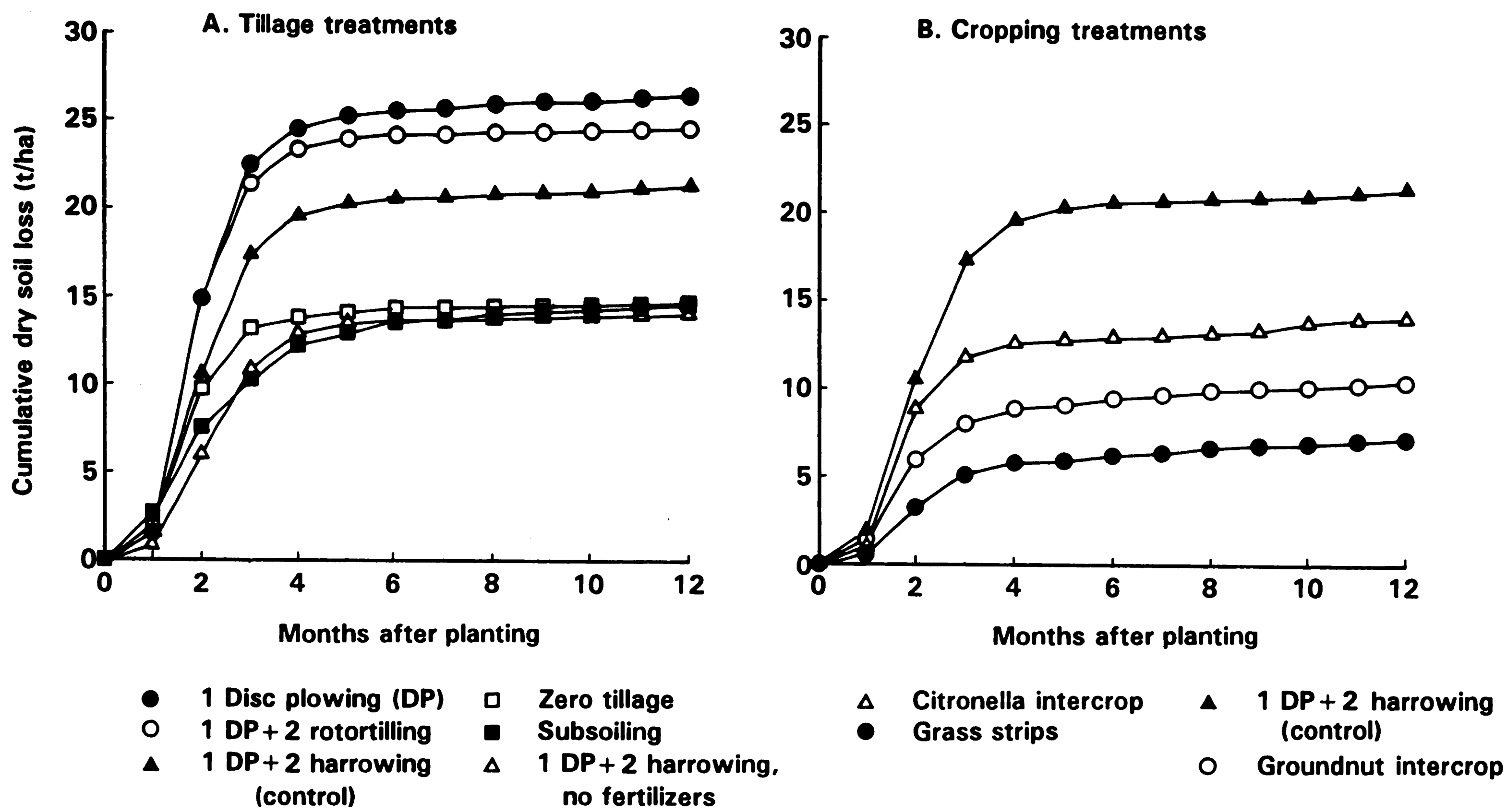

Figure 1. Effect of tillage and cropping treatments on soil loss due to erosion in cassava planted on 6-11% slope at MARDI, Serdang, Selangor, Malaysia in 1990 (second year).

4. Long-term Fertility Trial with Cassava on Peat

The objectives of this long-term trial are:

(a) to determine the optimum rates of N, P, K and lime for long-term maintenance of high yields in cassava grown on peat

(b) to develop a diagnostic computer program (DRIS) for nutrient requirements in cassava on peat soil, similar to the one made for mineral soils.

A partially confounded 3^4-factorial experiment was designed to test three levels each of N, P, K and lime over several cropping cycles of cassava. The rates in kg/ha were 150 (N1), 250 (N2) and 350 (N3) for N; 0 (P0), 30 (P1) and 60 (P2) for P_2O_5; and 80 (K1), 160 (K2) and 240 (K3) for K_2O. From the 6th season onwards, the N rates were changed to 0 (N1), 150 (N2) and 250 (N3), and the K rates to 0 (K1), 80 (K2) and 160 (K3). Lime rates in t/ha were 0 (L0), 3 (L1) and 6 (L2), using ground magnesium limestone. The treatments were assigned at random into 9 blocks, each of which also included a control plot (00).

Where the treatments included lime, it was incorporated into the soil about one month before planting the 1st and the 5th crops. Black Twig, the currently most widely planted cultivar (harvestable at 12 months), was used for the study up to the 8th season. In the 9th season, there was a switch to the new variety MM 92 (harvestable at six months). Mature woody stem cuttings of 60 cm length were planted vertically at a spacing of 1.0x1.0 m, after being dipped in a $CuSO_4$ solution for 10 minutes. Samples of youngest fully-expanded leaf blades were taken at three months after planting and sent to the laboratory for chemical analysis; similarly, stem samples of 5 cm length were taken at 100 cm from the base joining the original planted cutting.

Figure 2 shows the yields obtained in response to the different levels of the nutrients applied to successive crops. The effect of N on root yield was significant in the 1st season of cropping when both N2 and N3 gave higher yields than N1. It was again significant in the 4th season when the highest level, N3, gave a much higher yield than N2 and N1. However, in the 7th season, yields decreased with increasing rates of N application.

The effect of P was not significant in each season's analysis of variance, but the higher yields observed in the P1 treatment compared to P0 during most of the cropping cycles indicated the importance of P application.

The effect of K was significant in the 1st and in the 4th season when the middle level of the applied nutrient, K2, gave significantly higher yields than K1.

Compared to the effects of the major nutrients under study, the effect of liming on root yield was clearly more consistent. From the 1st to the 5th season, liming at 3 or 6 t/ha produced significantly higher yields than no liming. The residual main effect of liming on yield was manifest when none was applied over three seasons. However,

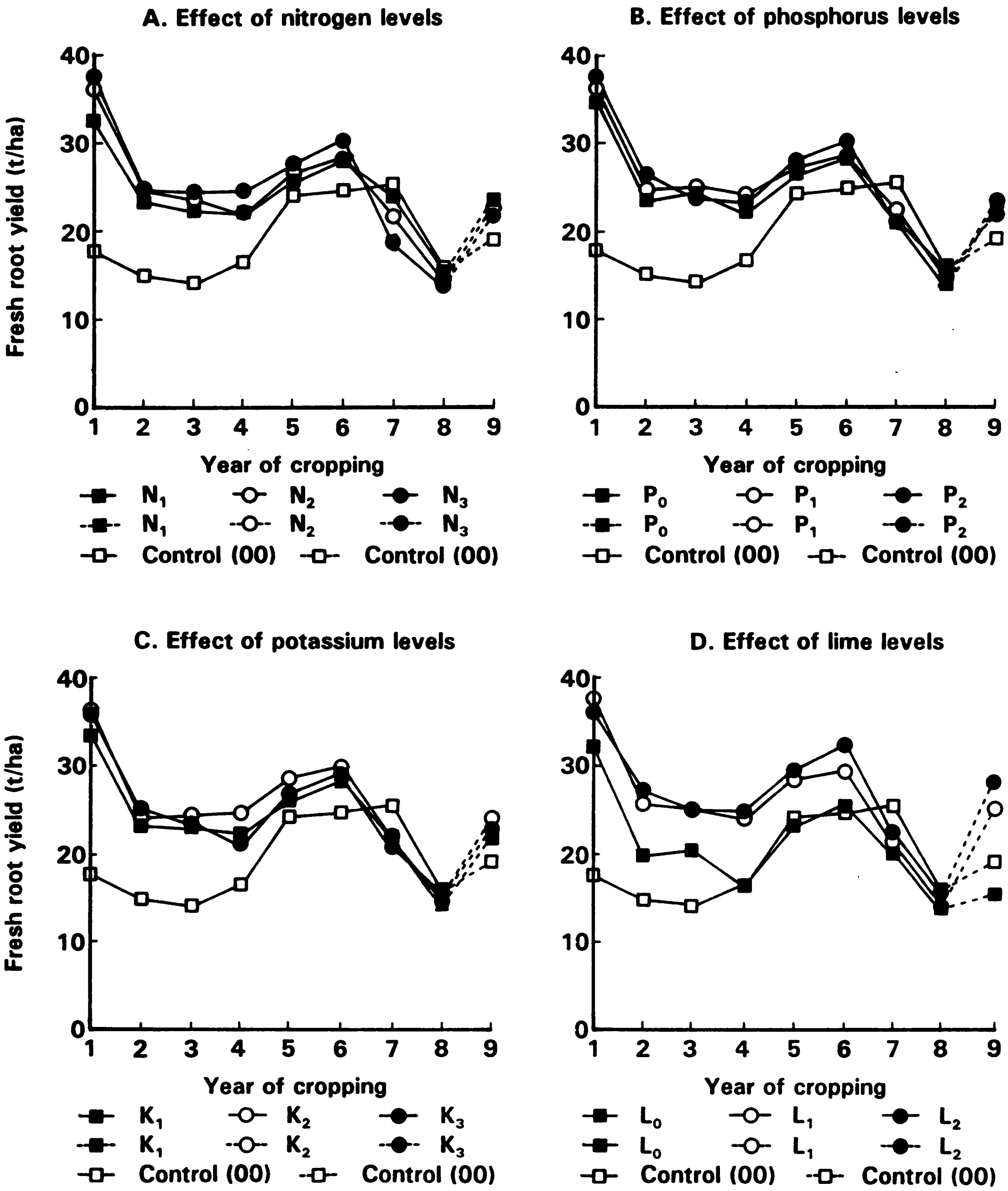

Figure 2. Effect of annual applications of N, P and K as well as lime on fresh root yield of cassava over nine cropping seasons on peat soils at Pontian Peat Station. Lime was applied only before the 1st and 5th crop. Cultivar Black Twig was the test variety in the first 8 crops, MM 92 in the 9th crop.

liming in the 5th season did not leave significant residual effect on yield in the 7th and 8th seasons, except when N and K were not supplied, as will be shown later.

In general, compared with the yield of the first crop, subsequent yields were lower. Although the 5th and 6th season's yields appeared to improve, the 7th season's yield declined. As may be observed in **Figure 2,** the mean yields of the treated plots in the 7th season were lower than the mean yield of the untreated (00) plots. This phenomenon could be attributed to the aggravating effect of the applied nutrients on deficiencies of those critically needed nutrients that were not supplied to the current crop. Most probable among these was Ca, as may be inferred from the significant responses to liming in the earlier cropping seasons.

In the 7th season trial, N reduced the yield at increasing rates of application. No straight responses to P and K were observed, but the 3-factor interactions involving N, K and lime (L) were significant. The important implication of this interaction was that liming increased yields only when both N and K were not supplied, as shown in **Table 13.** In the absence of applied N and K, liming at the intermediate level (L1) was most effective in increasing yield.

Table 13. Yields of cassava (t/ha) during the 7th cropping cycle at the Pontian Peat Station with different combinations of K and lime (L) levels, but without applied N.

	L0 (0 t/ha)	L1 (3 t/ha)	L2 (6 t/ha)
K0 (0 kg K_2O/ha)	23.6	28.0	25.5
K1 (80 kg K_2O/ha)	25.9	21.9	26.7
K2 (160 kg K_2O/ha)	19.2	20.9	21.2

The decline in yield continued from the 7th to the 8th seasons when there was still no fresh application of lime. No significant differences in yield were detected between the treated and untreated (00) plots. With the switch-over from Black Twig to MM 92 in the 9th season, yields in the treated plots increased significantly over those of the untreated plots.

Data from a previous continuous cropping trial at Serdang have been used to generate a DRIS (Diagnostic Recommendation Integrated System) program for cassava on mineral soils. DRIS is increasingly being accepted as a useful technique in interpreting tissue analysis. It makes use of nutrient ratios in either leaf or stem samples to reflect the nutrient balance. As leaf samples are collected when the crop is around three months of age, this has an advantage over stem samples collected at harvest, in that the current crop may still be 'saved' by immediate fertilizer corrections. A similar DRIS program is now being developed for cassava grown on peat soils using data from this long-term fertility trial.

5. Studies on the Effect of Flooding on Cassava Yield

These studies were carried out in lysimeters, where the water-table was maintained at 15 cm below the peat soil surface (optimum level established by Tan and Ambak (1989)), except when flooding was imposed on variety Black Twig at $3\frac{1}{2}$ months after planting, at the onset of root bulking (Wholey and Cock, 1974), for durations varying from 1 to 4 days. A control with no flooding was included. None of the duration treatments reduced root yields significantly from the control, implying that cassava can withstand flooding for a period of 1-4 days at $3\frac{1}{2}$ months to fully recover by 9 months **(Table 14).** Nevertheless, flooding for 4 days reduced fresh root yield by 26% and starch yield by 30%. Only the harvest index was significantly reduced by flooding for 3-4 days.

Table 14. Effect of duration of flooding at 3.5 months on yield and other agronomic traits of Black Twig grown in lysimeters with peat soil and harvested at 9 months.

Flooding duration (days)	Root yield (kg/plant)	Harvest index	Starch content (%)	Starch yield (g/plant)
0	1.82 a	0.76 a	20.7 a	375 a
1	1.63 a	0.78 a	20.1 a	327 a
2	1.70 a	0.72 abc	20.5 a	344 a
3	1.57 a	0.68 c	19.1 a	306 a
4	1.35 a	0.70 bc	19.7 a	264 a

Note: Values in the same column bearing the same letter are not significantly different from one another according to the DMR test at $P \leq 0.05$

A second similar study, using variety MM 92 harvested after 6 months, produced significant yield reductions (24% for fresh root yield, 30% for starch) when the duration of flooding was 4 days **(Table 15).** Again, the harvest index was reduced with a longer duration of flooding, while starch content was unaffected by flooding.

Table 15. Effect of duration of flooding at 3.5 months on yield and other agronomic traits of MM 92 grown in lysimeters with peat soil and harvested at 6 months.

Flooding duration (days)	Root yield (kg/plant)	Harvest index	Starch content (%)	Starch yield (g/plant)
0	2.52 a	0.80 a	18.1 a	457 a
1	2.57 a	0.80 a	17.5 a	448 a
2	2.20 ab	0.74 b	17.5 a	386 ab
3	2.38 ab	0.72 b	17.2 a	413 ab
4	1.92 b	0.66 c	17.0 a	321 b

Note: Values in the same column bearing the same letter are not significantly different from one another according to the DMR test at $P \leq 0.05$

In a third study subsequently, the effect of flooding (for 4 days) at different growth stages of MM 92 was tested. Root yields were significantly reduced when flooding was imposed at 1, 4 and 5 months after planting, the most drastic being at 5 months **(Table 16).** The yield reduction resulting from flooding at this late crop stage was due to root rot. Surprisingly, no significant effect on starch content was detected among the treatments.

Table 16. Effect of flooding for 4 days at different crop growth stages on yield parameters of MM 92 grown in lysimeters with peat soil and harvested at 6 months.

Crop stage (after planting)	Root yield (kg/plant)	Harvest index	Starch content (%)	Starch yield (g/plant)
0	3.23 a	0.64 a	19.0 a	606 a
1 month	1.69 bc	0.64 a	21.2 a	354 bc
2 months	2.10 ab	0.56 a	22.0 a	443 b
3 months	1.55 bc	0.43 ab	21.4 a	327 bc
4 months	0.61 c	0.26 b	19.0 a	232 c

Note: Value in the same column bearing the same letter are not significantly different from one another according to the DMR test at $P \leq 0.05$

Thus, with respect to water-table management of peat soils, it is important to drain surface water from the field within 3 days to prevent adverse effects on the standing crop. When flooding occurs at an earlier stage of crop growth, it might be still worthwhile to keep the crop and accept some yield loss. If, however, there is a flood of more than 4-day duration at 5 months, it would be prudent to harvest immediately if possible, or write off the standing crop and replant.

6. Studies on the Effect of Moisture Stress on the Cyanide Concentration in Cassava Roots

The objectives of the studies were:

(a) to determine whether moisture stress increases the concentration of cyanide in roots of edible cassava clones

(b) to determine the critical stage of growth when moisture stress increases root cyanide concentration

The studies were carried out as a pot experiment using half oil-drums filled with mineral soil. Moisture stress was imposed for two weeks by covering the soil surface with plastic sheets at 4, 6 and 8 months after planting Black Twig, Perintis and Medan. A control with no moisture stress (plants watered daily) throughout the period of study was included. Moisture stress was monitored through stomatal resistance readings. The plants were harvested at 9 months.

No significant differences among treatments were detected for cyanide concentration (estimated by the modified sodium picrate method of Tan and Noor Auni (1981)) in the flesh of the roots, when the data were analysed as a whole **(Table 17).** However, within the edible variety Medan, there was a tendency for the cyanide concentration of the flesh to be higher when drought occured at an earlier stage (i.e. at four months after planting), whereas in a 'bitter' variety like Black Twig early drought seemed to decrease the cyanide concentration in the root flesh.

Table 17. Effect of drought at different growth stages on the cyanide concentration of cassava root skin and flesh. Data are average over three cassava cultivars.

Growth stage when drought imposed (after planting)	Cyanide in roots (µg/g)[1]	
	Skin	Flesh
Control (no drought)	173 ab	36 a
4 months	129 b	34 a
6 months	177 a	28 a
8 months	161 ab	38 a

[1] on fresh weight basis

Note: Values in the same column bearing the same letter are not significantly different from one another according to LSD test at $P \leq 0.05$

The second stage of the study involved imposing different durations of moisture stress at 8 months on the same three varieties. Analyses of the combined data set showed that a drought lasting 3 weeks seemed to increase the cyanide concentration in the flesh **(Table 18).** This was particularly true of Medan and Perintis (the edible varieties). Nevertheless, the increased cyanide concentration did not reach poisonous levels, i.e. more than 100 µg/g on a fresh weight basis.

Table 13. Effect of different durations of drought at 8 months after planting on the cyanide concentration of cassava root skin and flesh. Data are average over three cassava cultivars.

Duration of drought	Cyanide in roots (µg/g)[1]	
	Skin	Flesh
0 (control)	187 a	45 ab
1 week	139 ab	36 b
2 weeks	111 b	36 b
3 weeks	184 a	58 b

[1] on fresh weight basis

Note: Values in the same column bearing the same letter are not significantly different from one another according to LSD test at $P \leq 0.05$

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"GREEN REVOLUTION" AND CASSAVA BREEDING

Kazuo Kawano[1]

ABSTRACT

If a wholesale yield improvement of major crops by new high yielding cultivars was the definition of "Green Revolution", it was also a tacit expectation that a success similar to that in rice or wheat would be repeated in cassava when a cassava varietal improvement program was established at CIAT twenty years ago. It soon became clear that genetic improvement of yield in this crop would be a slow process because a multi-genic scheme controlled the yielding ability, as opposed to the basically single-gene scheme in rice and wheat. Technology adoption would also be slow because the main clients were small farmers in low-input environments and varietal improvement alone would not solve the problem; an integrated approach was required to diffuse the improved technology. One positive aspect was that working on cassava would contribute less to the widening of the gap between rich and poor farmers, the major negative-effect of the "Green Revolution".

Thanks mainly to the improvements in harvest index in the early years and in biomass and root dry matter content in later years, significant yield upgrading (up to 100%) of breeding populations took place virtually for all the major cassava growing environments. After a long gestation period, the number of cultivars released and the area planted are finally increasing rapidly. Earlier cultivars are contributing to enhancing production efficiency in some areas in Thailand and Indonesia. Later cultivars are poised to make major contributions in Thailand, Indonesia, China and Vietnam. A "Green Revolution" in cassava may be in the making in its own way.

INTRODUCTION

"The 'Green Revolution' that swept the Asian continent in the late-sixties and seventies was limited to relatively well-off farmers in the irrigated areas. The next major challenge is to raise the productivity and incomes of small farmers in the upland areas. Dealing with a small farmers' crop, grown mostly under low-input conditions, progress may be slower; yet, this is one inevitable research commitment toward greater social equity." With this statement, I concluded the opening presentation of the 2nd Workshop of the same network of Asian Cassava Research at Rayong, Thailand, six years ago. With "Green Revolution" we assume a wholesale yield improvement of

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major crops by new technology and the best examples are given by the high yielding cultivars of rice and wheat.

Asian cassava is shifting from being a traditional human food to an efficient raw material for multi-purpose agro-industrial processing. Upgrading the efficiency of production by high yielding and high root quality cultivars is ever important. Need for better natural resource management is now acutely felt and more efficient cultivars would offer additional alternatives for better resource management. It is with this increasing relevance that we present today the research advancement on the general objective set in the past Workshops.

If the high yielding rice cultivars generated at the International Rice Research Institute (IRRI) were the symbol of the "Green Revolution", it was also a tacit expectation that a success similar to that would be repeated in this crop, cassava, when a cassava varietal improvement program was established at CIAT, Colombia, twenty years ago. The targets implicated by the "Green Revolution" breeder Peter R. Jennings to me, a starting breeder, were as tough and ambitious as follows:

1. 100% yield increase by breeding.
2. Results to be measured only by the area planted with new cultivars and the resulting socio-economic benefits.

We soon learned that genetic yield improvement in cassava could be attained only by dealing with a multi-genic scheme, as opposed to the primarily single-gene scheme in rice and wheat, suggesting that the technical progress would be much slower. Small farmers in low-input agricultural environments were the main target and this also meant that the technology adoption would be slow. Expected production increases were to be geared with the enlarged marketing scheme and this required integrated approaches. One consolation was that working on cassava would contribute less to the widening of the gap between rich and poor farmers, the major negative effect of the "Green Revolution".

We also learned of the significant progress made by farmers and national research programs before we started working in a network with national programs, among which the following were particularly noteworthy:

1. The very successful selection of Rayong 1 by the farmers and the research experimental stations in Thailand, which supported the successful Thai cassava industry and could be called a medium size "Green Revolution".
2. Selected cultivars had contributed to the production efficiency in some parts of Indonesia, India and China.

The first decade of the CIAT cassava breeding program was spent mainly on general upgrading of the breeding population to be distributed to national programs. In the second decade, the breeding centers were more diversified and the collaboration with national programs was much enhanced.

IMPROVEMENT OF BREEDING POPULATIONS

Basic Productivity in Low Stress Environment

The building up of basic breeding populations started with the evaluation of all the germplasm accessions at CIAT headquarters in Cali, Colombia. Hybrids produced on the basis of selected germplasm accessions were soon incorporated into the evaluation scheme and in the later years the breeding population was composed mainly of the hybrids produced from the selected cross parents which were themselves hybrids. This basic scheme has been maintained ever since at headquarters as well as at the regional breeding center of the Thai-CIAT collaborative breeding program. The whole scheme can be described roughly as a large-scale recurrent mass selection.

CIAT headquarters (HQ) in Colombia is endowed with fertile soils and a favorable rainfall pattern, but the germplasm evaluation in this location did not represent any major cassava growing environment. Nevertheless, it had an advantage of evaluating genotypes for basic physiological yielding capacity without being confounded by other yield limiting factors.

Counting from the average productivity level of the original unselected germplasm accessions, approximately 100% upgrading in fresh root yield of the breeding population had been attained during the first ten years of population improvement at CIAT/HQ, although it was not accompanied by significant improvement in root dry matter content **(Figure 1)**. A great part of this basic yield upgrading was due to the improvement in harvest index rather than in biomass production **(Figure 2)**.

In retrospect, this wholesale upgrading of harvest index seems to have set the basis for the breeding for higher physiological yield capacity in the later generation materials.

Adaptation to High Stress Environments

It was known since the beginning of the program that the breeding population should be evaluated and the cross parents should be selected under high stress environments as well. No sooner the first evaluation of the germplasm population was undertaken at CIAT/HQ than the basic population and the subsequent hybrid populations were taken to evaluation sites having much tougher growing conditions. The contin-

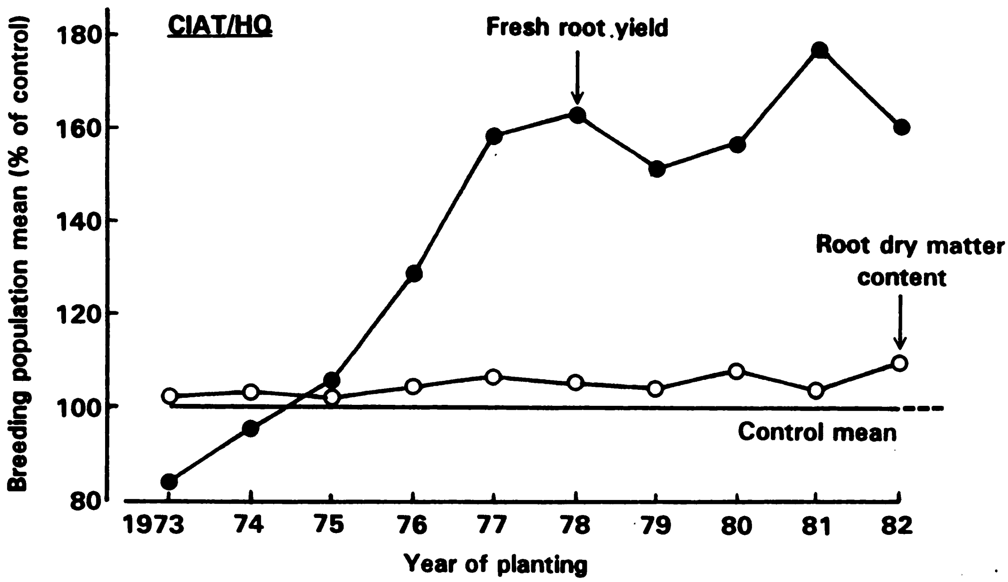


*Figure 1. Change in the mean of the breeding population (all entry mean in yield trials) in terms of fresh root yield and root dry ma*ter content at CIAT, Colombia in comparison with local check varieties.*

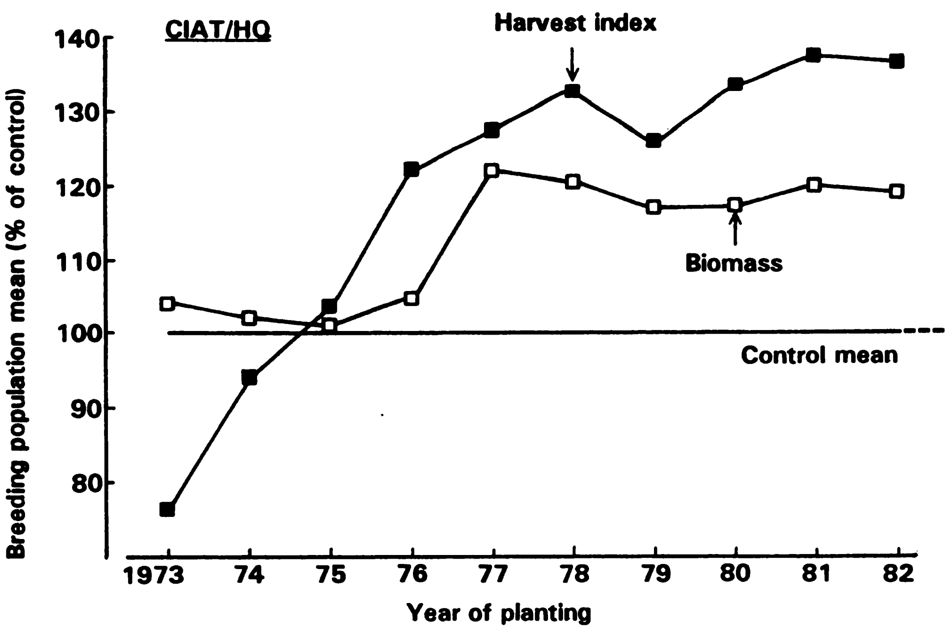


Figure 2. Change in the mean of the breeding population (all entry mean in yield trials) in terms of biomass and harvest index at CIAT, Colombia in comparison with local check varieties.

ued evaluation at the ICA/CIAT Carimagua station, located in the middle of the Colombian Llanos, where the soil is extremely acid and infertile and the disease and pest pressure is very high, identified many cross parents, especially for resistance to cassava bacterial blight and tolerance to acid soils.

Reciprocating the selection of cross parents between the low stress high yielding environment of Cali and the high stress, low yielding environment of Carimagua seems to have significantly enhanced the robustness of the breeding population.

Productivity in Semi-arid Environments

The Thai-CIAT breeding program was established at Rayong Field Crops Research Center in 1983 as a collaboration between the Field Crops Research Institute, Department of Agriculture, and the CIAT Cassava Asian Regional Program. Later, the cassava research project of Kasetsart University also joined this collaborative program. While producing superior cultivars for the Thai conditions is the primary objective of the collaborative program, generating advanced breeding populations for other national programs in Asia is an equally important objective.

During the last ten years, the basic yielding capacity of the breeding population continued to improve **(Figure 3)**. The enhancements in biomass **(Figure 4)** and root dry matter content **(Figure 3)** were the major components of the improvement, and the harvest index stayed mostly unchanged during the same period **(Figure 4)**. This is in contrast to the improvement during the first ten years at CIAT/HQ, when harvest index was the dominant factor in improvement **(Figure 2)**.

Outperforming the control took a much longer time in Thailand than in Colombia, probably because a superbly well-adapted cultivar (Rayong 1, the world's most widely planted and successful cultivar) was used in the Thai-CIAT evaluation as control, while average cultivars were used as control in the CIAT/HQ evaluation.

A comparison between CIAT/HQ and Thai-CIAT materials clearly indicated that the Thai-CIAT materials were better adapted to the conditions of Rayong, Thailand **(Table 1)**. This result, consistent through the 1987 to 1992 evaluations, justified the validity of generating breeding materials in Thailand, not only for the physical proximity to other Asian programs, but also for providing additional adaptability to the semi-arid growing conditions.

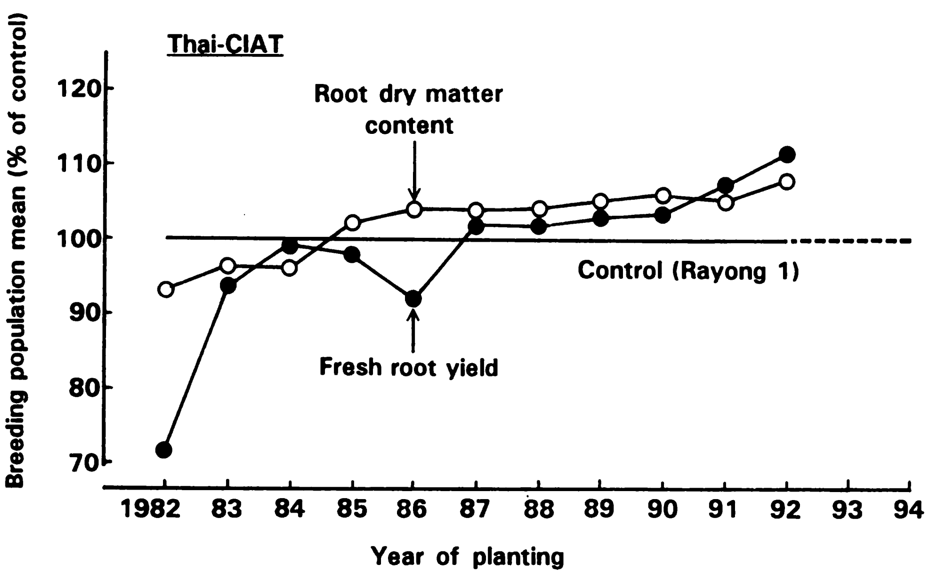


Figure 3. Change in the mean of the breeding population (all entry mean in yield trials) in terms of fresh root yield and root dry matter content in Thailand in comparison with the local check variety.

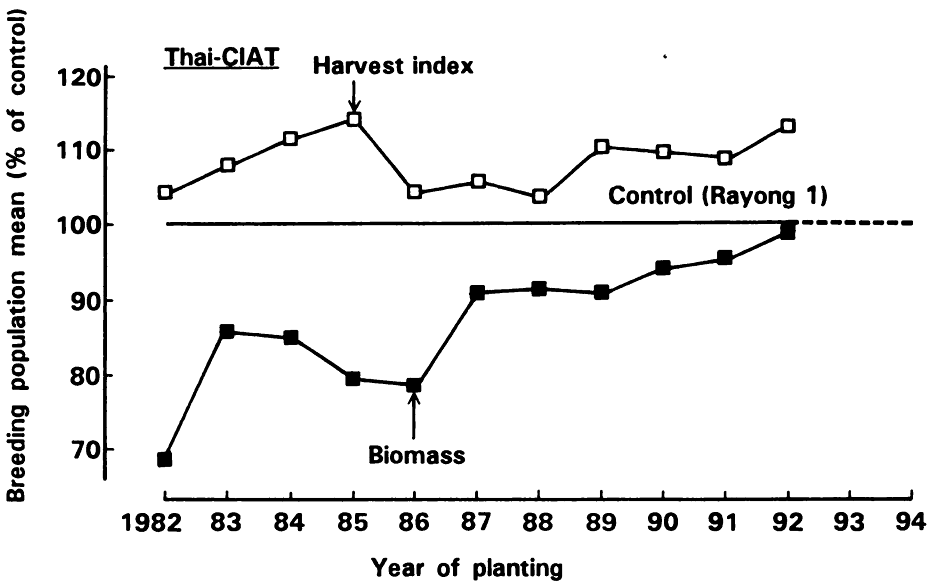


Figure 4. Change in the mean of the breeding population (all entry mean in yield trials) in terms of biomass and harvest index in Thailand in comparison with the local check variety.

Table 1. Comparison between clones originating from CIAT headquarters in Colombia and from the Thai-CIAT program in terms of yield performance at Rayong, Thailand, during two planting years.

Character	1986/87[1)]		1991/92[1)]	
	CIAT HQ clones	Thai-CIAT clones (% of CIAT HQ clones)	CIAT HQ clones	Thai-CIAT clones (% of CIAT HQ clones)
Dry root yield (kg/plant)	0.80	1.10 (137)	0.68	0.84 (124)
Fresh root yield (kg/plant)	2.44	3.21 (131)	2.19	2.53 (116)
Total plant weight (kg/plant)	4.81	5.71 (119)	4.08	4.20 (103)
Harvest index	0.51	0.56 (111)	0.54	0.60 (113)
Plant type rating[2)]	2.87	3.42 (119)	3.35	3.99 (119)
Root dry matter content (%)	32.9	34.3 (104)	30.9	33.1 (107)
Germination/survival of planting stakes (%)[3)]	45.3	72.6 (160)	75.3	83.4 (111)

[1)] Mean of all entries in Single-row Trial (735 CIAT HQ and 1228 Thai-CIAT clones for 1986/87 and 621 CIAT HQ and 1696 Thai-CIAT clones for 1991/92).

[2)] 1 = very poor, 5 = very favorable.

[3)] Data from Preliminary Yield Trial in following year.

Distribution of Breeding Materials

Using the cross parents selected through the evaluation schemes at CIAT/HQ and the Thai-CIAT program, hybrid populations have been produced and distributed to national cassava breeding programs in the world. During the past twenty years, a total of more than 350,000 hybrid seeds (meaning the same number of genotypes) from CIAT/HQ have been distributed to nine countries in Asia **(Table 2).** Starting from 1985, some 75,000 hybrid seeds from the Thai-CIAT program have been distributed to nine countries in Asia and to CIAT/HQ **(Table 3).** These constitute the basis of varietal selection in national programs these days.

Table 2. Number of cassava F1 hybrid sees from CIAT/Colombia distributed to Asian programs (up to 1993).

Country	1975-1990	1991	1992	1993	Total
	No. of seeds				
Thailand	109,411	9,583	11,727	6,275	136,996
Indonesia	28,800	4,219	9,552	12,074	54,645
China	35,999	5,511	6,021	7,158	54,689
Vietnam	13,850	3,750	4,500	5,950	28,050
Philippines	30,736	7,679	4,297	4,061	46,773
Malaysia	11,440	2,918	2,079	1,077	17,514
India	10,700		1,200		11,900
Sri Lanka	1,500				1,500
Taiwan	1,700				1,700
Total	244,136	33,660	39,376	36,595	353,767

Table 3. Number of cassava F1 hybrid seeds from CIAT/Colòmbia distributed to Asian programs (up to 1993).

Country	1985-1990	1991	1992	1993	Total
	No.of seeds				
Indonesia	13,813	1,139	1,393	3,869	20,214
China	5,871	741	1,793	4,713	13,306
Vietnam	4,700	1,435	2,441	4,730	13,306
Philippines	4,634	520		1,850	7,004
Malaysia	2,500			1,141	3,641
India	2,700			2,800	5,500
Myanmar	950				950
Sri lanka	750				750
Israel	750				750
CIAT/Colombia	6,721			2,614	9,335
Total	43,389	3,835	5,627	21,717	74,568

Selection by National Programs

The first significant upgrading of breeding populations in an Asian national program outside Thailand occured in our collaborative program in southern Sumatra, Indonesia **(Figure 5)**, indicating the value of CIAT breeding materials in the humid lowland tropics as well.

A similar population improvement in Hainan, China **(Figure 6)** was successful, but not as striking as the improvement in Sumatra, probably because the CIAT materials had not been selected for the subtropical conditions with the same intensity as for the hot lowland conditions, while the local control was a well-selected cultivar, a similar situation to Rayong 1 in Thailand.

Yet, the most spectacular yield upgrading took place in south Vietnam when the best clonal materials from Thailand were transfered to the Vietnamese program **(Figure 7)**, probably because the Vietnamese research program had been isolated for a long time and the Thai materials were well adapted to similar conditions in southern Vietnam. The progress we have accomplished in Thailand is best documented in this yield difference we are witnessing in south Vietnam.

Due mainly to repeated natural calamities, we could not document similar progress of selection in the Philippines. Yet, recent results **(Table 4)** appear to confirm the

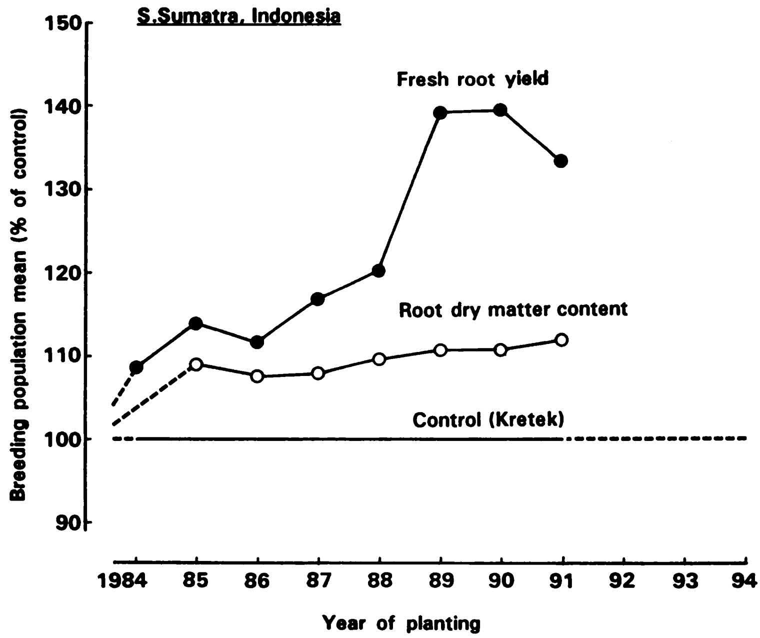


Figure 5. *Change in the mean of the breeding population (all entry mean in yield trials) in terms of fresh root yield and root dry matter content at UJF, Lampung, Indonesia, in comparison with the local check variety.*

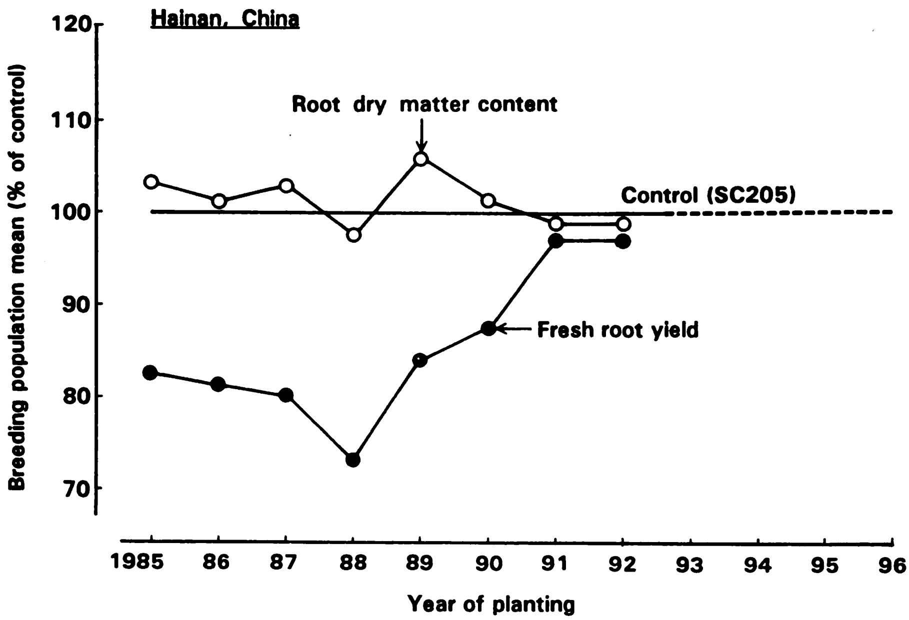


Figure 6. *Change in the mean of the breeding population (all entry mean in yield trials) in terms of fresh root yield and dry matter content at SCATC, Hainan, China, in comparison with the local check variety.*

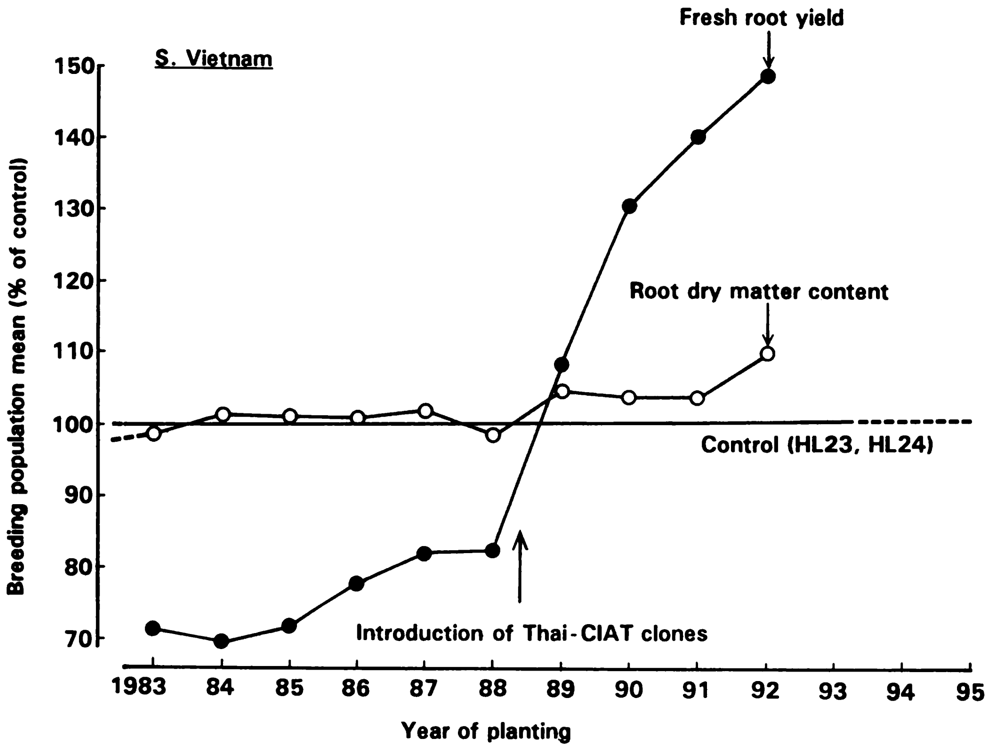


Figure 7. Change in the mean of the breeding population (all entry mean in yield trials) in terms of fresh root yield and root dry matter content at Hung Loc Research Center, South Vietnam, in comparison with local check varieties.

Table 4. Results of the Advanced Yield Trial at PRCRTC,[1] Leyte, Philippines.

Clone	Origin	Dry root yield (t/ha)	Fresh root yield (t/ha)	Root dry matter content (%)
Top five entries				
MT12-44	Thai-CIAT	20.2	65.0	30.9
MT16-6	Thai-CIAT	17.9	60.9	29.4
MT9-21	Thai-CIAT	17.4	57.1	30.6
MT4-251	Thai-CIAT	16.3	48.7	33.6
VC-1	CIAT/Colombia	16.0	54.3	29.3
All entries				
39 clones	Mostly Thai-CIAT	11.4	37.0	30.8
Local control				
Lakan		9.7	31.4	30.6

[1] PRCRTC, Philippines Root Crop Research and Training Center at Visayas State College of Agriculture in Baybay, Leyte, Philippines.

validity of our breeding materials in the humid lowland conditions of the Philippines as well.

Assessment of Validity of CIAT Material

Sufficient experiences with national programs have been accumulated to make it possible to assess the usefulness of our breeding materials under different situations **(Table 5).** Like any modern crop improvement program, the improved germplasm tends to give greater yield advantage under low than high stress environments. Yet, thanks to the inclusion of wide germplasm variability and high stress evaluation since the beginning of the breeding population formation, the materials appear to offer ample selection opportunities under high stress environments as well.

By combining CIAT/Colombia with Thai-CIAT breeding materials, we seem to be able to cover all the major cassava growing climates in Asia. The Thai-CIAT materials appear to be particularly well adapted to the semi-arid and seasonally dry lowland tropics. Consequently, our materials would be able to offer good selection opportunities to virtually all the important cassava growing countries in Asia.

Table 5. Usefulness of CIAT cassava breeding materials under different environments.

Environment	Breeding materials generated at	
	CIAT/Colombia	Thai-CIAT program
By level of stress		
Low	+++	+++
High	++	++
By climate		
Semi-arid	+	+++
Seasonally dry	++	+++
Humid	+++	++
Sub-tropics	++	++
By area		
Thailand	+	+++
Sumatra, Indonesia	+++	+++
E. Java, Indonesia	++	++
S. Vietnam	++	+++
N. Vietnam	++	++
Hainan, China	++	++
Guangdong, Guangxi, China	++	+
Philippines	++	+++
Malaysia (peat soil)	++	++

VARIETAL DISSEMINATION

Since the official release of Rayong 3 in Thailand in 1984, the total number of CIAT-related cultivars officially released in Asia has grown steadily **(Figure 8)**. The total number reached twenty by the end of 1993 and they can be classified into four categories **(Table 6)**. In the future, the main stream of cultivars released by Asian national programs will be clones selected from CIAT (both Colombia and Thailand) crosses as well as local crosses between local and CIAT parents. The estimated area planted with these cultivars has also grown accordingly and is now reaching the 150,000 ha point **(Figure 9)**.

Rayong 3 in Thailand and Adira 4 in Indonesia are reported to be planted in more than 50,000 ha. It is noteworthy that while Rayong 3 spread into the present acreage mainly through the concerted efforts of the goverment extension service, Adira 4 did the same through the initiative and efforts of the private sector.

We needed a long gestation period of nearly 15 years before being able to produce visible effects. It leaves little doubt that the recent progress is much indebted to the basic work conducted during the early years of the program. I am grateful to CIAT, which so far allowed us to structure our collaborative breeding scheme the way we desired. Needless to say, without the active collaboration of the national programs, nothing I am describing here would have come to reality.

PRESENT SITUATION

The present situation can be summarized as follows:

1. Significant yield upgrading (+100%) of breeding populations took place for all the major cassava growing environments.
2. The number of cultivars released and the area planted are increasing.
3. Earlier cultivars are contributing to enhancing the production efficiency in some areas in Thailand and Indonesia.
4. The latest cultivars are poised to make major contributions in Thailand, Indonesia, Vietnam and China.

Table 6. Number of CIAT-related cassava cultivars released by national programs in Asia (up to 1993).

Category	No.of cultivars	Country
Selected CIAT clones	5	China, Philippines, Vietnam
Selection from local cross of local parents	2	Indonesia, China
Selection from CIAT cross	8	Thailand, Indonesia,
Selection from local cross between CIAT and local parents	5	Malaysia, Philippines, Thailand

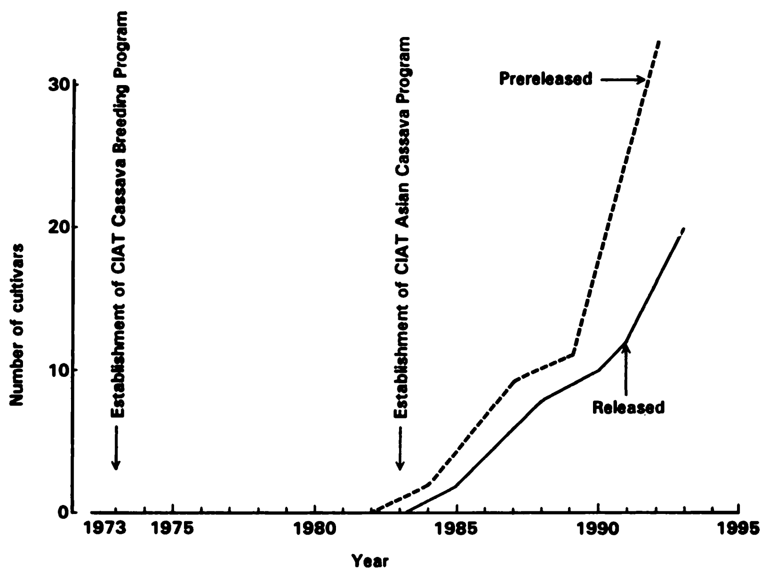


Figure 8. Increase in the number of CIAT-related cassava cultivars officially released and prereleased by Asian national programs during the past two decades.

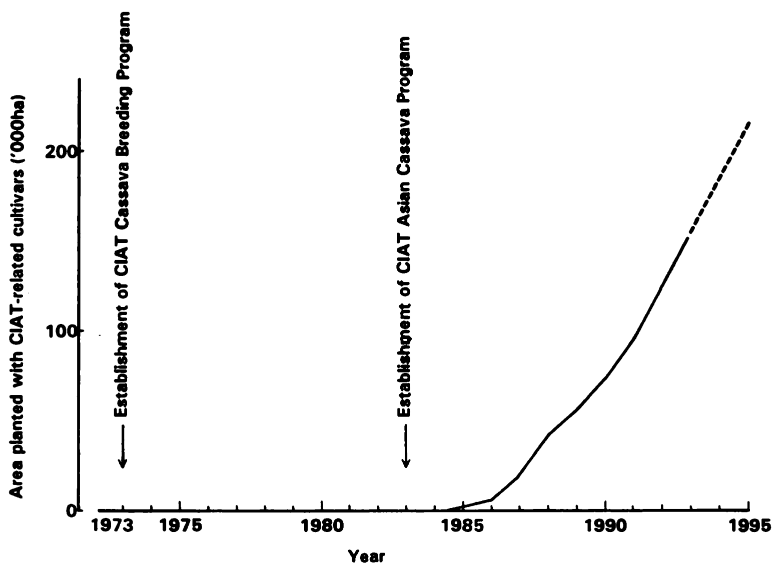


Figure 9. Increase in area estimated to be planted with CIAT-related cassava cultivars in Asia during the past two decades.

CONCLUSION

For reasons socio-economic as well as technical, a "Green Revolution" in the style of IRRI rice or CIMMYT wheat will not be repeated in case of cassava. Nevertheless, in the making is a green revolution in cassava in its own way.

AGRONOMY RESEARCH IN THE ASIAN CASSAVA NETWORK - TOWARDS BETTER PRODUCTION WITHOUT SOIL DEGRADATION

R.H. Howeler[1]

ABSTRACT

Since 1987 cassava agronomy research has been conducted by scientists from national cassava programs in Asia in collaboration and with small financial assistance from the CIAT cassava program. This paper summarizes and pulls together the results obtained, mainly corresponding to the period of 1990 to 1993.

Research on cultural practices concentrated on determining the best time of planting and harvest, optimum planting methods and plant spacing as well as intercropping systems that increase farmers' financial returns. Planting cassava stakes in a vertical or inclined position generally increased yields compared with horizontal planting, but differences were not large and depended to some extent on the variety and on soil moisture conditions during planting. Vertical planting always resulted in quicker sprouting and canopy formation, which helps to reduce weed competition and erosion. Among various intercropping systems used in Asia, the interplanting of cassava with peanuts usually produced highest net incomes. A normal square planting arrangement often produced higher total net incomes than the wide-row or double-row arrangements.

Long-term fertility trials have now been conducted for 3-5 years in nine locations in four countries. Significant responses to N were observed in seven locations and to P and K in four locations each. Responses to fertilizer application, especially to that of K, have been increasing over time. Only in Hung Loc Centre in south Vietnam no significant responses to fertilizer application were observed even after three years of continuous cropping. In most other locations the combined application of N, P and K more than doubled cassava yields.

Erosion control trials have been conducted in 12 locations in six countries. The most effective practices to reduce erosion varied somewhat among locations, but generally included contour ridging, closer plant spacing, fertilizer application, mulching and reduced tillage. Other practices, such as the planting of leguminous tree hedgerows, grass contour barriers or intercropping, will have long-term benefits in terms of erosion control, soil fertility maintenance and improving soil moisture conditions. Since the effect of these practices are rather site-specific and depend to a great extent on the socio-economic conditions of farmers, the choice of the best components of the technology, aimed at increasing farmers' income

[1] CIAT Cassava Asian Regional Program, Dept. Agric., Chatuchak, Bangkok, Thailand.

while preventing soil degradation, will need to be done on farmers' fields and through more active farmer participation in the research.

INTRODUCTION

Cassava agronomy research in Asia has been conducted by national programs in various countries for more than 60 years. The earliest cassava research in Asia was reported by Nijholt (1935) and den Doop (1937) in Indonesia on the effects of fertilizer and green manure application. In the late 1960s and early 1970s there were already several reports of cassava agronomy research in Malaysia, India and Thailand, and during the 1970s and 1980s cassava research in many countries intensified. In 1987, a Cassava Agronomy Network was established during the second Regional Cassava Workshop held in Rayong, Thailand. During that workshop researchers from seven countries discussed their priorities in cassava agronomy and concluded that cassava soil fertility maintenance and erosion control were the two topics of greatest urgency. Thus, during the past seven years, much of the cassava agronomy research in Asia has concentrated on developing cultural practices, such as fertilizer application, green manuring etc. to maintain or improve soil fertility and other practices that help to reduce soil erosion. A limited amount of research was continued on other aspects of cultural practices, such as time and methods of planting, stake size and position of planting, plant populations and intercropping.

PRESENT STATUS AND FUTURE TRENDS FOR CASSAVA PRODUCTION IN ASIA

Cassava continues to play a very important role in the agricultural economies of many countries in Asia; this is especially true in Southeast Asia, where cassava is the third most important food crop, both in terms of production (on a dry weight basis) and in terms of planted area **(Figure 1).** According to FAO estimates, cassava production in Asia reached a maximum of nearly 55 million tons in 1989 and declined slightly during the following three years, with a production of 51.24 million tons in 1992 **(Figure 2).** This decline in 1990 and 1991 was mainly due to a marked decline in cassava yield and production in Thailand and Indonesia. In 1992 cassava production increased again but did not quite reach the same level as in 1989 **(Figure 3).**

Average cassava yields in Asia have continued to increase, reaching 13.5 t/ha in 1992; this compares with 12.0 t/ha in South America and 7.6 t/ha in Africa. In 1992 the highest yield in the world, 21.05 t/ha, was obtained in India; this was followed by Thailand, China, and Indonesia. Among Asian countries the largest producer remains to be Thailand with presently about 1.4 million ha of cassava and over 21 million tons of fresh root production.

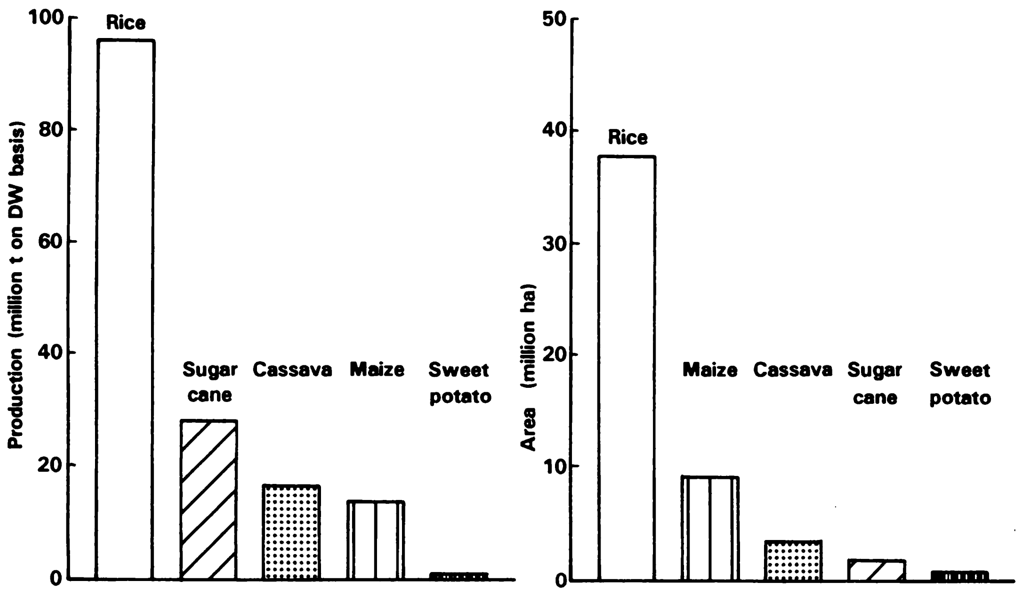


Figure 1. Production (on dry weight basis) and area of the major food crops grown in Southeast Asia in 1991.
***Source** : FAO Production Year Book for 1991.*

However, there are some clouds on the horizon. According to the new Common Agricultural Policy (CAP) in the European Economic Community (EEC) the support price for cereals within the EEC will be reduced by about 30% during the next three years, which will thus make these cereals more competitive with cassava in the production of animal feeds. This is expected to lower the price that animal feed companies in the EEC can pay for cassava to remain in the feed rations at the same level as before. Thus, countries like Thailand, that depend heavily on the export of cassava to the EEC, will either havc to reduce the cassava planted area or will have to accept a considerable reduction in the price of fresh cassava (estimated at 35-45%). The expected price of US$21 per ton for fresh cassava in Thailand is actually slightly below production costs; this will force many farmers to start growing other crops. Severe price reductions are

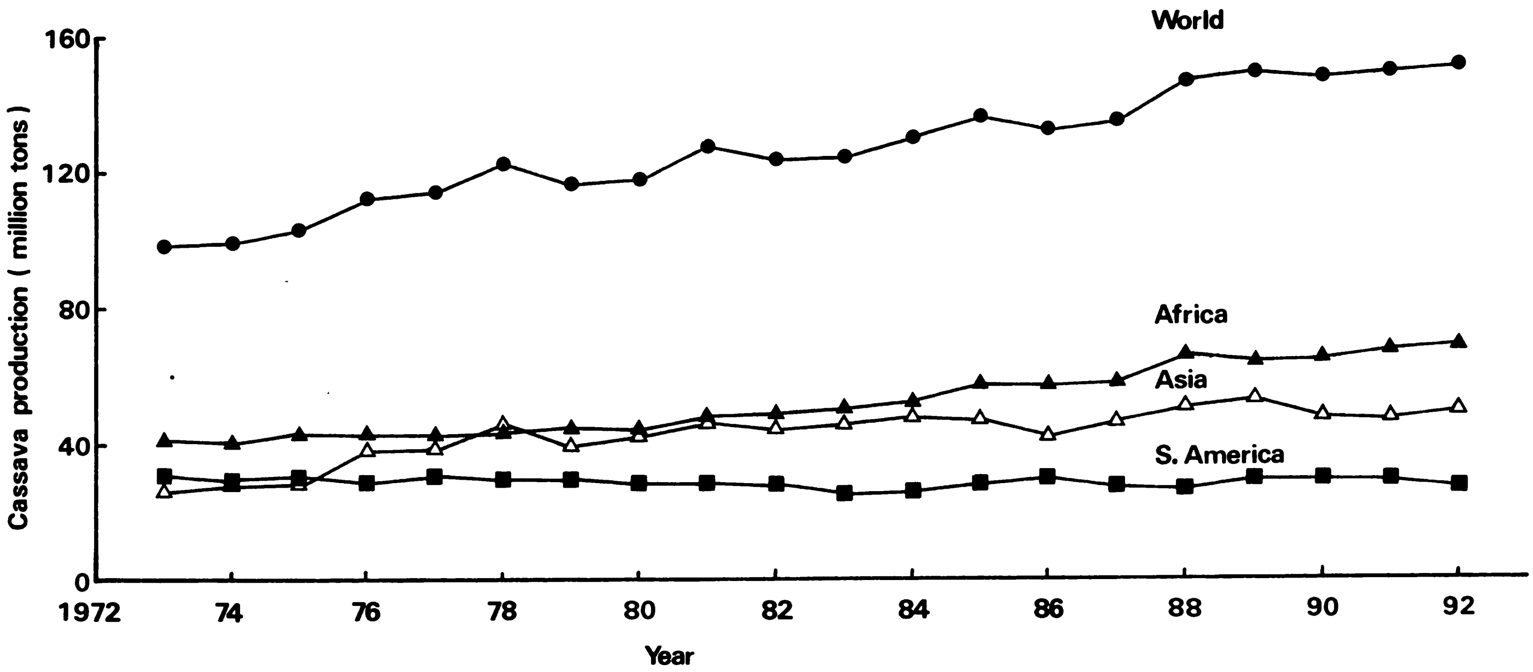


Figure 2. Trend in cassava production in the world and in the three major producing continents from 1973 to 1992.
***Source** : FAO Production Year Books.*

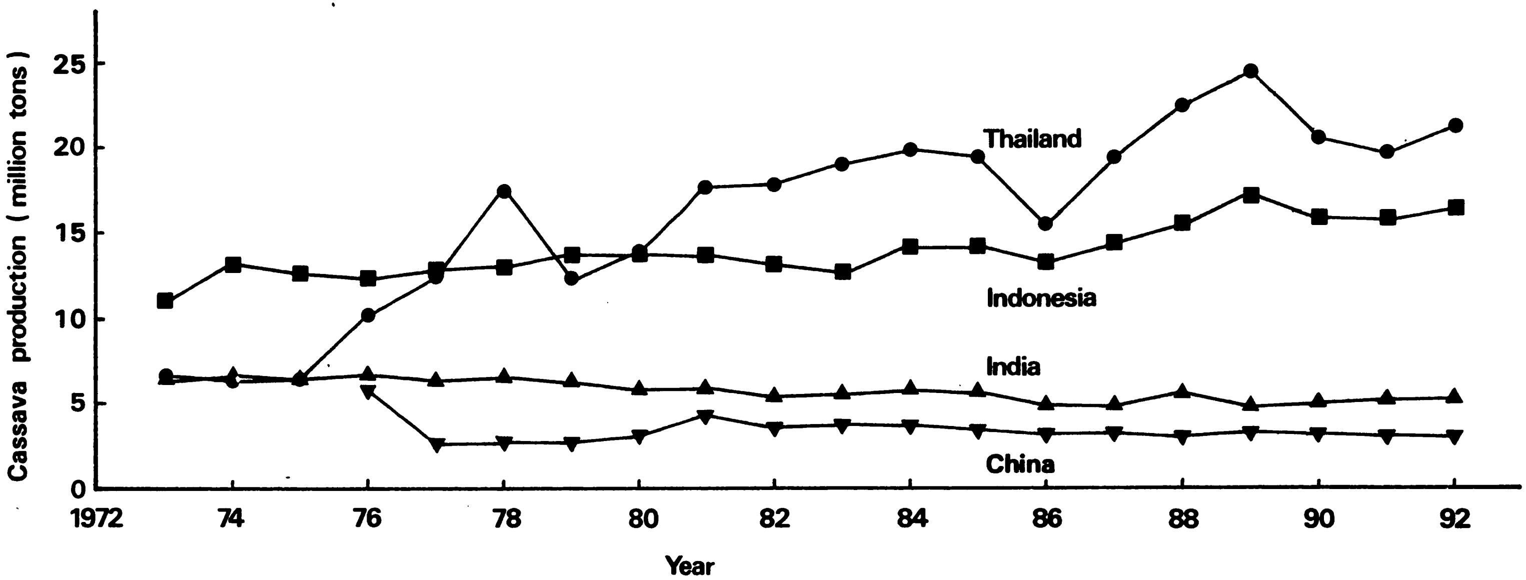


Figure 3. Trend in cassava production in four major cassava growing countries of Asia from 1973 to 1992.
***Source** : FAO Production Year Books.*

already causing hardship for many cassava farmers in Thailand as well as in northern Mindanao of the Philippines. A solution to this problem will need to be found by searching for alternative uses for cassava (such as further-processing, as used principally in China) and by increasing yields or decreasing production costs through better varieties and more cost-effective cultural practices.

RESEARCH ON CULTURAL PRACTICES

1. Land Preparation

An intensive study on the effect of different methods of land preparation on soil physical characteristics and on cassava yields was conducted in two locations in Thailand (Silpamaneephan, 1994). **Figure 4** shows that in the sandy loam soils of Sri Racha, the

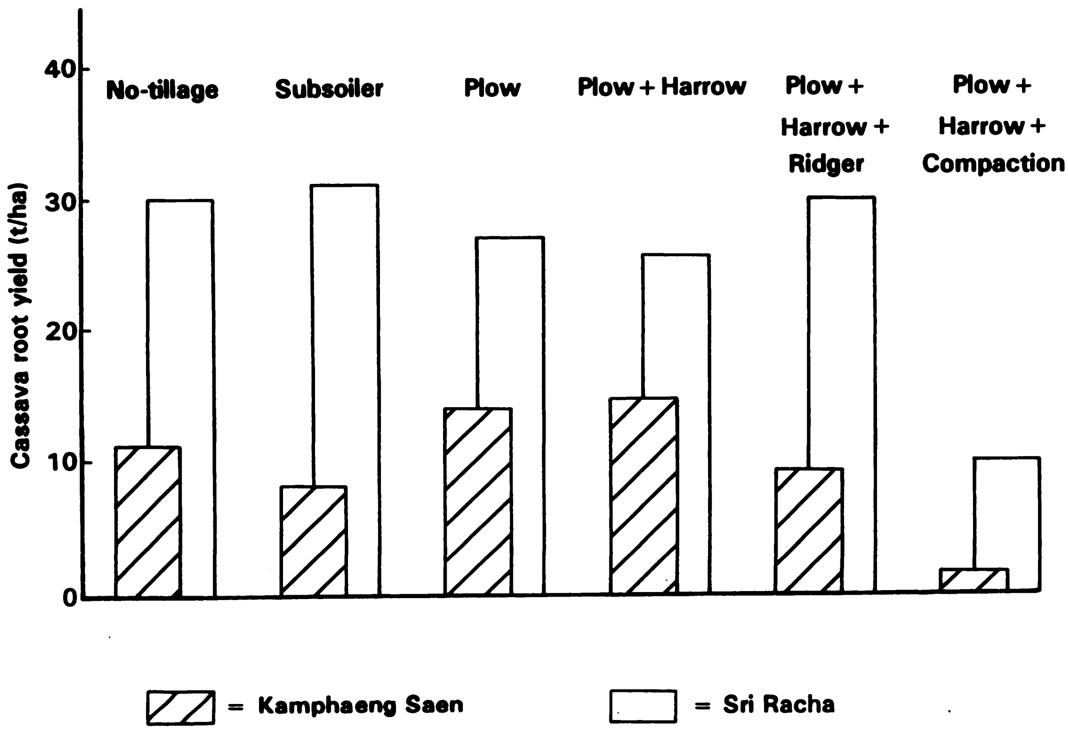


Figure 4. Effect of various tillage operations on the yield of cassava, Rayong 1, at two locations in Thailand in 1991/1992.
***Source** : Silpamaneephan, 1994.*

various methods of land preparation had no significant effect on cassava yield, with no-tillage resulting in the same high yield as intensive land preparation including ridging. However, when intensive land preparation was followed by compaction from excessive traffic with tractor, cassava growth was seriously affected and yields were significantly reduced. This marked yield decline was observed at a soil bulk density of about 1.8 t/m^3 and a penetrometer resistance of about 45 kg/cm^2. Thus, soil compaction due to either inadequate land preparation, the presence of hardpans, or by excessive tractor traffic, can cause a serious decline in cassava yield, both by restricting root penetration and root bulking. But, in light textured or loose soils, zero- or minimum tillage may also be a practical way to reduce production costs without seriously affecting cassava yields.

2. Time of Planting

A time-of-planting trial has been conducted for the past four years at the South China Academy of Tropical Crops (SCATC) in Hainan, China, with the objective of studying the effect of temperature and rainfall on cassava yield and the possibility of planting cassava outside the traditional planting period of Feb to May; this would enable a more continuous supply of cassava roots for the processing industry. **Figures 5** and **6** show the effect of planting date on the yield of three cassava cultivars when harvested at 8 and 12 months, respectively. These figures also show the fluctuation in temperature, rainfall and soil moisture content during the three cropping cycles.

When cassava was harvested at 8 months **(Figure 5)** root yields of all three cultivars were markedly affected by planting date. High yields were obtained when planting was done in early spring (Feb-May) and very low yields were obtained with planting in early fall (Sept-Nov). It can be seen that low yields were not obtained when cassava was planted during the coldest or driest season, but were obtained when cassava was planted 3-4 months before the coldest or driest period, i.e. the cold and dry weather occured during the period when cassava normally has its most rapid growth and when root bulking initiates. Since the soil moisture content during the latter part of 1991 and the first part of 1992 never dropped below 60% of available soil moisture (bottom **Figure 6**), it is likely that root yields were mainly reduced by low temperature during the root bulking initiation phase. This markedly affected both the root number per plant and the weight of each root. In cassava planted in Oct 1991 and harvested at 8 months, the root number per plant was only about 30% of normal in both cultivars. However, when cassava was harvested at 12 months **(Figure 6)**, yields of the local cultivar SC205 were considerably higher than those of the introduced cultivar, Nanzhi 188, and the former was much less affected by low temperatures than the latter. Yields of Nanzhi 188 were still rather low when planted in Sept-Dec. It appears that the cold-

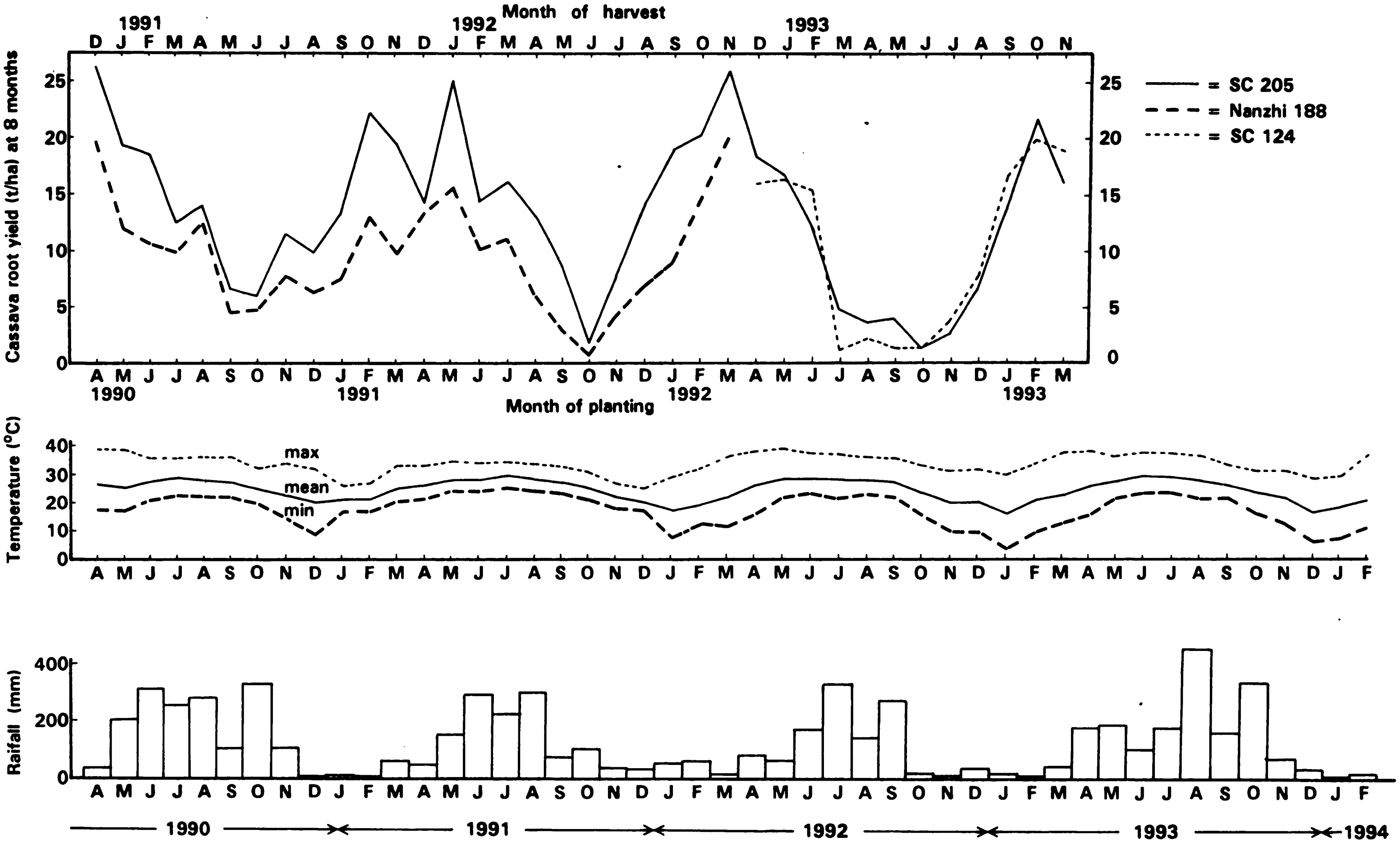


Figure 5. Effect of month of planting on the root yield at 8 months after planting of three cassava cultivars during three cropping cycles in SCATC, Hainan, China. Below are shown the monthly mean as well as the absolute maximum and minimum air temperature as well as the rainfall distribution.

Source : *Zhang Weite, SCATC, Hainan.*

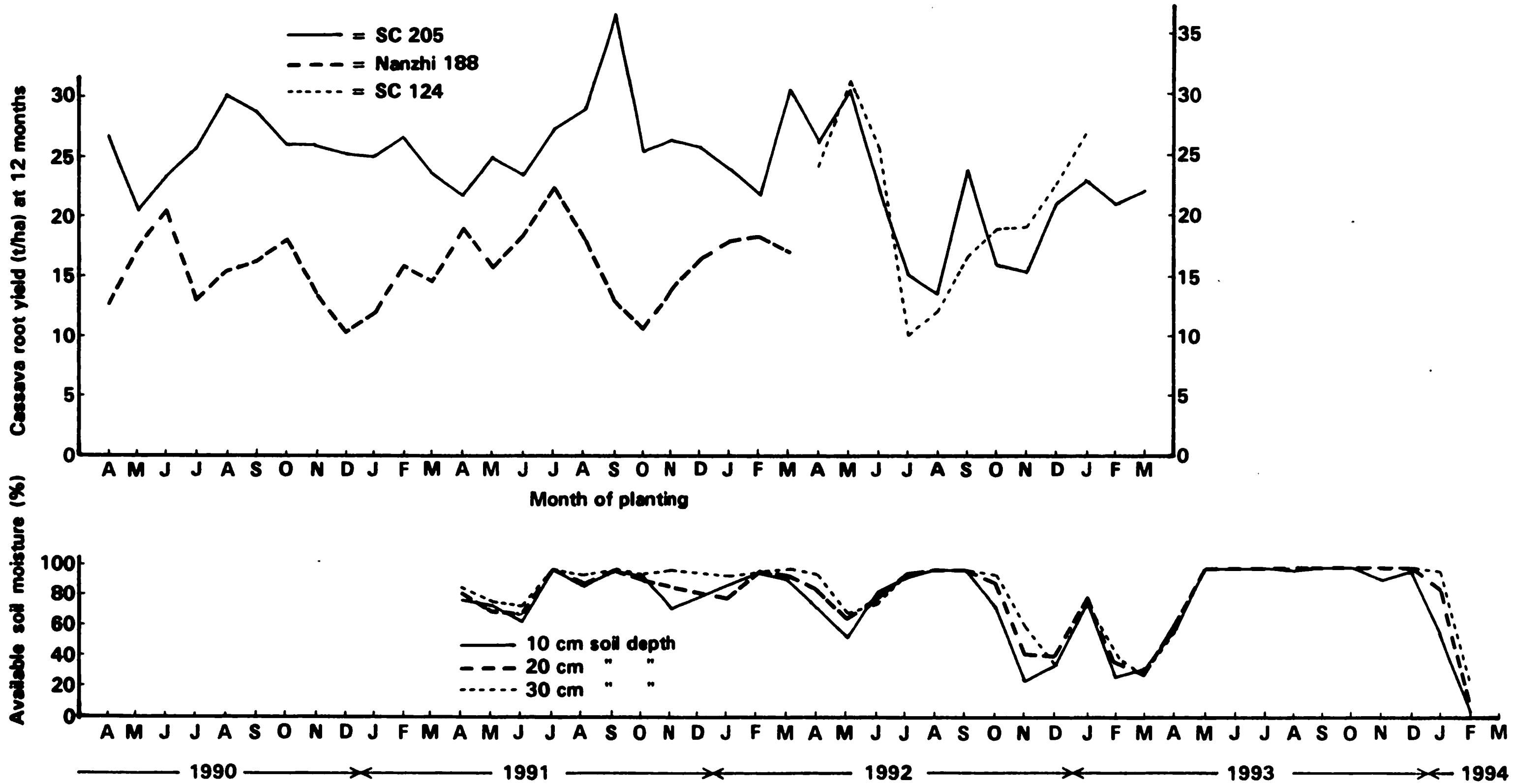


Figure 6. Effect of month of planting on the root yield at 12 months after planting of three cassava cultivars during three cycles in SCATC, Hainan, China. Below is shown the available soil moisture content at 10, 20 and 30 cm depth during the last two cropping cycles.

***Source :** Zhang Weite, SCATC, Hainan.*

tolerant SC205 was better able to re-initiate root bulking after the coldest months had passed, resulting in a marked increase in yield between the 8th and 12th month; yields of Nanzhi 188 also increased during these last four months, but the cassava planted in the early fall never quite recuperated from the effect of cold temperatures during root bulking initiation.

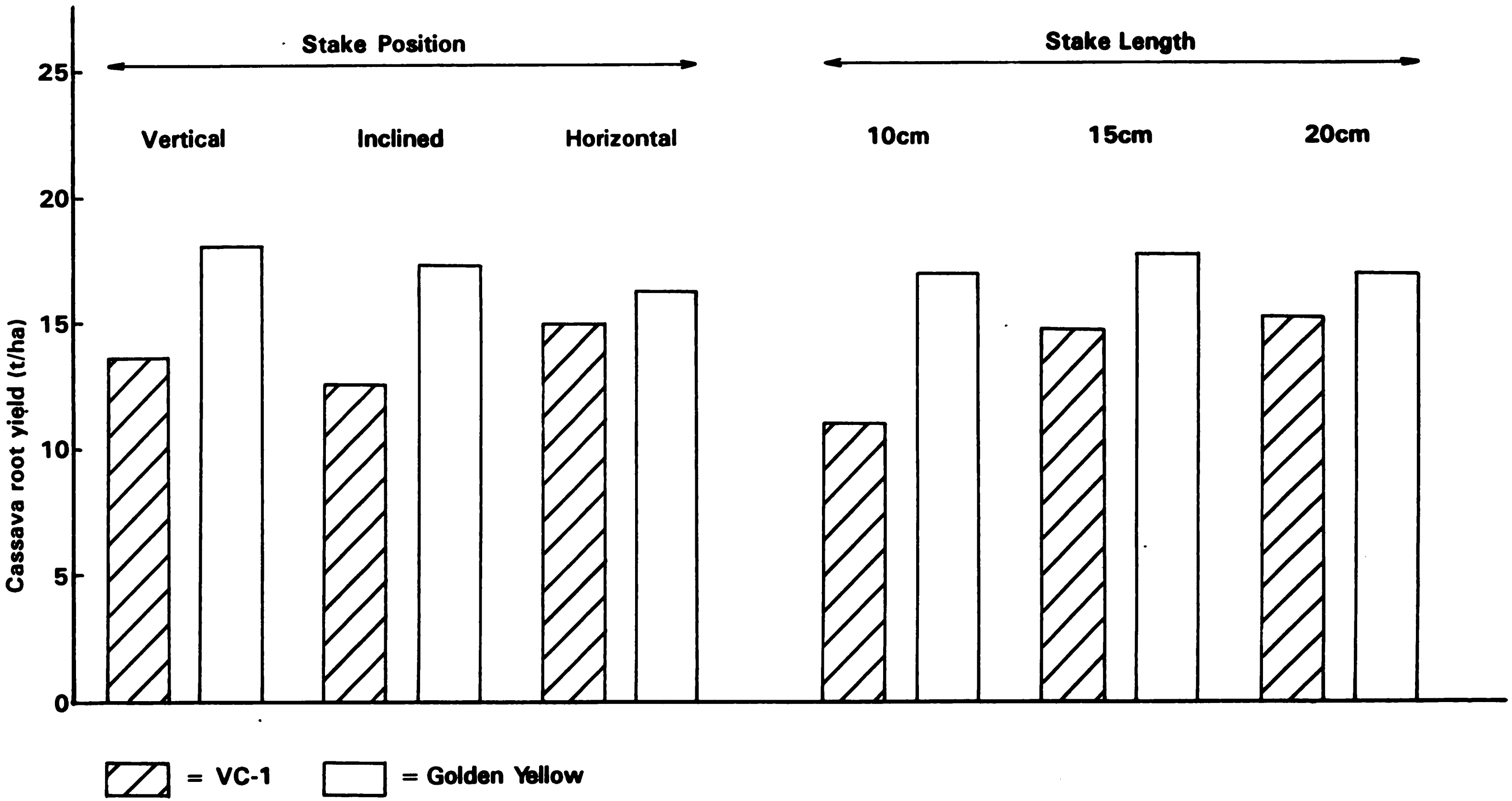
In the third cycle, Nanzhi 188 was replaced by the newly released cultivar SC124. During the winter of that cropping cycle (1992/93) both the temperature and rainfall were lower than in the previous two years, and this affected the yield of both cultivars, even when harvested after 12 months.

From a practical point of view, it can be concluded that under the soil and climatic conditions of Hainan, cassava can be planted year-round as long as a well-adapted cold-tolerant cultivar like SC205 is used. Cassava can be harvested at 8 months when planted in the first half of the year (Jan-June) or harvested at 12 months when planted at any time of the year. This flexibility in planting and/or harvesting time should allow a continuous supply of raw material throughout the year.

3. Method of Planting

Earlier reports from Thailand (Tongglum *et al.*, 1992) indicate that stake position at planting can have a significant effect on germination and yield. Under the conditions of Rayong, Thailand, research on stake position during three years indicated that vertical or inclined planting resulted in significantly higher yields than horizontal planting. Especially when cassava was planted in the early dry season, vertical planting was better than inclined planting, which in turn was much better than horizontal planting.

Similar trials conducted in Bohol, Philippines, in Nanning, China and in Hung Loc, Vietnam, had less conclusive results. In Bohol, a 3-year experiment showed no significant effects of stake position when cassava was planted in the early rainy season. However, there was a significant interaction with cultivars, Golden Yellow generally giving better yields when planted vertically, and VC-1 when planted horizontally **(Figure 7)**. This is because germination of VC-1 may be seriously affected by poor stake quality. When using short stakes of 10 or 15 cm length, horizontal planting of VC-1 resulted in a much better stand and higher yields than vertical planting. But, using normal stakes of 20 cm length, vertical planting resulted in the highest yields in both cultivars. In Hung Loc, vertical planting also gave highest yields in both cultivars (Nguyen *et al.*, 1995), but these differences were not statistically significant. In Nanning inclined planting was slightly better than vertical or horizontal planting. However, these results varied somewhat between years and between cultivars (Tian *et al.*, 1995), indicating the effect of weather on germination. During a period of unexpected drought in the spring of 1991, vertical planting resulted in much better germination and better



Figuer 7. Effect of stake position and stake length on the root yields of two cassava cultivars planted in Ubay, Bohol, Philippines. Data on stake position are averaged over stake lengths and vice versa.

Source : *Julieta Ladera, BES, Bohol.*

plant height at 2 months; the experiment, however, was not harvested due to excessive loss of plant stand in some treatments, mainly those planted horizontally.

Thus it may be concluded that vertical planting tends to give a better and faster germination, especially when planted during periods of low soil moisture. When planted in the early wet season this may also help reduce weed competition and erosion, but may have no significant effect on yield. When planted on heavy soils, farmers may prefer planting horizontally, since this tends to facilitate the harvest.

4. Intercropping

In countries where farm size is small and labor is abundant, farmers often intercrop cassava with grain legumes, rice or maize in order to increase their income and spread labor, food production and income more evenly throughout the year. If well managed this may also improve soil fertility and reduce erosion.

During the past five years intercropping trials have been conducted in Rayong, Thailand; in Hung Loc and Agric College #3 in Vietnam; in Bohol island of the Philippines; and in Yogyakarta and Lampung in Indonesia. In general, intercropping reduced the yield of cassava by competition for light, nutrients and water, but because of the additional production of the intercrop the total gross or net income was increased.

In Hung Loc Center and Agric. College #3 in Vietnam intercropping cassava with peanut reduced cassava yields on average by 18 and 6%, respectively, but in both locations intercropping with peanut resulted in the highest net profits compared with other intercropping systems. In Hung Loc, however, cassava monoculture gave still higher profits (Nguyen *et al.*, 1995). Intercropping with peanut tends to reduce cassava yields more than with other crops, such as soybean, mungbean or cowpea; this is because peanut is more tolerant of adverse conditions and will generally grow vigorously, producing good yields, which result in a higher total income to the farmer. This was also observed in Bohol, Philippines (Evangelio *et al.*, 1995).

In Indonesia, it was found that planting cassava at 1.0x1.0m gave higher total gross income than planting at 2.0x0.5 m in Yogyakarta and Bogor (Wargiono *et al.*, 1992), while in Lampung there were no significant differences in total gross income from planting in square, wide-row or double-row systems (CIAT, 1992). However, the double-row system was found to be more profitable than the square arrangement for intercropping with peanut or sweet corn in Malaysia (Tan, 1990).

Long-term cassava intercropping trials have been conducted since 1975 in both Rayong and Khon Kaen Research Centers in Thailand. **Table 1** shows that during 17 years the average yield of cassava was most depressed by intercropping with peanut, while gross income was highest for intercropping with sweet corn, followed by either peanut or soybean. **Table 2** shows that long-term cassava cropping with fertilization

Table 1. Average yields of cassava and intercrops in long-term intercropping trials conducted for 17 years (1975-1991) in Rayong and Khon Kaen Field Crops Research Centers in Thiland.

	Cassava yield (t/ha)		Intercrop yield (t/ha)		Total gross income[2] (฿/ha)	
	Rayong	Khon Kaen	Rayong	Khon Kaen	Rayong	Khon Kaen
Cassava monocrop	18.98	25.99	-	-	12,1477	16,634
Cassava + sweet corn	·18.97	21.54	16.650[1]	13.970[1]	20,466	20,771
Cassava + mungbean	17.44	20.33	0.556	0.241	17,278	15,662
Cassava + peanut	17.01	16.42	0.910	0.637	18,166	15,605
Cassava + soybean	16.92	23.24	0.675	0.345	16,229	17,634

[1] Number of ears/ha

[2] Prices : cassava ฿ 0.64/kg, sweet corn ฿ 0.50/ear
mungbean 11.00/kg, peanut 8.00/ kg
soybean 8.00/kg
1 US $ is about 25 baht

Source : Tongglum *et al.,* 1993.

markedly depressed soil pH in Rayong, it had little effect on percent organic matter (OM), while it increased the contents of available P and exchangeable K, especially in Khon Kaen. Intercropping with peanut and soybean may have slightly increased soil OM, but had no effect on soil P or K compared with cassava monocropping. Thus, in these trials intercropping had little or no long-term effect on soil fertility.

RESEARCH ON SOIL FERTILITY MAINTENANCE

Over 20 years of fertilizer trials, conducted on three soil series in Thailand, have shown that continuous planting of cassava without fertilizer application resulted in a gradual decline in yields **(Figure 8).** The same has been observed with other crops. This effect is partly due to nutrient exhaustion and partly due to erosion.

1. Nutrient Removal from the Soil

Many people consider cassava a crop that extracts excessive amounts of nutrients from the soil. In a recent experiment in Sri Racha, Thailand, over a period of nearly two years, the nutrient extraction, both in the harvested and non-harvested products, of seven crops was determined; nutrients in the former are completely removed from the field, while those in the latter are normally returned to the soil for recycling into the soil's nutrient pool. **Table 3** shows that cassava planted for forage production, in which leaves and stems were cut every 3-4 months for animal feed, indeed removed large amounts of N, P and K, while nothing was returned to the soil. But when cassava was grown for root production, the removal of N and P, when calculated per ton of DM removed, was less than that of other crops, while removal of K was similar to most

Table 2. Effect of 17 years of cassava intercropping on several soil fertility parameters in Rayong and Khon Kaen Field Crops Research Centers in Thailand.

	Rayong								Khon Kaen							
	1976				1992				1976				1992			
	pH	OM (%)	P (ppm)	K (ppm)	pH	OM (%)	P (ppm)	K (ppm)	pH	OM (%)	P (ppm)	K (ppm)	pH	OM (%)	P (ppm)	K (ppm)
Cassava monocrop	5.82	1.12	18	65	4.53	0.89	36	41	4.8	0.58	8	10	4.6	0.50	18	53
Cassava + sweet corn	6.07	1.25	55	65	4.33	0.98	33	35	4.8	1.05	16	14	4.7	0.60	21	64
Cassava + mungbean	6.02	0.87	12	36	4.23	0.99	42	27	4.8	0.35	12	12	4.7	0.50	21	53
Cassava + peanut	6.27	0.95	21	68	4.38	1.12	37	32	4.5	0.63	9	12	4.4	0.60	21	84
Cassava + soybean	5.72	1.41	64	75	4.30	1.21	41	33	5.0	0.73	5	12	4.7	0.60	19	53

1) Annual application of 46 kg/ha of N, P_2O_5 and K_2O

Source : Tongglum *et al.,* 1993.

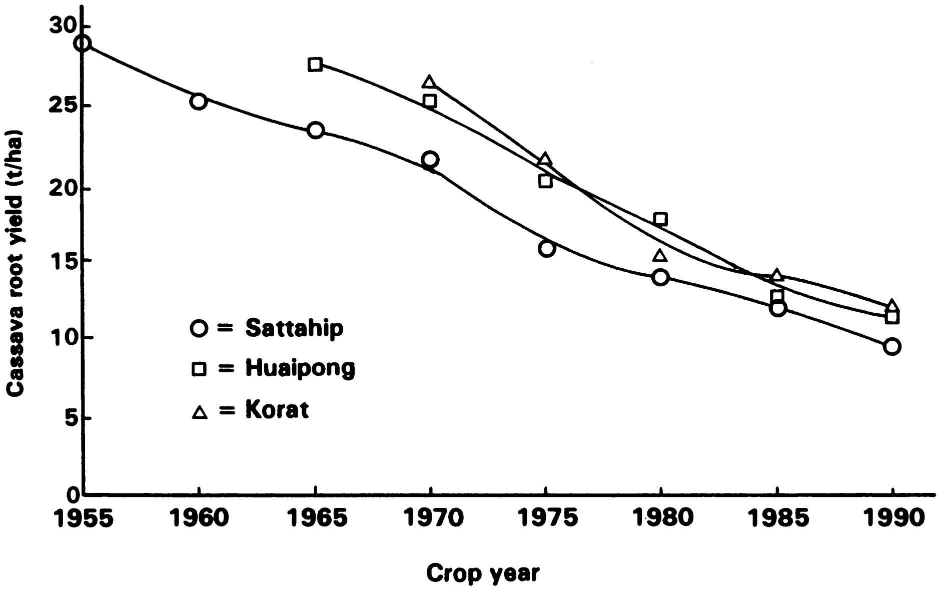


Figure 8. Decline in cassava fresh root yields due to continuous cultivation without fertilizer application in three soil series in Thailand.
***Source** : Sittibusaya, 1993.*

Table 3. Dry matter and major nutrients in the harvested and non–harvested products of various crops grown during 22 months in Sri Racha, Thailand, 1989–1991.

Crop	DM production (t/ha)		Nutrients removed (kg/ha)			Nutrients returned (kg/ha)		
	harv. prod.	non-harv. prod.	N	P	K	N	P	K
Cassava for roots	9.01	5.90	102	19	104	182	20	87
Cassava for forage	11.82	-	329	39	193	-	-	-
Maize	8.78	12.76	118	44	87	101	13	271
Sorghum	5.10	17.18	79	25	51	147	27	305
Peanut	4.90	8.59	213	19	52	133	25	184
Mungbean	2.73	2.99	114	14	59	51	6	64
Pineapple	7.58	19.21	82	15	188	161	31	279

Source : Putthacharoen *et al.*, 1992.

other crops, but less than in pineapple. However, it was also shown that most other crops returned large amounts of K to the soil in crop residues, while cassava returned relatively large amounts of N in fallen leaves and stems (about 65% of total absorbed N). Thus, cassava does not extract more nutrients than other crops, but it has a reputation to do so mainly because the nutrients that are removed are seldom replaced or are not replaced in the right proportions, leading to a gradual reduction in the soil's productivity.

2. Soil Fertility Maintenance through Green Manuring

Research on the effect of green manuring on cassava yields and soil fertility is being conducted in Khon Kaen and Rayong provinces of Thailand. In Khon Kaen, five years of green manure trials indicate that green manuring with cowpea increased cassava yields significantly and relatively high yields of cassava could be maintained with moderate levels of fertilization (0 to 50 kg/ha of N, P_2O_5 and K_2O) (Sittibusaya *et al.*, 1995).

In Pluak Daeng, Rayong, green manuring without fertilizer application tended to increase cassava yields compared with the unfertilized check, but yields were always low due to the late planting of cassava after green manure incorporation (Tongglum *et al.*, 1992). **Table 4** shows similar effects for two recent trials in the same location. Incorporation of pigeon pea or mulching of *Crotalaria juncea* were most effective in increasing cassava yields, while *Sesbania rostrata* was least effective. However, the normal early-season (June) planting of cassava without green manures resulted in still higher yields even without fertilizers, because cassava could benefit from an additional 2-3 months of rainy season, which in the case of the green manure treatments were used for growing the green manures. Thus, from a practical stand point the green manures did not produce any benefits to the farmer, and after two years had no measurable effect on soil fertility. However, in countries with a longer rainy season, the growing and mulching of green manures may actually increase cassava yields while helping to control weeds and erosion. In drier areas like Thailand, one possibility would be to interplant the green manures between cassava rows at time of planting cassava and pulling up and mulching the green manures after 1 1/2-2 months; or, alternatively, to seed the green manures about 1-2 months before the cassava harvest and plant the next cassava crop after incorporation or mulching of the green manures. These alternatives could be more practical and should be further investigated.

3. Soil Fertility Maintenance through Fertilizer Application

Since fertilizer application is one of the principal means that farmers have to increase yields, it is important to determine the exact fertilizer requirements in different

Table 4. Average effect of cassava planting time, fertilization or green manuring[1] on cassava yields in Pluak Daeng, Thailand in 1991/92 and 1992/93.

Treatments	DW green manures (t/ha)		Nutrient application[2] (t/ha)			Cassava root yield (t/ha)	
	Incorp	Mulched	N	P	K	Incorp.	Mulched
1 June planting, no fertilizers	-	-	-	-	-	13.48	10.67
2 June planting, with fertilizers	-	-	100	-	42	16.04	14.03
3 Sept planting, no fertilizers	-	-	-	-	-	4.73	4.79
4 Sept planting, with fertilizers	-	-	100	-	42	5.85	5.64
5 Sept planting, after *Sesbania rostrata*	0.80	1.35	23	2.9	21	4.35	4.72
6 Sept planting, after *Mucuna fospeada*	2.92	4.41	115	8.0	62	6.48	8.79
7 Sept planting, after *Crotalaria juncea*	6.50	7.22	120	8.1	71	8.25	9.07
8 Sept planting, after pigeon pea	3.81	4.30	97	9.4	51	8.56	6.85
9 Sept planting, after cowpea	2.01	3.00	65	6.4	46	6.29	4.79
10 Sept planting, after *Canavalia ensiformis*	3.40	4.00	100	7.8	49	6.00	7.04

[1] Green manures were planted in June or July, cut in late Aug or Sept and either incorporated or mulched before cassava planting in early Sept or Oct. Cassava was harvested at 9 months in treatments 3-10 and at 10 months in treatments 1 and 2.

[2] Nutrients in the green manures had been either produced through N-fixation or through uptake from the soil.

Source : Anuchit Tongglum, FCRC, Rayong.

kinds of soils, so farmers can maximize their yields without wasting money on fertilizers they don't need. Thus, long-term fertility trials were established in many cassava growing areas in Asia with the objective of determining both the short-term nutrient response and the long-term nutrient requirements in the predominant production systems of each region. The combined information from these trials can also be used to define criteria for diagnosing nutrient deficiencies, such as critical nutrient concentrations in plant tissue and soil, which in turn can be used to calculate more exact nutrient requirements on the basis of soil analysis results.

Figure 9 shows the locations of the various trials and the principal short- and long-term responses. The relative yields, i.e. the yield obtained without the nutrient as a percent of the highest yield obtained with the nutrient, as well as soil and tissue analyses data are summarized in **Table 5.** In most locations there was both a short- and long-term response to N, with the response generally becoming more pronounced with each successive cropping cycle. An initial P response was observed mainly in Guangzhou in China, in Agric. College #3 in Vietnam and in Jatikerto in E. Java, while a subsequent P response was also observed in ViSCA, Philippines and in Umas Jaya, Indonesia. An initial K response was found only in Agric. College #3 and in Lampung, Indonesia as well as in the first cycle in Jatikerto. Responses to K tended to increase over time, resulting in highly significant responses in Nanning and Guangzhou of China and in Bohol of the Philippines **(Figure 10).**

Figure 11 shows the relation between the relative responses to N, P and K and the concentrations of N, P, and K, respectively, in youngest fully-expanded leaf blades, sampled at 3-4 months after planting in four trials in China. Except for a couple of wayward points, there was a reasonably good relation between the relative N and K response and the N and K concentrations in the leaves, allowing the estimation of a critical level (corresponding to 95% of maximum yield) of 4.6% N and 1.7% K. This compares with critical levels of 5.6% N and 1.42% K obtained from trials in Colombia (Howeler and Cadavid, 1990). Similar data from Agric. College #3 in Bac Thai, Vietnam **(Figure 12)** also resulted in a critical level of about 1.7% K for two local cultivars. The relation with P concentration was not very good and no critical P levels could be estimated.

Similarly, **Figure 13** shows the relation between relative cassava responses to N, P and K and the OM, available P and exchangeable K contents of the soil, respectively, as determined from ten long-term fertility trials. In this case, there was no good relationship between N response and % OM, which is commonly observed also in other crops. This is the main reason that OM contents are seldom used to recommend rates of N application; these rates are determined mainly experimentally. But there was a rather good relation in the case of P and K, allowing the estimation of critical levels of 4.5 ppm

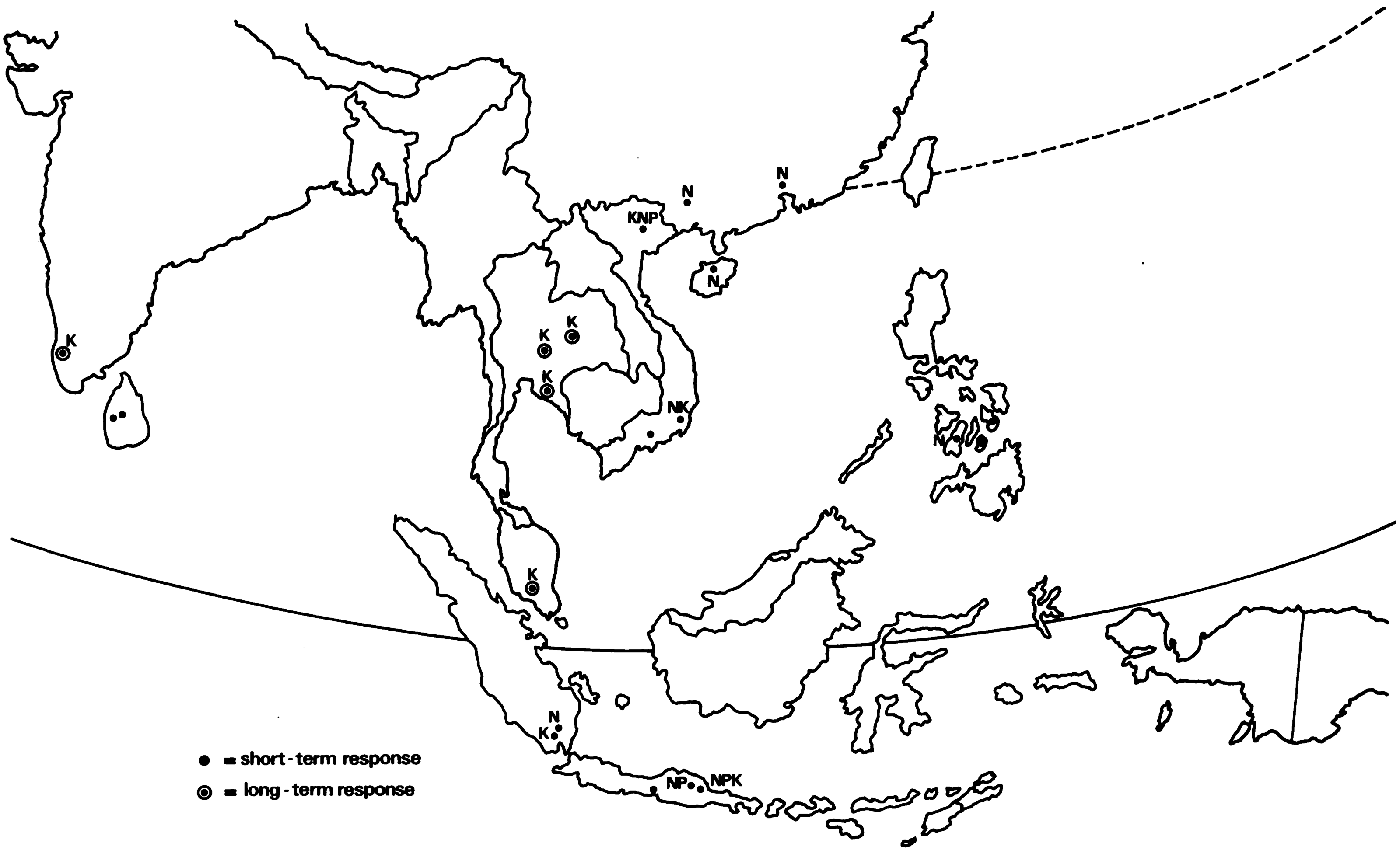


Figure 9. Short- and long-term responses of cassava to application of N, P and K in long-term fertility trials conducted in various locations in Asia.

Table 5. Relative root yields (RY)[1] of one or two cassava cultivars (V1 and V2), the organic matter, available P (Bray II) and exchangeable K levels of the soil and the N, P or K concentrations of youngest fully-expanded leafblades at 3-4 months after planting in check plots of N, P or K, respectively, in long-term fertility trials conducted in 13 locations in Asia.

Location trial	N: RY_N V1	RY_N V2	Soil OM (%)	Tissue N (%) V1	Tissue N (%) V2	P: RY_P V1	RY_P V2	Soil P (ppm)	Tissue P (%) V1	Tissue P (%) V2	K: RY_K V1	RY_K V2	Soil K (me/100g)	Tissue K (%) V1	Tissue K (%) V2
Nanning C-89-6	70	62*	2.40	4.14	-	87	93	15.7	0.47	-	98	93	0.14	1.61	-
Nanning C-90-7	60*	48**	2.00	3.86	-	99	86	11.5	0.52	-	85	74**	0.11	1.65	-
Nanning C 91-7	60	65*	-	-	-	83	80	-	-	-	84	82	-	-	-
Nanning C 92-7	76	51**	2.30	3.42	3.73	72*	75	13.7	0.45	0.37	82	77	0.13	1.81	1.22
Guangzhou C-89-1	69**	79*	1.60	-	-	97	93*	3.9	-	-	95	91	0.09	-	-
Guangzhou C-90-4	69*	59	1.00	4.09	4.20	75*	59*	4.9	0.54	0.68	98	88	0.10	1.58	1.81
Guangzhou C-91-5	74*	38**	1.10	5.01	5.24	93	59*	2.6	0.71	0.69	85	68*	0.09	2.22	2.12
Guangzhou C-92-5	58*	44**	1.70	3.93	3.36	73	45*	2.5	0.51	0.39	53**	61**	0.08	1.42	1.24
Hainan C-92-3	72*	68*	-	-	-	83	92	-	-	-	95	74	-	-	-
Hung Loc V-90-1	92	93	2.95	-	-	92	100	18.4	-	-	100	96	0.19	-	-
Hung Loc V-91-1	100	92	-	-	-	94	96	-	-	-	84	100	-	-	-
Hung Loc V-92-1	91	98	-	-	-	100	95	-	-	-	85	80	-	-	-
AC #3 V-90-4	67*	50**	-	-	-	84**	70**	-	-	-	17**	27**	-	-	-
AC #3 V-91-4[2]	83*	79**	2.60	4.76	4.90	71**	74**	9.7	0.45	0.53	22**	19**	0.04	1.34	1.77
AC #3 V-92-4	53*	59**	1.90	4.41	4.27	75	74**	4.7	0.33	0.41	16**	11**	0.04	0.51	0.63
Tarokan I-88-2	51**	-	1.60	-	-	80*	-	4.8	-	-	100	-	0.13	-	-
Umas Jaya I-87-1	61**	76	2.14	-	-	87	75	4.0[3]	-	-	94	100	0.19	-	-
Umas Jaya I-88-7	92	-	2.38	-	-	74*	-	19.0[3]	-	-	91	-	0.17	-	-
Umas Jaya I-89-7	92	-	-	-	-	73	-	-	-	-	96	-	-	-	-
Umas Jaya I-90-7	73*	-	-	-	-	72	-	-	-	-	99	-	-	-	-
Umas Jaya I-91-7	95	-	-	-	-	89	-	-	-	-	81	-	-	-	-
Umas Jaya I-92-7	89	-	2.40	-	-	94	-	3.5[3]	-	-	85	-	0.14	-	-

Table 5. (continued)

Location trial	N: RY_N V1	N: RY_N V2	N: Soil OM (%)	N: Tissue N (%) V1	N: Tissue N (%) V2	P: RY_P V1	P: RY_P V2	P: Soil P (ppm)	P: Tissue P (%) V1	P: Tissue P (%) V2	K: RY_K V1	K: RY_K V2	K: Soil K (me/100g)	K: Tissue K (%) V1	K: Tissue K (%) V2
Jatikerto I-88-1	75**	-	-	3.58	-	79**	-	-	-	-	82**	-	-	-	-
Jatikerto I-89-1	51**	-	-	-	-	100	-	-	0.38	-	84	-	-	1.65	-
Jatikerto I-90-1	16**	-	-	-	-	73*	-	-	-	-	93	-	-	-	-
Jatikerto I-91-1	41**	-	-	-	-	98	-	-	-	-	83	-	-	-	-
Yogyakar I-91-3	71	-	26	-	-	95	-	2.2	-	-	76	-	0.23	-	-
Lampung I-91-5	77	-	-	-	-	100	-	-	-	-	78*	-	-	-	-
VISCA P-88-3	90	-	-	-	-	100	-	-	-	-	73	-	-	-	-
VISCA P-89-3	86	-	2.8	-	-	37**	-	1.7	-	-	78	-	0.15	-	-
VISCA P-90-3	75	-	-	-	-	73	-	-	-	-	79	-	-	-	-
VISCA P-92-3	91	-	-	-	-	45*	-	-	-	-	64	-	-	-	-
Bohol P-89-5	92	99	1.4	-	-	97	90	9.1	-	-	96	100	0.08	-	-
Bohol P-90-5	48	72**	1.7	-	-	90	100	3.1	-	-	76	88	0.08	-	-
Bohol P-91-5	38	46	-	-	-	100	74	-	-	-	30**	58	-	-	-
Bohol P-92-5	57	48**	-	-	-	76	90	-	-	-	27**	36**	-	-	-
Negros P-89-7	72**	83	1.7	-	-	94	92	2.5	-	-	92	94	0.16	-	-
Negros P-90-8	62*	55**	-	-	-	91	88	-	-	-	85	100	-	-	-
Negros P-91-8	66**	45**	2.1	-	-	100	85	2.7	-	-	94	96	0.23	-	-

* = significant response (P<0.05); ** = highly significant response (P<0.01).

[1)] Relative root yield = root yield of check plot as a percent of the highest yield when the nutrient is applied.

[2)] Leaf samples taken at 6 months.

[3)] Bray I.

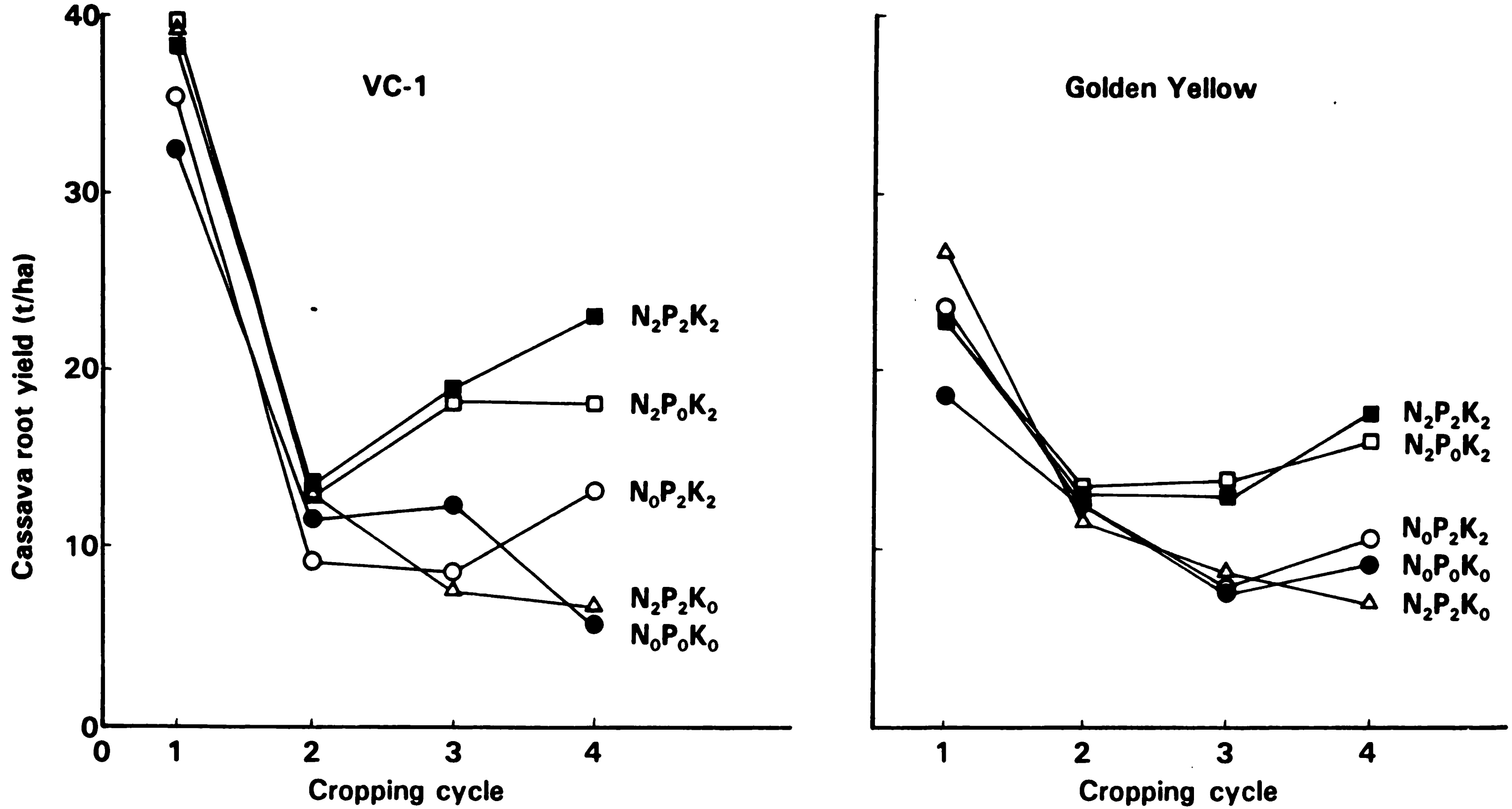


Figure 10. Effect of various levels of application of N, P and K on the root yield of two cassava cultivars grown during four consecutive cropping cycles in Bohol Experiment Station, Ubay, Bohol, Philippines.

***Source :** Julieta Ladera, BES, Bohol.*

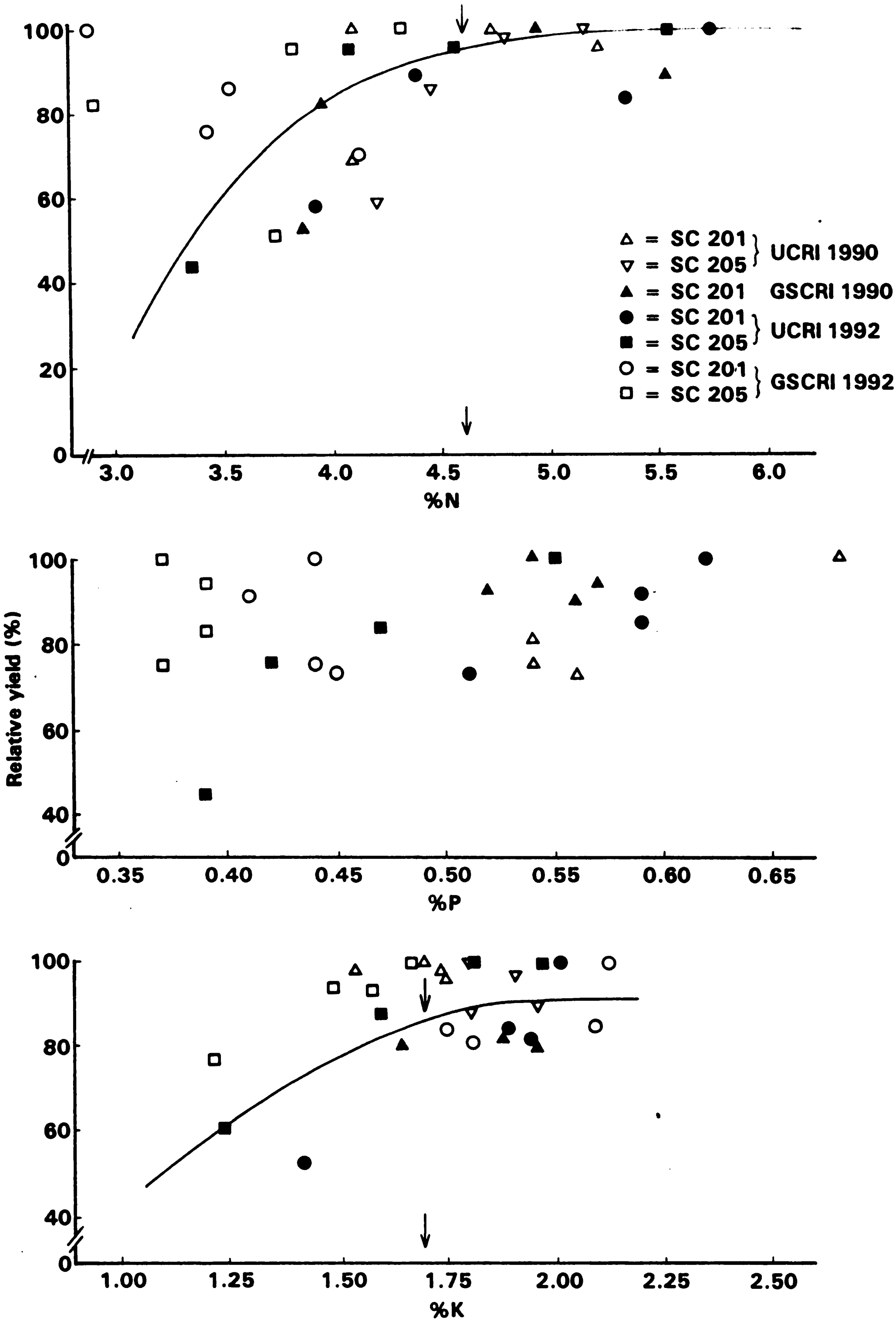
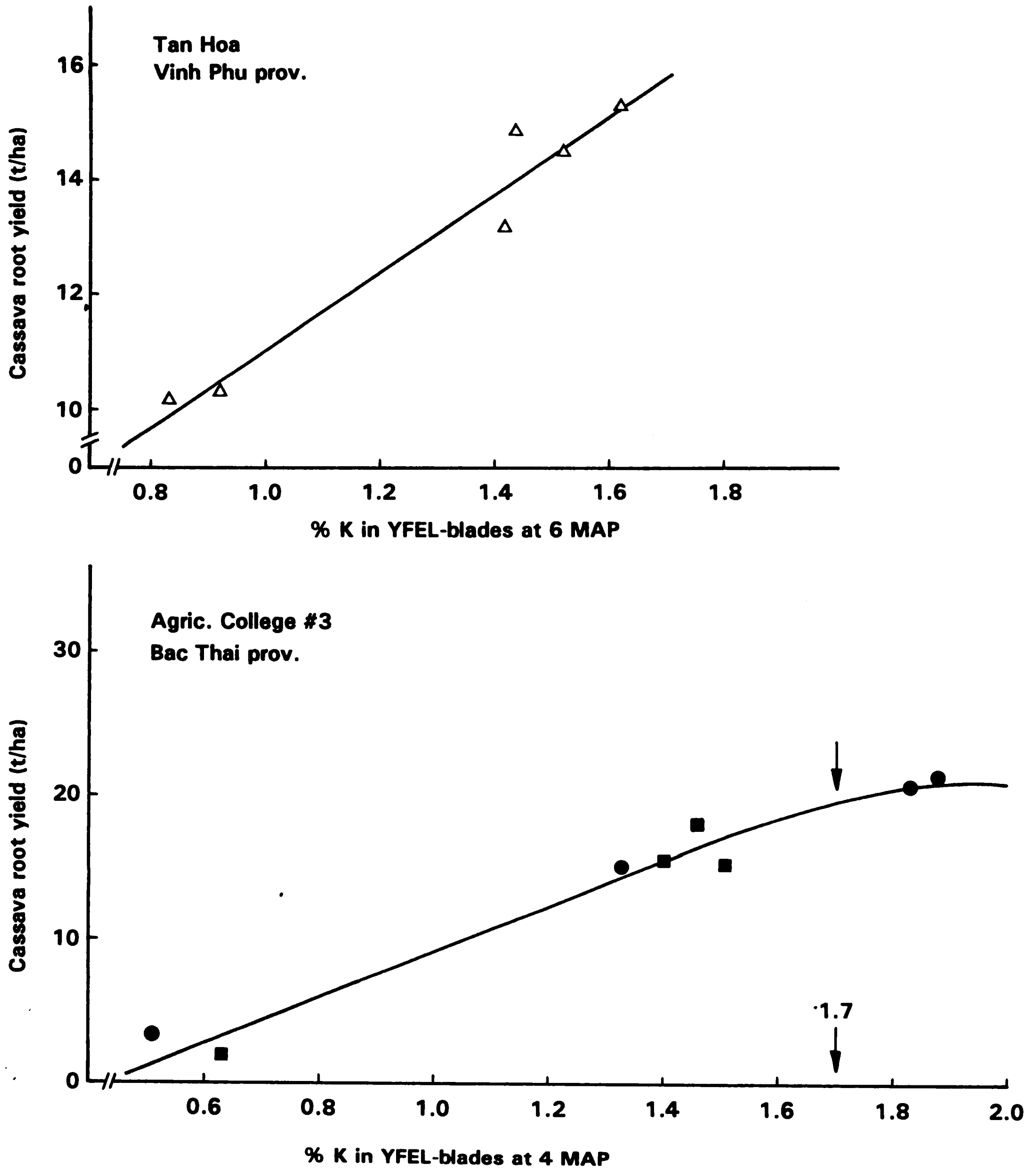


Figure 11. The relation between the relative yield of cassava and the concentration of N, P and K in the youngest fully-expanded leafblades at 3-4 months after planting in two cultivars in two long-term NPK trials conducted in China.



Figuer 12. Relation between cassava root yield and the K concentration in youngest fully-expanded leaf (YFEL) blades sampled at 6 months after planting (MAP) in Tan Hoa (top) and at 4 MAP at Agricultural College #3 in Bac Thai province of Vietnam in 1992/93. Arrow indicates the critical level corresponding to 95% of maximum yield.

***Source** : Tran Dai Ngia, Agricultural College #3, Bac Thai.*

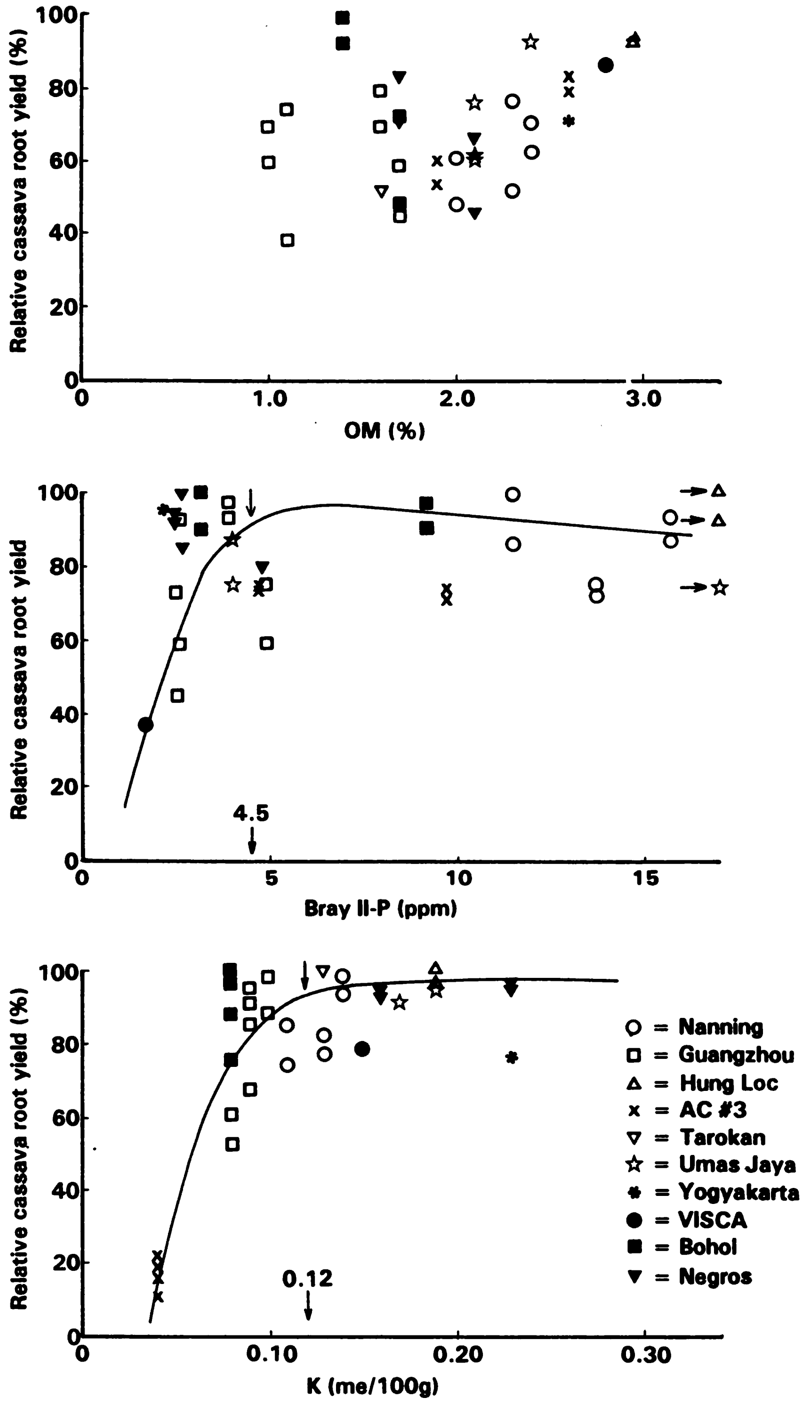


Figure 13. Relation between the relative cassava root yield, i.e. the yield of cassava without the nutrient as a percent of the highest yield with the nutrient, and the organic matter (OM), available P and exchangeable K contents of the soil in ten long-term NPK trials conducted in Asia from 1987 to 1993.

Bray II-extractable P and 0.12 me/100g (47 ppm) of exchangeable K. This compares with critical levels of 4.0 ppm P and 0.17 me K/100g determined previously in Colombia (Howeler and Cadavid, 1990), and with 0.19 me K/100g estimated from long-term fertility trial data of Kabeerathumma *et al.* (1990) in India. The very low critical level for available P indicates that in most soils in Asia (see Appendix Tables) cassava will not respond to P applications. This low critical level is due to a very effective symbiosis between cassava and native mycorrhizae in the soil, which help the plant absorb P even when the P concentration in the soil is low.

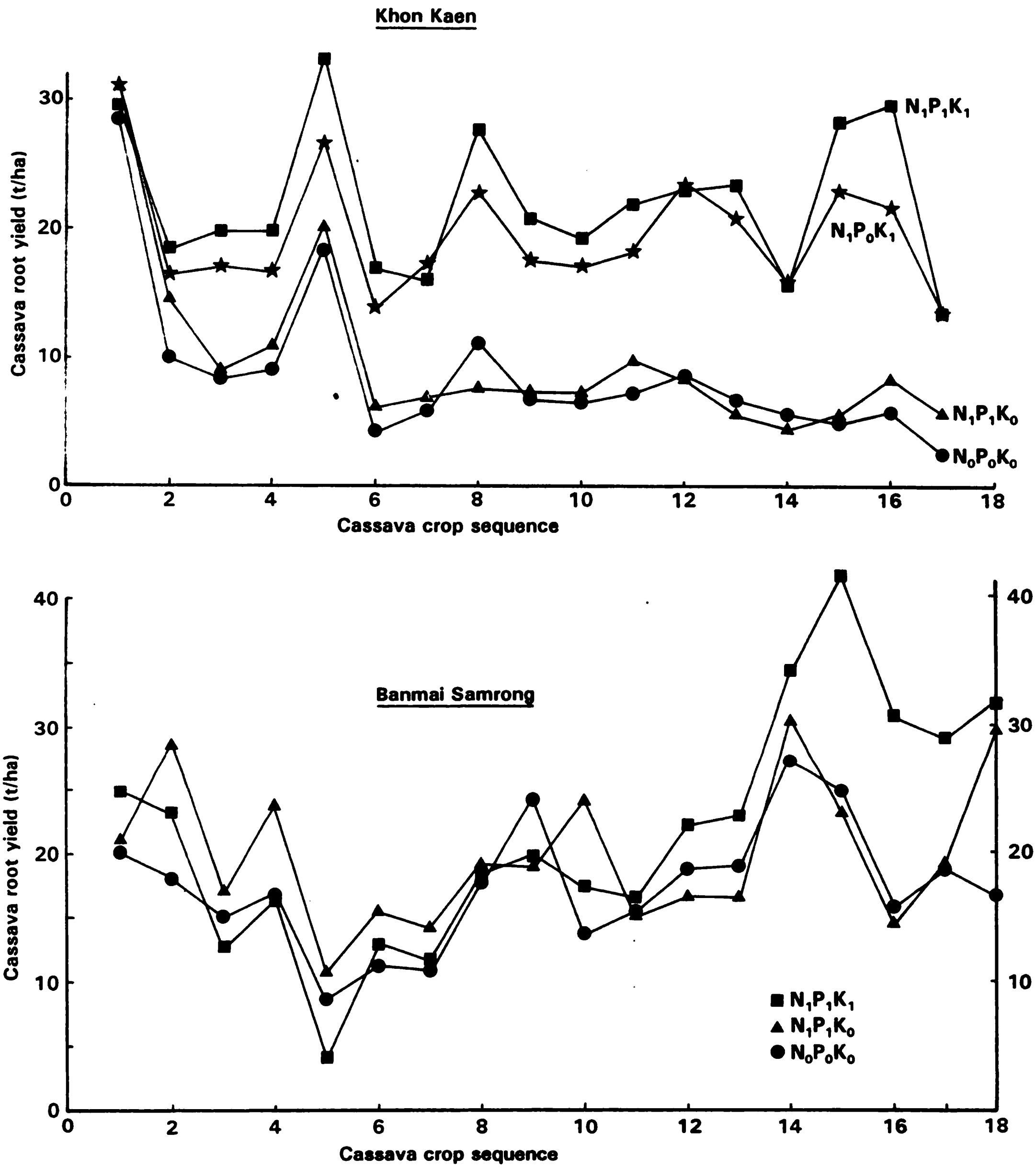
In Thailand, two long-term fertility trials in Khon Kaen and Banmai Samrong have now completed 17 and 18 years of continuous cropping, respectively **(Figure 14).** In the very infertile soils of Khon Kaen in the Northeast, the yield of check plots have fallen to 2.6 t/ha, compared with 5.9 t/ha for the NP and 13.4 t/ha for the NPK treatments. There was no response to P but a highly significant response to K. In the rather fertile soil of Banmai Samrong, however, there was a highly significant response to N, but a significant response to K was obtained only in some years. After 18 years of continuous cropping the exchangeable K content of the soil in check plots was still about 0.3 me K/100g, which is well above the critical level. This is a rather exceptional case and not typical of most cassava growing areas.

CONTROL OF SOIL EROSION

Table 6 and **Figure 15** indicate that soil losses due to erosion in Asia are much more serious than in either Africa or Latin America. This is because rainfall is rather high in Southeast Asia, while due to population pressure even rather steep slopes are intensively cultivated and forests are disappearing at increasing rates. In addition, many of the light-textured soils used for cassava production in Asia, particularly in Thailand, parts of Vietnam and in Bohol island of the Philippines, are very susceptible to erosion. Highest erosion losses in cassava trials in Asia have been measured in Hainan island of China, where intensive rainfall in early spring coincides with the stage of slow early growth of cassava, when much soil is exposed to rainfall impact. **Table 7,** which summarizes the results of many cassava erosion trials conducted in Asia and in Colombia, shows that soil losses measured in Asia tend to be much higher than in Colombia, even though slopes were generally steeper in the latter. Thus, due to a combination of high intensity rains and erodable soils, soil losses due to erosion can be a serious problem in Asia. Unless measures are taken to reduce erosion, future soil productivity will be affected.

1. Effect of Different Crops on Erosion

In Sri Racha, Thailand, erosion losses were measured in seven crops grown on 7%



Figuer 14. Effect of annual applications of N, P and K on the yield of cassava, cv·Rayong 1, grown continuously for 17 and 18 years in Khon Kaen and Banmai Samrong, Thailand. N_1, P_1 and K_1 correspond to applications of 50 kg/ha of N, P_2O_5 and K_2O, respectively.
***Source :** Chote Sittibusaya, Soils Division, DOA, Bangkok.*

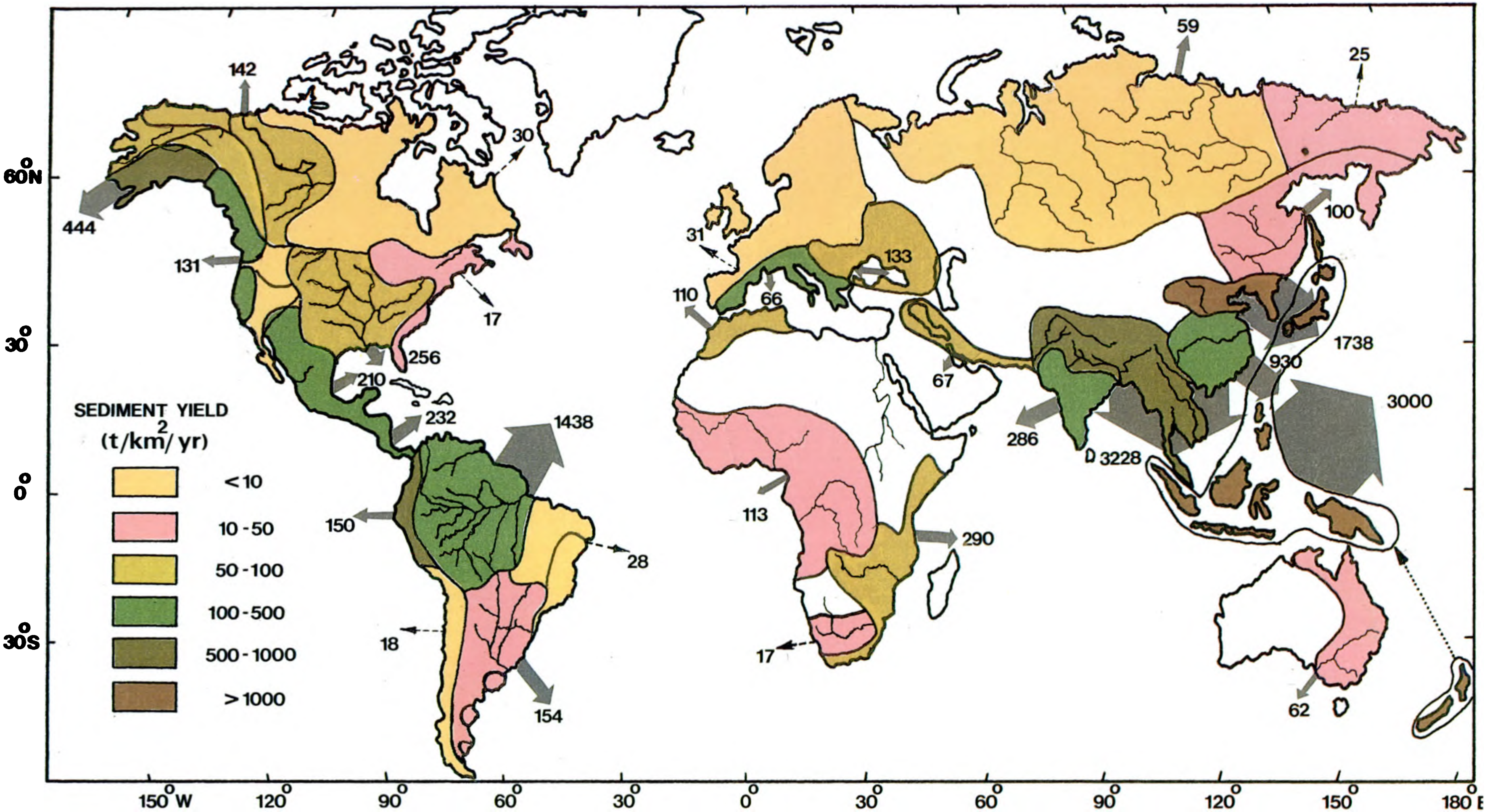


Figure 15. Annual discharge (millions of tons) of suspended sediments from various drainage basins of the world. Width of arrows correspond to relative discharge. Direction of arrows does not indicate direction of sediment movement.

Source : *Milliman and Meade, 1983.*

Table 6. Rates of erosion of the continents.

Continent	Area (10^6 km^2)	Mechanical denudation rates (metric tons/km^2/year)
Africa	29.81	47.0
Asia	44.89	166.0
Australia	7.96	32.1
Europe	9.67	43.0
North and Central America	20.44	73.0
South America	17.98	93.0

Source : Modified from suspended river sediment data, Strakhov (1967) in Chorley, 1969.

slope during nearly two years (Putthacharoen *et al.*, 1992). **Figure 16** shows that dry soil losses reached nearly 150 t/ha after two crops of cassava for root production; this compares with about 70 t/ha for cassava grown for forage production or mungbean and 30-45 t/ha for sorghum, peanut, pineapple and maize. Erosion was very high for cassava grown for root production because cassava was widely spaced at 1.0x1.0 m, resulting in slow canopy closure. In contrast, cassava plants grown for forage production were closely spaced at 0.5x0.5 m, resulting in more rapid canopy development; in addition, this crop was not replanted in the second year, but only tops were cut four times during the two-year period. Erosion losses in mungbean were more severe than in the other short-cycle crops, because mungbean produces a more open canopy, while the shorter growth cycle permitted the planting of three crops, compared with only two crops of maize, sorghum and peanut and one crop of pineapple during the two year period. Thus, under the soil and climatic conditions of Sri Racha, cassava for root production did cause more severe erosion than most other crops, mainly because the rather short rainy season permitted only one crop per year of the short-cycle crops like maize, sorghum and peanut, while after their harvest the soil remained well protected by crop residues and weeds. However, **Table 8** shows that in Lampung, Indonesia, average soil losses during three years for cassava (planted at 1.0x1.0m) were only slightly higher than for upland rice and maize, and similar to those of peanut. Intercropping cassava with upland rice and maize followed by peanut reduced soil losses to 42.7 t/ha, compared with 49.2 t/ha in cassava monoculture. Thus, it can be concluded that cassava may sometimes cause more erosion than other food crops, depending on soil and rainfall characteristics as well as on the management practices used in each crop. Management practices must be used that minimize soil erosion.

2. Effect of Cassava Cultivars on Erosion

In order to determine the effect of plant architecture on soil erosion, four cassava cultivars of distinct growth habit were grown in Pluak Daeng, Thailand, on about 5%

Table 7. Average dry soil losses due to erosion measured in cassava trials in various countries of Asia as well as in Colombia, S. America.

Country	Site	Slope (%)	Soil texture	Organic matter (%)	Dry soil loss (t/ha)
China	-Qifeng - Hainan	8	sandy clay loam	2.4	154
	-SCATC - Hainan	15	clay	1.8	128
	-SCATC - Hainan	25	clay	2.0	144
	-Nanning - Guangxi	12	clay	1.7	16
Indonesia	-Malang - E. Java	8	clay	1.5	42
	-Tamanbogo - Lampung	5	clay	1.8	47
	-Umas Jaya - Lampung	3	clay	2.7	19
Malaysia	-MARDI - Serdang	6	clay	-	10
Philippines	-Baybay - Leyte	25	clay loam	1.9	54
Thailand	-Sri Racha - Chon Buri	8	sandy loam	0.6	15
	-Sri Racha (farmer's field)	8	sandy loam	0.5	18
	-Pluak Daeng - Rayong	5	sandy loam	0.7	21
Vietnam	-Agric. Coll.#3 - Bac Thai	5	sandy clay loam	1.6	23
	-Agric. Coll.#3 - Bac Thai	10	sandy clay loam	1.6	39
	-Agric. Coll.#3 - Bac Thai	15	sandy clay loam	1.6	105
Colombia	-Mondomito - Cauca	27	clay	4.7	45
	-Mondomito - Cauca	30	clay	-	2
	-Las Pilas - Cauca	40	clay loam	11.0	3
	-Agua Blanca - Cauca	42	clay loam	5.1	18
	-Popayan - Cauca	15	loam	24.8	15
	-Popayan - Cauca	25	loam	24.8	7

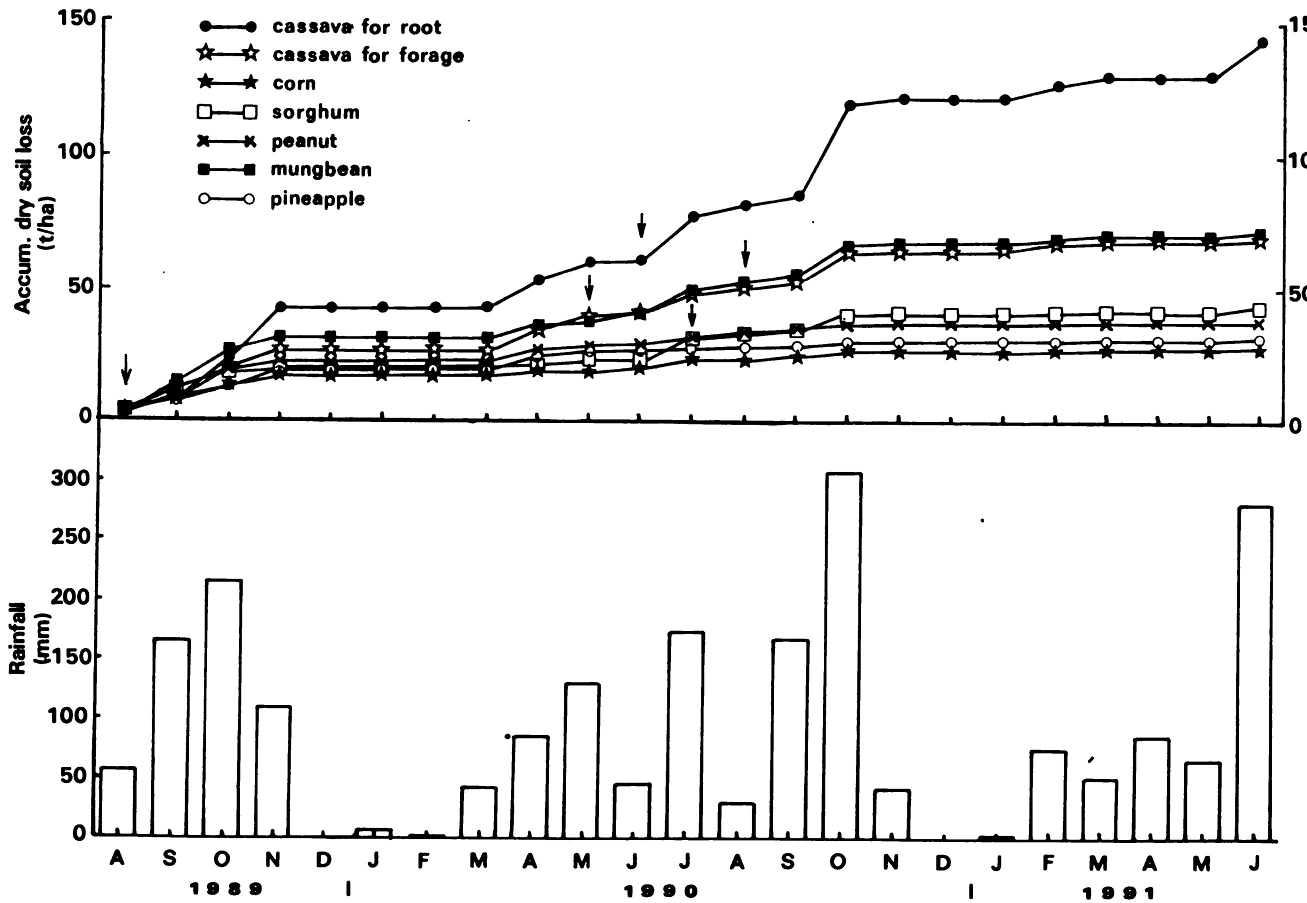


Figure 16. Accumulative dry soil losses due to erosion in various crops grown during a 22 month period on 7 % slope in Sri Racha, Chonburi, Thailand in 1989/91. Arrows indicate time of planting. Rainfall distribution is shown below.

Source : *Putthacharoen, 1993.*

Table 8. Effect of cropping systems and cassava row spacing on dry soil loss due to erosion and on total crop value on an Ultisol with 5% slope in Tamanbogo, Lampung, Indonesia. Data are average values for trials planted in 1987, 1988 and 1989

	Soil loss (t/ha)	Total crop value ('000Rp/ha)
Cassava monoculture 1.0 x 1.0 m	49.2	1386
" " 2.0 x 0.5 m	92.9	1242
" " 2.73 x 0.6 x 0.6 m	100.8	1240
Upland rice followed by cassava (1.0 x 1.0 m)	43.4[2)]	1193
Maize " " "	37.4[2)]	943
Peanut " " "	50.6[2)]	1261
Intercropped C+M+R-P (cassava 1.0 x 1.0 m)	42.7	1466
" C+M+R-P (" 2.0 x 0.5 m)	62.9	1551
" C+M+R-P (" 2.73 x 0.6 x 0.6 m)	60.1	1486

1) C = cassava, M = maize, R = upland rice , P = peanut.
2) about 90% of soil losses occured during the first crop.
Source : Wargiono, BORIF, Bogor.

slope during 1991/92 and 1992/93. Each cultivar was grown with and without fertilizers at a spacing of 0.8 x 0.8m as well as with fertilizers at a wider spacing of 1.0 x 1.0m. **Table 9** shows that in 1991/92 erosion losses were similar for Rayong 1, Rayong 3 and Rayong 90, but slightly lower for the more erect cultivar Hanatee; erosion losses were much more affected by cultural practices, such as spacing and fertilizer application, than by plant architecture. Soil losses were particularly high without fertilizer application. **Figure 17** shows that in 1992/93 soil losses were slightly lower in Rayong 3 and Hanatee than in Rayong 1 and Rayong 90. Again, soil losses were about twice as high when cassava was grown without fertilizers compared with the fertilized treatments; plant spacing had little effect on erosion with the wider spacing actually causing slightly less erosion than the closer spacing. Interestingly, closely-spaced cassava without fertil-

Table 9. Effect of plant type, plant spacing and fertilizer application on total soil losses dne to erosion on 5% slope in Pluak Daeng, Rayong, Thailand in 1991/92.

Variety	Plant type	Dry soil loss (t/ha) 1 x1 m +F	0.8 x 0.8 m +F	0.8 x 0.8 m -F	Av.
Rayong 1	erect, late branching	4.23	5.72	11.81	7.25
Rayong 3	prostrate, profuse branching	7.83	6.37	8.54	7.58
Rayong 90	prostrate, early primary branch.	4.31	4.67	12.57	7.21
Hanatee	erect, no branching	5.11	5.40	6.95	5.82
Average		5.37	5.56	9.97	

Source : Anuchit Tongglum, FCRC, Rayong.

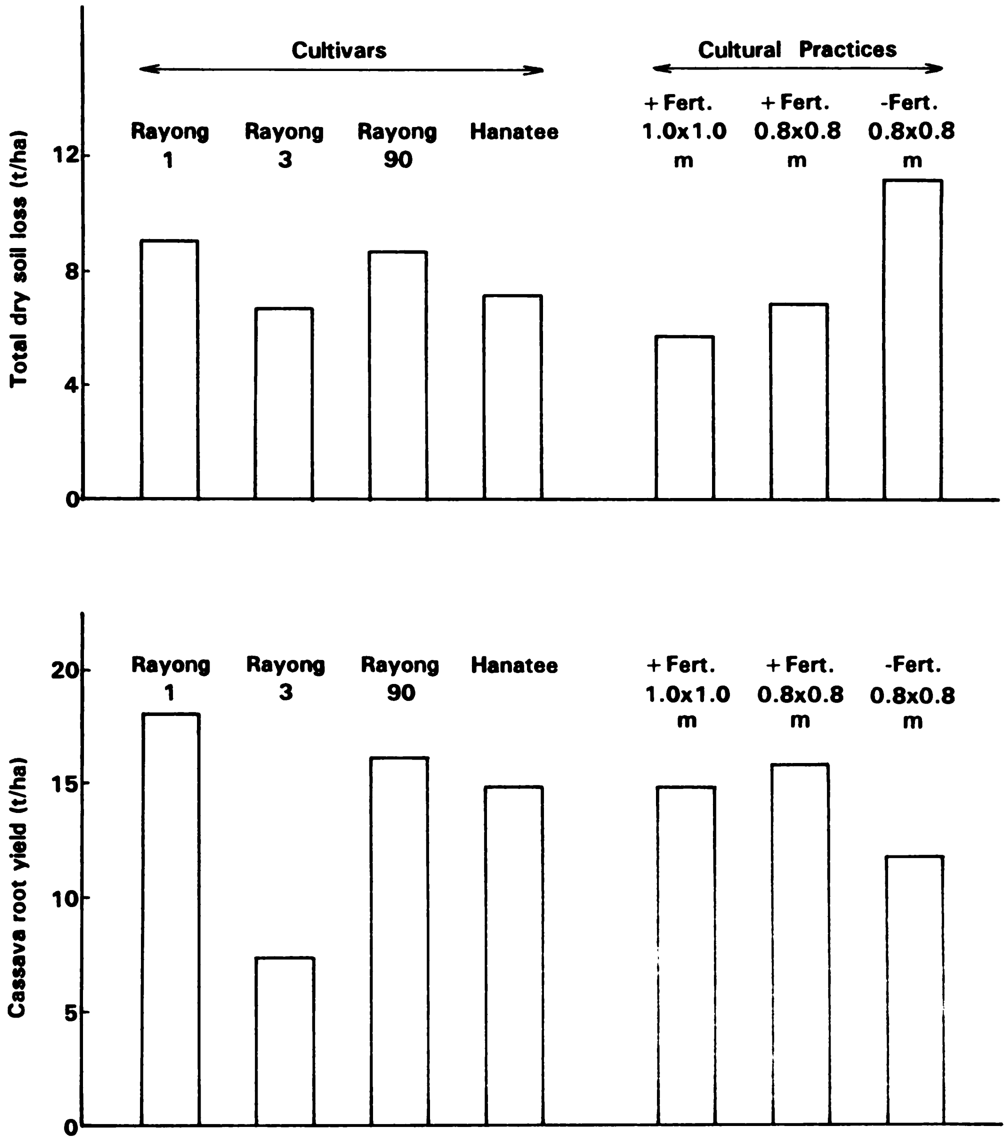


Figure 17. Soil loss due to erosion (top) and fresh cassava root yield (bottom) of four cultivars with different plant architecture and at two planting distances with or without fertilizers in Pluak Daeng, Rayong, Thailand in 1992/93. Data for cultivars are averaged over three cultural practices, and those for cultural practices are averaged over four cultivars.
***Source** : Anuchit Tongglum, FCRC, Rayong.*

izer had a similar per cent canopy cover as the wider spaced cassava with fertilizers **(Figure 18)**, but the latter caused significantly less erosion than the former. This is probably because the fertilizers do not only stimulate early crop canopy development, but they also stimulate weed growth, which in turn protects the soil from erosion. Thus, crop canopy cover is important, but is not the only factor that determines erosion. Having large leaves and good leaf retention, the more erect Hanatee tended to cause less erosion than the highly branched but less vigorous Rayong 3, especially in 1991/92. Thus, overal vigor and good leaf retention seems to be more important than branching habit in reducing soil erosion. This was also observed in Nanning, China, where a highly branched but less vigorous cultivar caused more erosion than the erect but vigorous SC201 (Tian *et al.*, 1995).

3. Effect of Cultural Practices on Erosion

Numerous trials on the effect of cultural practices on erosion have been conducted in about ten locations in six countries of Asia. **Figures 19** and **20** are typical examples of trials conducted in Pluak Daeng, Thailand and in Hainan, China, respectively. In both locations highest soil losses were observed when cassava was grown with intensive land preparation without ridging **(Figure 20)** or with up-and-down ridging **(Figure 19)**, and when no fertilizers were applied. In both locations contour ridging and zero- or minimum-tillage (one plowing only) were very effective in reducing erosion. In China, the use of *Brachiaria decumbens* or *Stylosanthes guianensis*, planted as contour barriers to reduce the flow of run-off water, were particularly effective. In Baybay, Leyte, however, the use of mulch of dry grass was consistently the most effective way to reduce erosion while increasing the yield of cassava (Evangelio *et al.*, 1995). Planting contour barriers of vetiver grass, lemon grass, or citronella grass were not so effective in Khaw Hin Soon, Thailand or in Baybay, Philippines during the first 1 or 2 years of establishment. But in subsequent years these grass barriers will probably become increasingly more effective in reducing run-off and promoting water infiltration. Thus, in Colombia, vetiver grass barriers became more effective than barriers of other grass or legume species and even more effective than contour ridging (CIAT, 1994). In Malang, Indonesia, barriers of elephant grass (*Pennisetum purpureum*) were most effective in reducing erosion while increasing cassava yields (Wargiono *et al.*, 1992). This grass tends to occupy more space than single rows of vetiver grass, but in countries where cut-and-carry grasses are used to feed livestock, elephant grass is probably preferred over vetiver grass. In Malaysia (Chan *et al.*, 1994) reported that alternating double rows of cassava with natural grass strips was most effective in reducing erosion in the 2nd year after establishment while having no significant effect on yield.

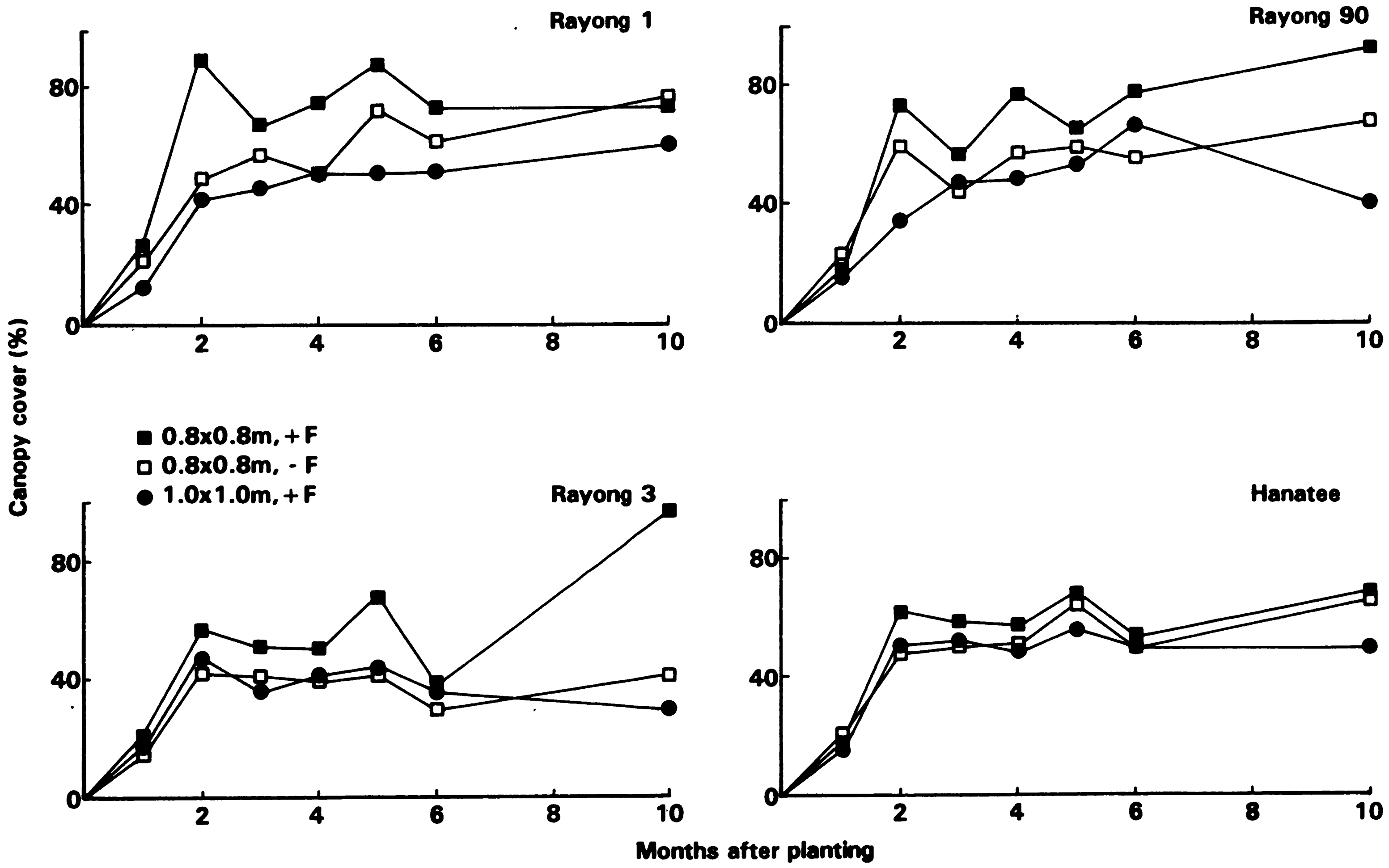


Figure 18. Rate of canopy cover of four cassava cultivars grown at two planting distances and with or without fertilizers in Pluak Daeng, Rayong, Thailand in 1992/93.

Source : *Anuchit Tongglum, FCRC, Rayong.*

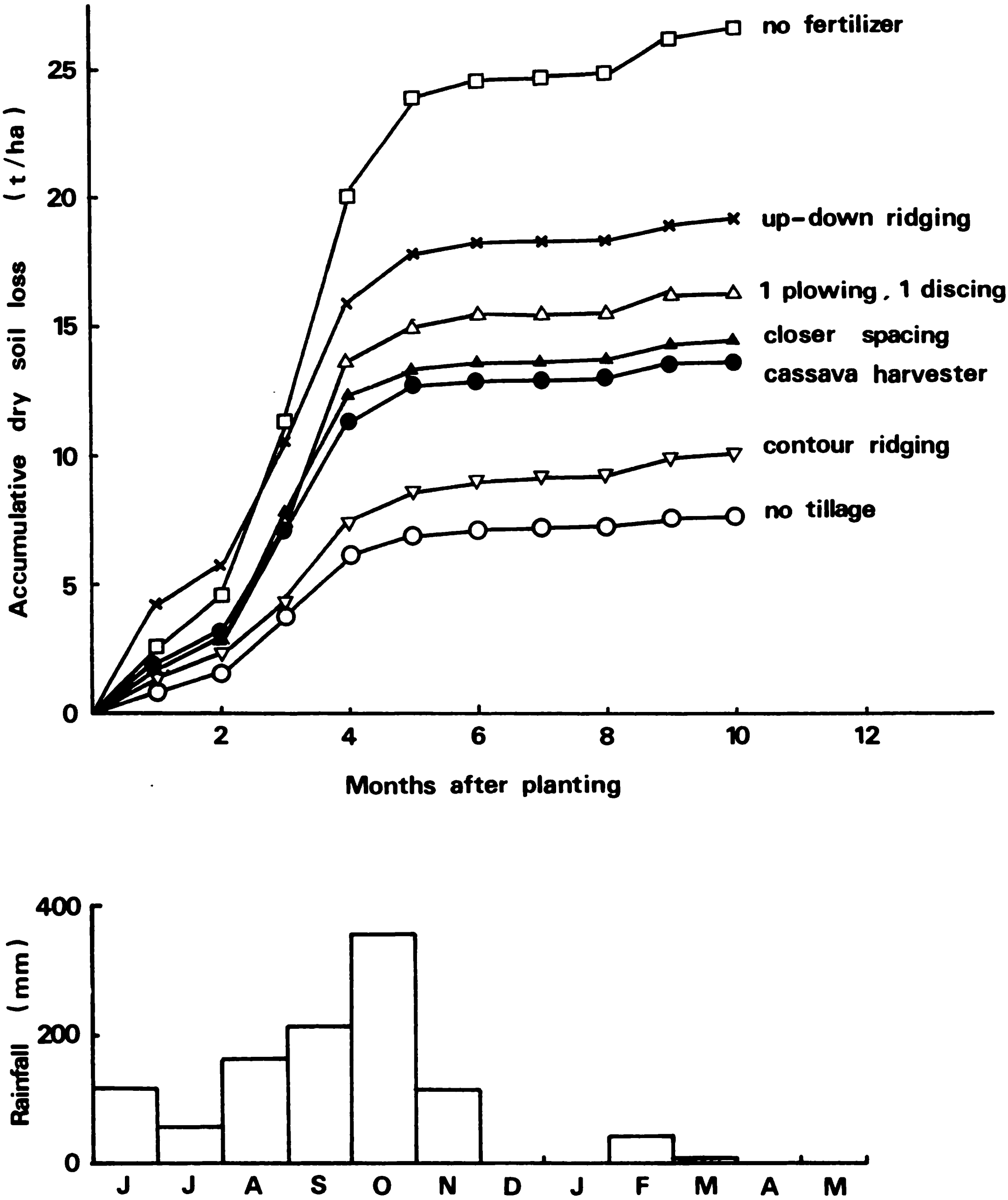


Figure 19. Effect of various crop and soil management practices on soil loss due to erosion during a 10 month cropping cycle of cassava on 4% slope in Pluak Daeng, Rayong, Thailand in 1990/91. Rainfall distribution is shown below.
Source : *Anuchit Tongglum, FCRC, Rayong.*

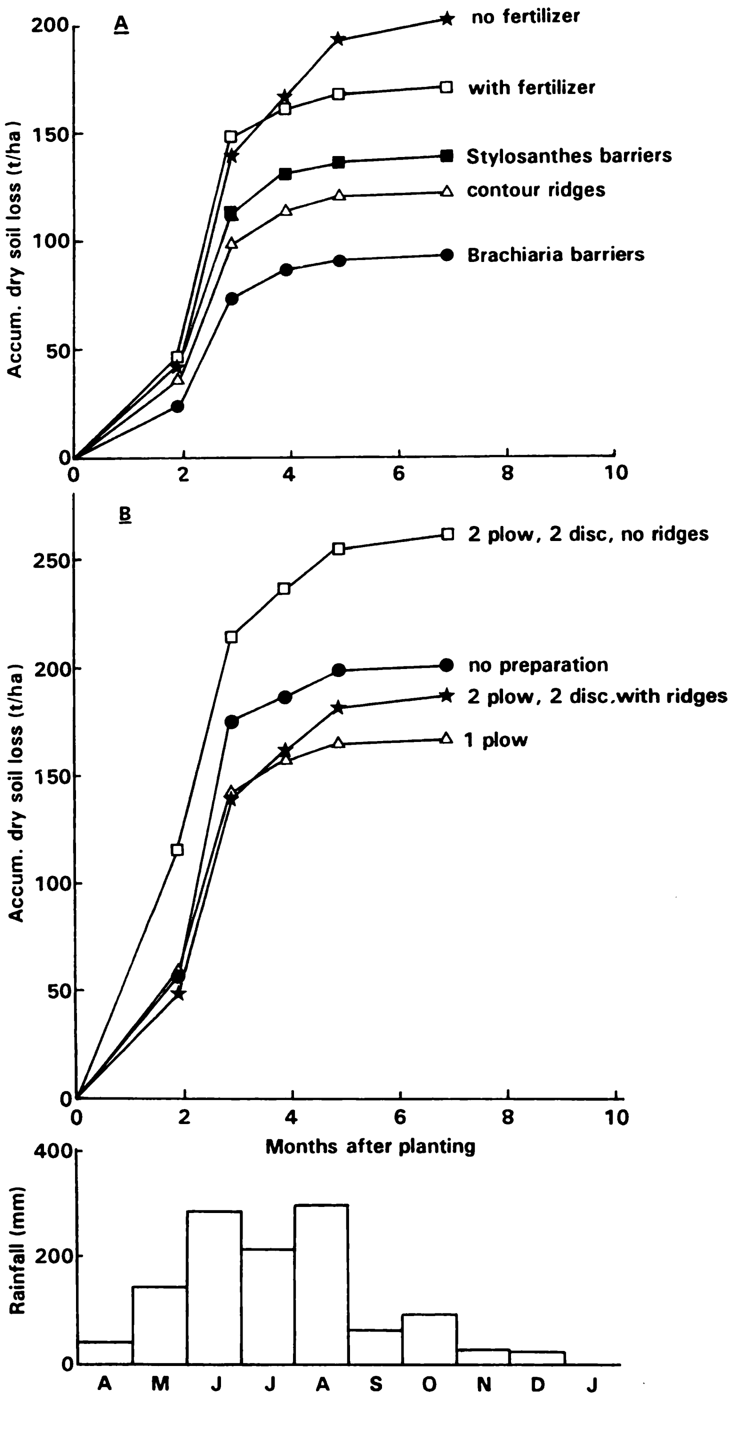


Figure 20. Effect of cultural practices (A) or land preparation methods (B) on the accumulative soil loss due to erosion when cassava, SC205, was grown on 15 and 25% slope, respectively, at SCATC, Hainan, China in 1991. Below is shown the rainfall during the growth cycle. ***Source** : Zhang Weite, SCATC, Hainan, China.*

Thus, every practice tends to produce certain benefits, while also having certain limitations. **Table 10** summarizes these benefits and limitations for various soil/crop management practices. Greatest long-term benefits are probably derived from fertilizer or manure application, intercropping and contour barriers of leguminous tree hedgerows, cut-and-carry grasses or vetiver grass. Which practice is most suitable for a particular location can best be determined by on-farm erosion control trials. To enhance the adoption of the suggested practices it is very important to involve farmers actively in these on-farm trials, so as to get their feedback about the usefulness and practicallity of the various practices. In Thailand we have initiated this process of farmer-participatory research by conducting simple erosion control trials in farmers fields in four locations of Rayong province during the past two years. **Table 11** shows the erosion losses and cassava yields during 1992/93. The recommended practice of closer spacing (0.8x0.8m), fertilizer application and contour ridging increased yields on average 25% and reduced erosion 15% compared with the "farmers' practices" in the region. In fact, many farmers in this part of the country are already using many of the recommended practices. A recent survey (OAE, 1992) in the area showed that 32% of farmers now plant cassava on contour ridges, 42% plant at a close spacing of 0.8x0.8 m and 97% of farmers apply some, although generally not enough, fertilizers. Thus, progress is being made, but a still wider adoption of these and other soil conservation practices is necessary in order to increase cassava yields while preventing the degradation of the soil resource base.

Table 10. Effect of various soil/crop management practices on erosion and yield, as well as on labor and monetary requirements and long-term benefits in cassava-based cropping systems.

	Erosion control	Terrace formation	Effect on cassava yield	Labor requirement	Monetary cost	Long-term benefits	Main limitation
Minimum or no-tillage	++	-	-	+	--	+	compaction, weeds
Mulching (carry-on)	++++	-	++	+++	+	++	mulch avail., transport cost
Mulching (in-situ production)	+++	-	++	++	+	++	compitition
Contour tillage	+++	+	+	+	+	++	
Contour ridging	+++	+	++	++	++	+	not suitable on steep slopes
Leguminous tree hedgerows	+	++	+	+++	+	+++[1]	delay in benefits
Cut-and-carry grass strips	++	++	--	+++	+	+++[1]	competition, high maintenance
Vetiver grass hedgerows	+++	+++	+	+	+	+++	
Natural grass strips	++	++	-	+	-	++	high maintenance cost
Cover cropping (live mulch)	++	-	---	+++	++	+	severe competition, high maint.
Manure or fertilizer applic.	+++	-	+++	+	+++	+++	high cost
Intercropping	++	-	-	++	++	+++	labor intensive
Closer plant spacing	++	-	+	+	+	++	

[+] = effective, positive or high
[-] = not effective, negative or low
[1] = value added in terms of animal feed, staking material or fuel wood

Table 11. Effect of plant spacing, fertilization and contour ridging on total dry soil loss due to erosion and on cassava (cv Rayong 1) root yield in four locations[1] of Rayong province, Thailand in 1992/93.

Treatments	Soil loss (t/ha)					Root yield (t/ha)				
	A	B	C	D	Av.	A	B	C	D	Av.
1 1.0x0.8m, no fertilizers	46.74	40.28	134.19	24.31	61.38	11.80	19.69	25.51	28.19	21.30
2 1.0x0.8m, with fertilizers[3]	11.90	15.02	76.55	40.30	35.94	22.37	30.50	24.30	28.00	26.29
3 1.0x0.8m, no fert., contour ridges	13.49	17.81	15.54	12.07	14.73	12.05	29.94	21.94	31.69	23.91
4 1.0x0.8m, no fertilizers	15.07	21.18	69.53	60.14	41.48	13.89	27.11	28.71	31.26	25.24
5 0.8x0.8m, with fert., contour ridges	19.85	15.82	44.85	8.56	22.27	21.05	34.04	25.61	32.11	28.21
6 Farmer's practice[2]	18.06	24.06	26.73	35.98	26.21	14.40	21.08	27.49	27.02	22.50

[1] A = Land Development Center, Pluak Daeng district, 6% slope
B = Farmer's field, Nong Rai village, Baan Khaay district, 8% slope
C = Farmer's field, Huai village, Klaeng district, 15% slope
D = Farmer's field, Huai village, Klaeng district 10% slope

[2] Farmer's practices vary slightly among locations, but generally include a planting distance of 1.0x(0.6-0.8)m, no ridging and the application of about 200 kg 15-15-15/ha in locations A and B.

[3] With fertilizer = application of 312 kg 15-15-15/ha at 1 month after planting.

Source : Anuchit Tongglum, FCRC, Rayong, Thailand.

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CASSAVA TECHNOLOGY ADOPTION: CONSTRAINTS AND OPPORTUNITIES

Guy Henry and Maria Veronica Gottret[1]

ABSTRACT

The impact of improved technological components depends to a large extent on the appropriateness of the intervention for the end-user, the efficiency of the technology transfer mechanism and the socio-economical and political conditions of the technology target area. In order to optimize impact the constraints in each of these areas of influence need to be analyzed and opportunities need to be identified to alleviate these constraints.

From a different perspective these constraints can be divided into technical, institutional, socio-economical and political limitations. Technical constraints include the appropriateness of the technology intervention. Institutional constraints include the research/extension integration, technology transfer mechanism, seed multiplication capacity, and adoption information feed-back mechanism. The socio-economic constraints include the presence and capacity of commercial seed multiplication and distribution entities and the market situation regarding possible price premiums or potential demand for additional supplies (as a consequence of the technology adoption). The political constraints may be adverse governmental policy interventions.

The results from different adoption studies are used to demonstrate the importance of appropriate technologies, institutional support, transfer mechanism, and market influence. One case study treats the adoption and impact of cassava technologies within the Integrated Cassava Project in Colombia's north coast. The other study concerns the adoption of cassava variety Rayong 3 in Thailand.

The last section of the paper identifies and discusses various opportunities that are open to research and extension institutions to alleviate adoption constraints and that subsequently can translate into higher impact.

INTRODUCTION

Current cassava world production has surpassed 150 million tonnes (FAO, 1993). The increase in world cassava acreage, over the last 5 years, has been only slight or has remained constant. Depending on the area, cassava yields have only increased marginally. During the last decade, cassava yield growth in Africa, Asia and Latin America were 1.26%, 1.01% and 0.67%, respectively (FAO, 1993). To some extent this low annual increase can be attributed to an increasing worldwide trend of cassava production

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shifting to even more marginal areas, especially in SE-Asia and Latin America. With increasing population and urbanization pressure, and further intensification of agriculture, agricultural lands have become increasingly scarce. Higher value crops, such as pineapple and rubber are substituting cassava in large areas in Thailand, south China and Vietnam. The result is that cassava is increasingly grown on soils with lower productivity potential. In addition, the oftentimes hilly or mountainous cassava areas pose an increasing danger to the sustainability of these systems in the absence of sustained input usage to maintain soil fertility and reduce erosion. These are widespread conditions that are faced by national cassava R&D activities.

As has been often noted, cassava research has been long underfunded compared to primary crops, at both the national and international level. The use of scarce cassava R&D resources that are available emphasize, to a major extent, the development of technological components to alleviate biotic and abiotic constraints and varietal improvement. As such, an increasing number of technological components have become available. However, the number of components that have actually seen a significant adoption by the users, i.e. cassava producers or processors, has only been small. The major question that arises regards the limiting factors in the cassava technology transfer process.

In this paper this question is being addressed. The objective is first to identify, and subsequently analyze the major constraints in the cassava technology transfer process. This analysis will be followed by two case studies analyzing cassava component adoption in Colombia and Thailand, respectively. These studies form the basis for discussing possible opportunities to alleviate technology transfer limitations. The paper concludes with some recommendations that can serve an action plan for national cassava R&D to optimize cassava technology transfer (TT) and hence, impact.

CASSAVA TECHNOLOGY TRANSFER LIMITATIONS

In order to identify the major cassava TT limitations, it is useful to first discuss the trajectory of technology components, from first inception to final reception by the end-user. Cassava R&D activities can be envisioned to be organized in a cassava R&D cycle, that is made up of six stages (Henry and Best, 1994). These stages are: (1) problem and opportunity identification; (2) basic knowledge generation; (3) development of technology components; (4) testing and adaptation in systems; (5) release and diffusion; and (6) adoption and impact. As such, the first three stages concern the development of appropriate technology components *per-se*, while the latter two stages for the most part involve the area of TT. The fourth stage can be visualised as a phase where all the actors, i.e. users, researchers and TT agents, come together in an integrated fashion. This stage also serves as a bridge, where the emphasis changes from technology research to technology transfer. However, these two parts are very much integrated within the cycle through feed-back mechanisms. What is relevant in our context, is that although the last two stages emphasize TT, the product of the first three stages plays a crucial role regarding the TT process.

The ultimate objective of any R&D activity is to achieve impact from a technology component adoption in a pre-defined target area or group of the population, in as short a time period as possible. The first prerequisite for a component to be adopted is, that the component must be appropriate to the final user. The appropriateness means that the component should fulfil two requisites: it fills an important need, and the component fits into the whole system of the user. This system is governed by many aspects, i.e. agronomic, social, cultural, economic, institutional, etc. Hence, the user orientation during the first four stages will have a profound effect on the degree of final adoption by that same user group.

With this in mind, constraints in the cassava TT process can be divided into basically five general areas: (1) technological; (2) biological; (3) institutional; (4) socio-economic; and (5) political constraints. Following, each of these areas will be discussed separately

1. Technological Constraints

For the major part these constraints relate to the technological component that is being transferred. This, as was mentioned already, focusses on the appropriateness of the technological component. The key issue with this respect is that a component can only be appropriate if the need and subsequent solution for it has been identified, developed and adapted with a full user perspective, or what is also called "client orientation". R&D must be user- or demand-driven, instead of what still occurs too often, which is scientist- or supply-driven.

A full user-perspective starts at the problem and opportunity identification stage in the form of a need assessment, in which major constraints of the users (cassava producer, processor, etc.) are analyzed and prioritized. There are a range of methodologies (Ashby, 1990; Merrill-Sands, 1989; Bunders, 1990; Nweke *et al.*, 1990; Henry, 1992; Fujisaka, 1991). In general, they differ in the level of intensiveness, but are similar in philosophy. The next stage of technology development must take into account that the technological component has to fit into a very specific user environment. Once alternative prototype components have been developed, they need to undergo a rigorous socio-economic evaluation or validation. The prototypes that have fulfilled all validations so far, will then be tested under user level conditions. At this stage an intensive integration between user, researcher and TT agent is of major importance. One final component may be selected by the user and/or require further modification or adaptation to be appropriate to the various needs of the user and his system. This component will then be used for further diffusion by TT agents.

As can be visualized, there is ample space for this process to break down and subsequently result in inappropriate technology that will not stand up to the rigorous requirements of the end user, and therefore fails to be adopted. Most technologies that fail to be adopted do not fill a major user need, do not fit the user system, incorporate too much risk, require scarce or expensive additional inputs, etc. (Fujisaka, 1991).

2. Biological Constraints

These constraints can be labeled endogenous limitations that are inherent to the specific biological characteristics of the cassava plant. As shown in **Table 1,** the average growing cycle of cassava is 12 months, and can vary between 8-24 months (Henry, 1991). For example, there are many regions in Colombia, Paraguay, Brazil and south China where cassava is harvested after 18-24 months. When comparing this aspect with crops such as beans, rice and maize, which have growing cycles of 3-4 months, it becomes obvious that cassava's long growing cycle represents a relative comparative disadvantage regarding multiplication.

Cassava's vegetative reproduction system has an additional constraining effect on TT. In general, the main stems of the mature cassava plant form the new planting material, called stakes. Sexual cassava seed is only being used in cassava breeding programs, and so far, has no commercial applications (Henry and Iglesias, 1992). On the average, 8-12 stakes can be cut from a mature plant. When comparing the multiplication rate (the number of hectares planted with stakes generated from an initial one hectare) of different crops as shown in **Table 1,** the differences are striking. While cassava on the average can generate planting material for just 10 ha in one year, both maize and rice have a multiplication rate of 1600, or 160 times more than cassava.

Another characteristic of cassava's vegetative reproduction system is the weight and bulkiness of the stakes. As shown in **Table 1,** to plant one hectare of cassava, one needs 1000 kg of stakes, whereas, for example in the case of maize, this amounts to only 25 kg. The practical difference is renting a small truck or horse and cart, *versus* carrying the seed home in a burlap bag.

These aspects have obvious implications for varietal diffusion. First, it will take a major effort in terms of finances, land, personnel and time to produce basic seed stock for a new variety. Secondly, in the absence of a commercial seed system, national cassava programs will carry the major responsibility of the multiplication activities. Thirdly, it will take a long time to get any significant variety diffusion. Moreover, it will take each adopting cassava farmer several years to introduce his new variety to any major extent of his cassava area. Hence, cassava's inherent low multiplication rate and physical stake characteristics have a major negative effect on varietal diffusion, or increases the time period of the intial or experimental stage of adoption, as shown by Gottret and Henry (1993).

Table 1. Production, agronomic and multiplication constraints of cassava and other crops.

Crop constraints	Cassava	Rice[1)]	Beans	Maize[2)]
Growing cycle (months)	12	4	4	4
Rate of multiplication[3)]	10	1,600	400	1,600
Weight of planting material for 1 ha (kg)	1,000	100	50	25
Commercial seed availability	none	high	medium	high
Crop yield related to seed yield	no	yes	yes	yes
Geographical concentration of producers	low	high	medium	medium

1) Irrigated rice
2) Lowland maize
3) For cassava: 1 cycle, for other crops: 2 cycles
Source : Henry, 1991.

3. Socio–economic Constraints

In the above discussion, reference has already been made to the importance of stake production in the cassava TT performance. As was shown in **Table 1**, primary crops like corn and rice enjoy well established commercial seed multiplication and distribution systems. Cassava stakes, however, in general are not commercially sold. Traditionally, cassava farmers exchange cassava stakes among each other, according to necessity. In several Asian countries like Thailand, Vietnam and China, some commercial stake multiplication and sales have occurred. However, these have largely been efforts by cassava farmers taking advantages of temporal scarcity on an *ad-hoc* basis.

The majority of cassava is grown under adverse climatological and soil conditions (El-Sharkawy, 1993). In addition, the majority of traditional cassava markets are narrow with relatively low demand elasticities (Henry and Best, 1994). These adverse sets of conditions imply, among others, a high level of both production and market risk at the farm level. Facing this scenario, the incentives for a small cassava farmer to adopt improved technologies are rather few. Hence, under these conditions, cassava technology adoption will be constrained. In addition, aspects of farm size and land tenure have long been recognized (Feder *et al.*, 1987). A further aspect for which little information exist, is the fact that in general (except in parts of Thailand, Indonesia and Malaysia), cassava areas are largely scattered within regions. Hence, there do not exist large concentrations of crop area together, as is much more the case of primary crops like rice (Henry, 1991). This implies that the speed of adoption in a given geographical zone oftentimes will be slow.

4. Institutional Constraints

It has long been recognized that institutional aspects exercise an important influence on the performance of TT in general (Feder *et al.*, 1987), and on cassava TT in particular (Henry, 1991). In the above discussions some institutional issues have already surfaced. In the following, these will be further elaborated.

First of all, the structure and organization of the basic TT system, and its links and integration with the R&D activities is of major importance. In many countries for example, the departments of extension and R&D are different institutions under the same Ministry of Agriculture. Moreover, a National Seed Service activity may be an additional separate entity, as in the case of Indonesia. This kind of organizational framework may pose difficulties in conducting an efficient and effective integration and collaboration. In certain countries one still can observe that technological components are being released to an extension service as being a final phase and product of the R&D effort. In some countries like China and Vietnam, individual research institutes and universities have developed their own extension activities. Although one may visualize a better integration of R&D and TT, at the same time there exist an immediate danger that these efforts remain very location specific, since in general, collaboration between institutes could be improved.

Secondly, many cassava R&D and TT systems lack the structure, facilities, funds and network for adequate cassava stake multiplication. This can result in an insufficient supply of stakes at the moment of official release of a new cassava variety. This, and the oftentimes inadequate publicity about a new variety, may lead to low technology adoption levels and rates.

Thirdly, national extension services, with few exceptions suffer a chronic lack of operational funds and, to a lesser extent, also manpower. In addition, extension personnel invariably will put more emphasis on primary crops and larger farms (Feder *et al.*, 1987). This will further reduce the technical attention for cassava TT and technical follow-up, especially when improved cultural practices are concerned, which demand a more intensive and higher level of technical assistance.

There are several additional aspects that could be called institutional. However, these are also highly dependant on political issues (like most institutional aspects). As such, these will be discussed in the following section.

5. Political Constraints

An issue that is fundamental for many subsequently implied constraints, is the little attention being paid by national governments to cassava R&D, relative to primary crops like rice, maize, etc. This has been the very reason to label cassava an "orphan crop". In general, national cassava R&D suffer from very limited resources, except maybe in Thailand where cassava is a primary crop, generating considerable income from pellet and starch processing and exports (Henry, 1991), or in the case of India. The limited resources available most often are directed to varietal improvement and towards alleviating biotic and abiotic cassava stresses. Only few programs include socio-economic and/or postharvest R&D activities. As such, a proper integration between cassava production, processing and market research aspects is difficult under these conditions.

The share of total cassava R&D resources for cassava TT activities is oftentimes not in line with the relative importance of the crop. Operational funds and personnel for TT activities may be limited, which results most often in sub-optimal cassava technology adoption rates and levels. Besides some SE-Asian countries, cassava TT systems are traditionally structured and show evidence of sub-optimal linkages. In addition, too little is seen of alternative TT agents, i.e. NGOs, private sector, etc., to compensate for the possible lacks in governmental TT activities.

Another constraint that could be labeled both political and/or institutional, is the absence of a cassava "lobby". In the majority of countries, there do not exist formal cassava producer or processor organizations to represent the interests of the cassava sector in dialogues with the national government. This has been partially responsible for the low level of government priorities for various cassava sectors. Moreover, the cassava sector in countries like Colombia, Brazil, Indonesia, and India, at some time or another, have significantly suffered from the negative indirect effects from governmental interventions targeted to primary crops like rice, corn and wheat. This has resulted in many cases in severe market distortions, which subsequently further increase the (market) risk faced by cassava farmers and processors. Under these risk conditions, it is very difficult for a farmer or processor to introduce additional risks by experimenting with new technologies. Hence, adverse government policies have been partially and/or indirectly instrumental for low cassava technology adoption rates in some countries.

A further political/institutional constraint is the relatively low availability of credit for small cassava producers or processors in the majority of cassava producing countries. This fact has serious implications for cassava R&D and TT. First, the inavailability of credit limits the technological options that can be recommended to components that do not require any additional capital outlay (Feder *et al.*, 1987). Moreover, even if some credit would be available, cassava farmers in the majority of areas, already face such a great production and market risk, that the additional risk of not being able to pay off a loan, oftentimes is a major deterrent.

So far, in this paper the most relevant issues that constrain cassava TT have been discussed. For most issues, generalizations were made in order to be more clear. However, besides the many limitations facing cassava TT, there exist several viable opportunities to alleviate some of these constraints. Hence, in the next two sections of this paper, data from cassava adoption case studies in Colombia and Thailand will be presented that will clearly show opportunities to improve cassava TT and subsequent adoption.

CASE 1: TECHNOLOGY ADOPTION CHARACTERISTICS IN COLOMBIA

One of the most important cassava production zones in Colombia is the Atlantic Coast. In this region cassava has traditionally been marketed for fresh, human consumption and for producing typical processed cassava products, also for human consumption. Cassava processing for industrial uses has existed only in the form of a medium-scale cassava starch factory, which processes around 75 tonnes of roots per day.

During the 1970s cassava research was primarily targeted toward generating improved production technology components. At the end of that period, it became increasingly clear that as small cassava farmers in Latin America faced considerable marketing risks (besides production risks), they were reluctant to experiment and adopt improved production technologies. At the beginning of the 1980s, it was hypothesized that increasing cassava productivity had to be based on the premise of linking the small farmer to growth markets, and hence depended on improving and stabilizing cassava markets. CIAT with its national partners then developed an integrated approach to cassava production, processing and marketing research, called Cassava Integrated Projects[1].

One of the best feasible socio-economic/technological options for diversifying cassava markets was the development of the dry cassava industry. In 1981 the Colombian government-sponsored Integrated Rural Development (DRI) Program initiated a project to develop the dry cassava industry on the Atlantic Coast, with the collaboration of various national and international institutions. Subsequently, in 1982 the first cassava drying plant, managed in the form of a small farmer cooperative, began producing dried cassava chips. Currently, more than 160 cassava drying plants (both cassava farmer coops and private plants) are operating throughout Colombia (Henry, 1991). This new industry provides dried cassava chips as a raw material in animal feed concentrates, an industry under expansion since the 1980s. Although the price paid by

[1] *For an extensive review of this approach, see Pérez-Crespo (1991).*

the drying industry is, in most cases lower than that paid by the fresh cassava market, the quality standards are lower. A floor price for cassava was established, as the price for dried chips is tied to the minimum feed grain prices regulated by the government. It was hypothesized that the access to this new market, the decrease in the market risk faced by farmers, and affiliation to cassava farmer associations, would create an incentive for adopting improved technologies and increase cassava productivity in the region.

1. Factors Influencing the Adoption of Cassava Technologies

Although a wide range of improved production components were introduced in the region during the last decade, for the purpose of this paper only two technological components are analyzed: the adoption of an improved cassava variety, Venezolana, and the use of machinery for land preparation. The logistic regression for examining the factors influencing adoption was estimated with data obtained from a survey of 544 cassava producers conducted on the Atlantic Coast of Colombia in 1991[2]. The logistic[3] model explains the decision to adopt a given technology with 16 explanatory variables, including some that have been used traditionally in this type of analysis, such as farm size, cassava area, technical assistance, credit, etc., and others including coop-membership and distance to markets, to analyze the effect of the new market as an incentive for adoption.

The results presented in **Tables 2** and **3** show how the probability of adoption by the typical farmer will change if the farmer is member of a cassava drying coop, receives technical assistance or credit, has a farm on rolling land instead of flat land, or plants cassava in a mono- rather than an inter-cropped system (probabilities calculated by changing the zero for one in each dummy variable); and the elasticities of adoption with respect to changes in the distance to fresh and dry markets, relative importance of cassava in the farm, farm size, years of formal education and experience as cassava grower, percent land owned, age, family size and family labor (continuous variables).

Access to Markets:

The effect of markets on the adoption of cassava production technology can be analyzed through its relationship to distance to fresh cassava and cassava production input markets and distance to the nearest cassava drying plant, which is a new alternative market.

Adoption of both technological components is significantly affected by distance to

[2] For a detailed account of this survey, see Henry *et al.* (1994).

[3] A more detailed treatise of the methodology and the econometric modeling can be found in Gottret *et al.* (1993).

Table 2. The effect of farm household characteristics on the probability and extent of adoption of variety Venezolana on the Atlantic Coast of Colombia.

	Extent of Adoption		
	Partial	Total	At least partial
% of farmers who adopted the technology:	32.2	45.6	77.8
	Chi-spuare for Covariates		
-2 LOG L test	74.99 (P=0.0001)	81.37 (P=0.0001)	90.61 (P=0.0001)
Score	66.29 (P=0.0001)	74.80 (P=0.0001)	87.35 (P.0.0001)
	Probability of Adoption		
Typical Farmer[2)]	0.33	0.47	0.80
Coop member	0.62 ***	0.35	0.98**
Access to technical assistance	0.37	0.41	0.78
Access to credit	0.36	0.50	0.85
Farm on rolling land	0.25	0.59 **	0.85
Monoculture	0.27 ***	0.35 ***	0.64***
	Adoption elasticity (% change in probability of adoption for a 10% increase in the factor)		
Importance of markets			
Distance to fresh market	-2.49**	0.66	-0.17
Distance to drying plant	-2.74***	-2.62***	-0.84***
Farm characteristics			
Farm size	-0.43	-0.41	-0.12
Cassava area	-0.27	0.26	0.02
Relative importance of cassava	2.19	3.63***	0.98***
Farmer characteristics			
Land tenure	-1.07	0.87	0.09
Education	-1.63*	-0.01	-0.17
Experience	3.22*	2.16	0.89*
Age	0.03	2.40	0.60
Family size	5.99***	3.30***	1.45***
Family labor	-2.57***	-3.42***	-1.00***

*** = Significance level < 0.05, ** = level 0.10-0.05, * = level 0.15-0.10

1) This probability present the aggregation of both partial and total adoption.

2) The average cassava farmer on the Atlantic Coast has the following characteristics: 50 years of age, 3 years formal education, 21 years growing cassava, owner of 69% of his land, distance to nearest fresh market 16 km, distance to nearest drying plant 43 km, farm size 11 ha, 79% of the land farmed planted to cassava, 7-member family, of whom 3 work on the farm. On the other hand, the average cassava farmer does not belong to a cassava coop (93.3%) does not recieve technical assistance (67%) or credit (57%) for planting cassava, plants cassava intercropped (62%) on flat land (58%).

Table 3. The effect of farm household characteristics on the probability and intensity of machinery adoption on the Atlantic Coast of Colombia.

	Intensity of adoption		
	Every 2-3 year (low intensity)	Every year (high intensity)	At least partial every 2-3 yr[1]
% of farmers who adopted the technology:	4.3	36.3	40.6
	Chi-square for Covariates		
-2 LOG L test	27.55 (P=0.0357)	188.32 (P=0.0001)	122.62 (P=0.0001)
Score	30.47 (P=0.0157)	108.15 (P=0.0001)	111.74 (P=0.0001)
	Probability of adoption		
Average Farmer[2]	0.02	0.31	0.33
Coop member	0.11***	0.60***	0.85***
Access to technical assistance	0.06***	0.40***	0.48***
Access to credit	0.02	0.43***	0.47***
Farm on rolling land	0.02***	0.16***	0.18***
Monoculture	0.02	0.34	0.36
	Adoption elasticity (% change in probability of adoption for a 10% increase in the factor)		
Importance of markets			
Distance to fresh market	-6.00	-3.82***	-3.70***
Distance to drying plant	-2.23	-2.72***	-2.14***
Farm characteristics			
Farm size	-1.73	-0.31	0.23
Cassava area	-9.91	2.04***	1.62*
Relative importance of cassava	-2.95	-4.93***	-4.40***
Farmer characteristics			
Land tenure	2.13	2.29*	2.20***
Education	-2.44	-0.16	-0.30
Experience	1.70	0.39	0.27
Age	2.83	-3.64	-2.61
Family size	-1.61	0.71	0.52
Family labor	2.60	0.97	0.88

*** = Significance level < 0.05, ** = level 0.10-0.05, * = level 0.15-0.10

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drying plants. A decrease in the distance to the nearest drying plant of 10% (e.g., from 43 to 38.7 km) would increase the overall probability of adoption by about 2.7% for partial and total adoption of the variety Venezolana, and by 2.1% for using machinery to prepare the land. If a new plant were constructed in a village and the distance to the nearest drying plant is reduced to 20 km (by 50%), the probability of adoption would increase from 0.33 to 0.37, and from 0.47 to 0.53 for partial and total adoption of Venezolana, respectively. On the other hand, the same decrease in distance to the nearest drying plant will increase the probability of using machinery for land preparation from 0.33 to 0.37.

The distance to the nearest urban area (market for inputs and for fresh cassava) also has an effect on the adoption of machinery every year (high intensity adoption) and the adoption of Venezolana in part of the cassava area. A 10% decrease in distance to the nearest urban area will increase the probability of partially adopting Venezolana by 2.5% and the probability of using machinery for land preparation every year by 3.8%.

Access to Government Programs:

Government programs such as technical assistance and credit have a statistically significant effect on the adoption of machinery (increasing the probability of adoption from 0.33 to 0.48 and 0.47 if the farmer has access to technical assistance and credit, respectively), but have no statistically significant effect on varietal adoption. This may imply that new technological innovations that are more complex and therefore require more intensive technical assistance and additional financial resources, are affected by access to technical assistance and credit, as is the case of machinery use for land preparation. On the other hand, improved varieties are low-cost innovations and do not generally require intensive technical assistance; therefore, their adoption is not significantly affected by access to credit or technical assistance. It is important to be cautious in drawing the conclusion that technical assistance may have no effect on the adoption of improved cassava varieties. The lack of statistical significance of technical assistance on the adoption of this particular variety may be explained by the fact that Venezolana was introduced by the farmers themselves, although it was characterized and recommended by the research and extension agencies[4].

[4] Another new improved variety (MP12) analyzed in the adoption study with the same survey data (see Henry *et al.*, 1994) showed that the probability of adopting var. MP12 increased significantly if the farmer received technical assistance and credit.

Farm and Farmer Characteristics:

Only three of the five characteristics of the farm analyzed for each of the technology components, had a statistically significant effect on the adoption of technology components, varying between the two components and between total (high intensity) and partial (low intensity) adoption. Farm topography has a statistically significant effect on adoption of machinery (the probability of using machinery decreases from 0.33 to 0.18 if the farm is located on rolling vs flat land), a logical result given the easier access of machinery to flat land. Moreover, total adoption of Venezolana is also affected by farm topography. The probability of adopting Venezolana in all the cassava area increases from 0.47 to 0.59 if the farm is located on rolling vs flat land.

On the other hand, adoption of the improved variety is more affected by the cropping system (the probability of planting Venezolana decreases from 0.80 to 0.64 if the farmer plants cassava in a monoculture vs intercropped system).

The relative importance of cassava in the farm system, measured as the share of cassava in total cropping area, has a statistically significant effect on adoption of the two components; but the direction of the impact is opposite. While the probability of adopting Venezolana is higher on farms where cassava is relatively more important (i.e., a higher percent of the area under crops), the probability of adopting machinery is higher on farms were cassava is less important.

Farm size, one of the variables most used in adoption studies to explain the adoption of technology, did not have a statistically significant effect on the adoption of the two technological components analyzed in this study. This result can be explained, to a certain extent, by the fact that larger farms dedicate a major extent of their area to cattle raising and cassava is planted only for consumption on the farm. On the other hand, cassava area, in absolute terms, has a significant effect on the adoption of machinery, but not of the variety.

Membership in cassava drying cooperatives, as measured by the magnitude and significance in the change of the probability of adoption of the two technological components analyzed, is the most important characteristic of the farmer explaining adoption. The probability of using machinery for land preparation increases from 0.33 to 0.85 and the probability of planting the variety Venezolana increases from 0.80 to 0.98 if the farmer is member of a coop. When a distinction was made between the change in the probability of adopting Venezolana in all or part of the cassava area, the results show that coop membership increases the probability of adoption of the new variety only in part of the cassava area. This finding shows that coop members have a higher probability of adopting Venezolana than non-members, but they prefer to plant it only in part of their cassava area and to have a range of varieties rather than just one.

Land tenure, defined as the percent of land owned by the farmer, has a positive effect on the probability of adoption of machinery: A 10% increase in the percentage of land owned by the farmer increases the probability of adoption of machinery by 2.2%, but has no significant effect on the probability of adopting Venezolana.

Finally, varietal adoption is affected by family size and family labor, the probability of adoption of the improved variety being higher in bigger families with a lower availability of family labor. The reasons for this need to be explored further.

The results from this case study show that introducing the demand side in the analysis of the factors affecting the adoption process is important. In the case of cassava on the Atlantic Coast of Colombia, it was found that the adoption of the two specific technologies was significantly affected by market access, as measured by the access to fresh and dried cassava markets. Moreover, the study shows the importance of the cassava utilization technology in the adoption of production technology, which in turn is affected by the variables "distance to cassava drying plant" and "cassava drying coop membership." The introduction of the cassava drying industry has had a significant effect on cassava production technology adoption, supporting the theory that farmer associations can well serve as vehicles for technology diffusion.

It is also apparent that government programs that influence the access of farmers to information and credit are of great significance in the adoption of technology, especially for technologies that require more intensive technical assistance and greater capital investment to implement the technological change.

CASE 2: RAYONG 3 ADOPTION CHARACTERISTICS IN THAILAND

After Brazil, Thailand is the most important cassava producer in the world. Thai cassava has been used predominantly for processing into chips, pellets and starches for export. Traditional cassava variety, Rayong 1, has been planted throughout Thailand and predominates because of its excellent adaptation to existing harsh soil and climatic conditions. In collaboration with CIAT scientists, Thai cassava breeders selected a CIAT-bred variety[5], CM 407-7, and named it Rayong 3 (R3). This variety has a significantly higher starch content, compared to the local variety, Rayong 1. Besides, the drying time of chips could be reduced from 3 to 2 days **(Table 4).** The subsequent cost price reduction for the cassava processors was partially transmitted as a price premium to the producers of the new variety. These advantages have been the main driving force to the initial positive response of cassava farmers to Rayong 3.

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[5] A historical treatise on the development of this variety can be found in the CIAT Annual Report, 1991.

Table 4. Comparison of traditional Rayong 1 and improved Rayong 3 cassava varieties in Thailand.

	Variety	
	Rayong 3 (new)	Rayong 1 (traditional)
Fresh root yield (t/ha)	15.5	16.3
Stem and leaf yield (t/ha)	9.2	11.7
Harvest index	0.63	0.58
Dry matter content (%)	33.2	28.8
Chip drying time (days)	2.0	3.0

1) Average of six regional farm trials, 1988/89.
2) Measurements during dry season.
Source : Henry, 1991.

After several years of testing on experiment stations and farms, R3 was released in four provinces of northeastern Thailand in 1984. The Thai Dept. of Agricultural Extension (DOAE) started the diffusion by supplying "innovative" farmers with 600 stakes each. These farmers then provided 80% of the subsequently harvested stakes to their neighbors. With the partial financial help (for additional stake multiplication) from the Cassava Development Fund (a cassava producer and processor organization), by 1990 the R3 adoption was estimated at 70-80 thousand ha (Henry, 1991). However, during this time, doubts were expressed by farmers about certain negative characteristics of R3. These included poor architecture, lesser adaptability to poor soils, and sub-optimal stake storability. Hence, an adoption study was conducted by DOAE and CIAT during 1991/92 to analyze the different factors influencing R3 adoption (Klakhaeng *et al.*, 1995).

For this study a representative sample of 778 cassava farmer households were surveyed in nine provinces of east and northeastern Thailand. **Figure 1** shows that the major reasons for R3 adoption are higher yields (46%), and better starch content/prices (34%). These arguments are much in line with *ex-ante* research assessments. It is also shown that adoption is higher on relatively larger farms and in more fertile areas. This is in line with conclusions from the comparative adoption analysis by Feder *et al.*(1987).

What, in the context of this paper, is of even more interest, are the reasons for non-adoption. As such, **Table 5** shows the relative ranking of the two top reasons for not adopting R3. The first three reasons, soil fertility, harvesting and weeding problems were to be expected. The other four reasons, however, especially No. 4, was not anticipated. The last reason, high production costs, is basically the aggregated indirect effect

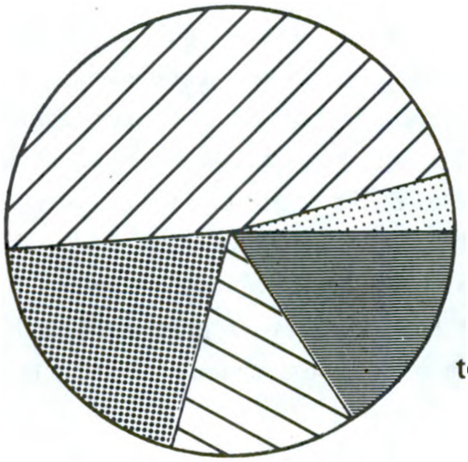

Figure 1. Farmers' reasons for adoption of Rayong 3 over Rayong 1 in nine provinces of NE and E Thailand, 1991/92.

Table 5. Relative importance of the most important reasons for non-adoption of Rayong 3.

	% of responses	Rank
Unsuitable soils	32	1
Difficult harvesting	24	2
Difficult weeding	16	3
Stake storage problems	12	4
Slow plant growth	8	5
Number of stakes available	6	6
High production costs	6	7

Source : DOAE, 1993.

from the reasons already mentioned.

Reason No. 6, the inavailability of stakes, which was mentioned by 6% of non-adopters, is surprisingly low for cassava varietal diffusion. This point can be further analyzed by looking at **Figure 2**, which shows the initial source of R3 stakes for the first planting. The majority of stakes (57%) originated from a government source (mainly DOAE and experiment stations); 21% from exchange between farmers; and 16% was bought commercially. The latter is made up for the greater part by cassava chip or starch factories, who have been actively involved in multiplying R3 planting material.

To further analyze R3 adoption, a logistic regression model[6] was used to estimate the influence of a series of factors that could possibly explain adoption. **Table 6** shows the parameter estimates of the regression. It is important to note that adoption was divided in "adopted and continued" and "adopted and abandoned", with the third being the sum of the two. This tries to capture the total initial adoption decision.

The results show that of the total adoption of 19.2%, two-thirds continued planting R3, while one-third at some time abandoned the variety again. The probability of R3

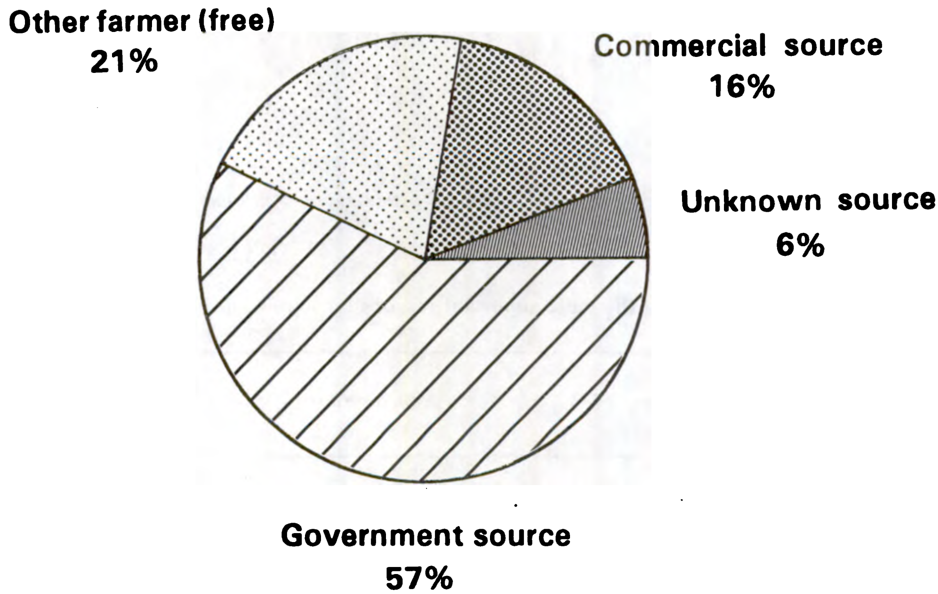

Figure 2. Source of Rayong 3 stake material in NE and E of Thailand, 1991/92..

[6] A similar analysis was used for the first case study in Colombia. For a more detailed discussion on the methodology, see Gottret *et al.* (1993).

Table 6. Influencing characteristics of Rayong 3 adoption dynamics in the NE and E of Thailand, 1991/92.

	Extent of adoption		
	Adopted and continued	Adopted and abandoned	All adopters
% of farmers:	12.9	6.3	19.2
	Probability of adoption		
Average farmer[1]	0.06	0.03	0.09
Women farmer	0.06	0.03	0.09
Women and/or children take decision to grow crop	0.08	0.03	0.12
Sell cassava root to collector	0.11**	0.04	0.15**
Starch content tested in plant	0.11***	0.06***	0.18***
Variety recommended by Agricultural Extension officer	0.07	0.02	0.08
Variety recommended by factory	0.06	0.03	0.07
Seed provided by Agricultural Extension officer	0.14***	0.08***	0.22***
Seed provided by factory	0.20**	0.27***	0.48***
Plants only cassava	0.03*	0.02	0.05
	Adoption elasticity (% change in probability of adoption for a 10% increase in the factor)		
Total family members			
Total family labor	-0.41	-0.20	-0.34
Percentage of land owned by the farmer	-0.02	-0.08	-0.05
Farm size	-0.23	-0.35	-0.24
Cassava area	0.01	0.20	0.06*
Percentage of crop area with cassava	0.21	0.13	0.21
Experience	0.96*	0.47	0.67
Cassava root prices	-0.40*	-0.95***	-0.53***
	0.78**	-0.51	0.47

*** = Significance level < 0.05, ** = level 0.10-0.05, * = level 0.15-0.10

1) The average farmer is defined as a male operator (72%), who makes the operation decisions (76%), has 11 years of experience growing cassava, heading 5-member household of whom 3 collaborate with farm activities. The farm measures 4.8 ha, of which 2.7 ha is planted with cassava, representing 67% of the area under crops. The average farmer sells cassava to the processing factory (86%), interchange varietal information with neighbors (68%), receives new planting material from neighbors (73%). The average root price received (at factory gate) is US $ 33/ton, and the starch content is not measured formally (64%).

Source: DOAE, 1993 and CIAT, 1993.

adoption and continuing by the "average" farmer[7] is 6%. The other factors in the Table show the additional probability of adoption relative to the average farmer. The highest and statistically significant probability of R3 adoption was found when stakes were provided to farmers by processing factories. This is followed by farmers who received stakes through DOAE. This is 14% and 8% higher, respectively, than the average farmer, three-quarters of whom received stakes from neighbors and/or friends. As such, TT government agents and processing factories have played the largest role in the adoption of R3.

Two other farmer characteristics that are market related are the factor of starch content being formally tested at the factory (11%) and that the farmer sells directly to the factory or to its collectors (11%). Only a formal test, most often the "specific gravity method", will be able to determine the higher dry matter content of R3, which will translate into a price premium. As such, intermediaries buying roots at the farm will, in general, not pay a price premium for R3.

What is of additional interest here is the relative difference in value between continuous adopters and adopters who later abandoned the variety. For the majority of characteristics, the absolute value for continuous adopters is higher, except for the factor "seed provided by the factory". As such, the farmers that adopted but abandoned were at first highly influenced by the opportunity of purchasing stakes at the factory. After experimenting with R3, other factors influenced the decision to abandon the variety, however, at a later stage. The other adoption characteristics in the Table do not show any statistical significance and as such are less relevant to the discussion.

Table 6 also shows results from the adoption regression model. However, the majority of the (continuous) variables included here have traditionally been used in adoption models, as concluded by Feder *et al.* (1987). Moreover, the effect of the factors (farm characteristics) is calculated as adoption elasticities. One factor that shows both a high value and significance is "cassava root price". Again, this is a market related adoption characteristic. Another characteristic of interest is "farmer experience with cassava". The statistically significant estimate shows that there exists a strong inverse correlation between experience and adoption. In other words, the longer the farmer's

[7] The "average" farmer is defined as a male operator (72%), who makes the operation decisions (76%), has 11 years of experience growing cassava, heading a 5-member household of whom 3 collaborate with farm activities. The farm measures 4.8 ha, of which 2.7 ha is planted with cassava, representing 67% of the area under crops. The "average" farmer sells cassava to the processing factory (86%), interchanges varietal information with neighbors (68%), receives new planting material from neighbors (73%). The average root price received (at factory gate) is US$ 33/ton, and the starch content is not measured formally (64%).

experience of growing cassava, i.e. the more traditional he is, the smaller the probability of R3 adoption. Moreover, this effect is even stronger pronounced in the group that later on abandoned R3. Other traditional factors, like farm size and cassava area, show a lesser significant influence.

Regarding these Thai adoption results, it can be concluded that market and price variables have had a much greater influence on cassava varietal adoption than the more traditional variables, like farm size, tenure and cassava importance. In addition, it can be pointed out that besides the DOAE, cassava processing factories have had a great impact on the adoption of R3.

CONCLUSIONS AND DISCUSSION

The first section of the paper identified and analyzed the major constraints in the cassava TT process, covering technical, biological, socio-economic, institutional and political aspects. Some of these constraints are specific to cassava, such as the low multiplication rate, high physical weight of stakes, absence of commercial stake multiplication, high levels of production and market risk faced by the cassava farmer, dispersed production areas, and low national cassava R&D funding. Other TT constraints may apply in general to many more crops, and/or are country specific, i.e. national TT structure, organization and performance, credit availability, sub-optimal R&D-TT linkages, and supply-led generation of inappropriate technology interventions. A combination of these constraints will invariably lead to low cassava technology adoption rates and levels.

The subsequent sections discussed two case studies regarding characteristics of cassava technology adoption, in Colombia and Thailand, respectively. The first study demonstrated that strengthening of the traditional cassava market by introducing the cassava drying industry, has had a significant positive effect on the adoption of cassava production technologies. This was shown through the large and significant effect of "coop membership" and "distance to markets". In addition, it can be argued that the cassava drying coops serve an additional role as effective entry points of new production technologies. As such they can be called vehicles for diffusion and are therefore alternative TT agents.

Moreover, the effective integration of production, processing and market research activities that are client oriented, together with a strong effort to link the various collaborating institutes, has been succesful in delivering appropriate high-priority technology components.

In the case of R3 adoption in Thailand, there already existed a strong market. Here again the results point out the importance of market and price (differentiation) aspects in the adoption process. Furthermore, the important and innovative role of cassava processing factories in the multiplication and distribution of planting material was demonstrated. Hence, incentives (price differentiation) and technology components (stakes), provided at the demand side, have had a major impact on the adoption of factors at the supply side. In addition, the collaboration of extension (DOAE), research, the producer/processor organization, and the processing factories has been highly effective and efficient in the diffusion of new cassava varieties. This in effect is linking national R&D with the private sector.

As has been demonstrated in this paper, cassava TT faces some major limitations that have resulted in relatively low adoption rates, compared to, for example, primary crops like rice, maize and wheat. On the other hand, cassava embodies some unique characteristics, the most important of which is the broad versatility of end-uses and markets, that offer a wide range of opportunities for both R&D and TT alternative strategies. As was pointed out by Henry and Best (1994), the majority of cassava supplies in Latin America and isolated areas of SE-Asia faces traditional, narrow, and often inelastic product markets. Under these conditions, impact from cassava R&D is only feasible if an integrated R&D-TT approach is implemented that effectively integrates cassava production, processing and market research efforts. The first step in this approach emphasizes the development of diversified cassava products and markets, through processing and market technologies. The positive effect of broader and more stable markets will create a "pull" at the farm level for improved cassava production technologies, as was shown in the case of Colombia.

If cassava market conditions are less adverse, and there exist a strong processing industry, like in several countries of SE-Asia, strong linkages need to be created between research, extension and private sector processors, in order to (a) develop appropriate high priority components through client-oriented R&D, (b) identify and optimally utilize alternative TT agents, as was shown for the case of Thailand.

While it is rather difficult, especially in the short run, to attempt to alleviate political and institutional TT constraints, there are several feasible opportunities for national cassava R&D programs to optimize the cassava TT process. It is important to identify and analyze these for each country and region with cassava importance, in order to suggest and implement alternative TT strategies that can maximize adoption in order to generate the much needed impact on the ultimate target user audience, which are the small and resource-poor cassava farmers and processors.

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THE CASSAVA BIOTECHNOLOGY NETWORK (CBN) AND CASSAVA BIOTECHNOLOGY RESEARCH

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ABSTRACT

The Cassava Biotechnology Network (CBN) was formed in response to the need for a forum to discuss cassava biotechnology issues and to foster cassava biotechnology research on priority subjects. In CBN, the experience and efforts of many different organizations and countries are pulled together to collaborate in research and to share techniques, results, genetic materials, and training opportunities. Through broad-ranging dialogue across disciplines, CBN has defined a set of cassava biotechnology research priorities.

The objectives of the Cassava Biotechnology Network are to promote integration of end-user priorities in cassava biotechnology research planning, to stimulate cassava biotechnology research on topics of established priorities, and to foster free exchange of information on cassava biotechnology research, including techniques, results, and materials. CBN organizes biennial scientific meetings and publishes scientific proceedings, a semiannual newsletter, and other material. Within CBN, informal working groups have formed around several of the priority cassava biotechnology research themes or areas, according to the technical demands of each theme and the comparative advantages of various laboratories. CBN supports these working groups through facilitating contact and encouraging meetings as necessary to clarify progress and coordinate planning.

THE CASSAVA CROP AND BIOTECHNOLOGY

Members of the Asian Cassava Researchers Network and participants in the International Symposium on Tropical Tuber Crops are well aware of the importance of cassava. Its starchy roots produce more calories per unit of land than any other crop, except sugarcane, and the production superiority of cassava over other crops is particularly important on acid soils and in other environments that are not productive for rice cultivation. Cassava can play two roles in tropical agriculture: in many countries it is a reliable crop for food security and it provides a raw material for economic development of areas that might otherwise be poor in resources. The Cassava Biotechnology Network (CBN) is one of the products of CIAT's response to the situation of a decade ago, when the importance of cassava was seldom mentioned internationally and was not well known outside the tropics. Powerful biotechnological tools for agricultural research were developing rapidly, but chiefly in countries where cassava was not grown.

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Consequently, little was being done to apply these new tools to cassava. Yet, biotechnology is an important tool for enhancing cassava as a traditional staple and for developing new forms of utilization to satisfy diversified markets.

CBN was founded in 1988 to provide a forum for cassava biotechnology issues and to foster cassava biotechnology research on priority subjects. Since then, many cassava biotechnology research projects have been organized and funded **(Table 1).**

Table 1. Cassava biotechnology research projects, partial listing, 1993.

Research Area	No. of projects	Countries & International Centers
Tissue culture, micropropagation	Many	Barbados, Brazil, Cameroon, Cuba, China, Indonesia, Nigeria, Panama, Peru, Samoa, Venezuela, Zaire, and others; CIAT, IITA
Regeneration	9	China, France, Netherlands, UK, USA, Zimbabwe; CIAT, IITA
Transformation	7	Canada, Brazil, UK, USA; CIAT, IITA
Molecular map, markers, fingerprinting	6	France, UK, USA; CIAT, IITA
Virus resistance	3	Netherlands, USA, Zimbabwe
Cyanogenesis	7	Denmark, Netherlands, Thailand, USA; CIAT, IITA
Photosynthesis	2	Australia, USA
Cryopreservation	2	France; CIAT
Processing	Many	Argentina, Brazil, CIAT, Colombia, Congo, France, Ghana, India, Nigeria, South Africa, Tanzania, UK, and others

Objectives of the CBN include:

1. Identification of priorities for cassava biotechnology research
2. Stimulation of complementary, collaborative biotechnology research on topics of established priority, through
   a. education of the research and donor communities concerning the importance of cassava and the role of biotechnology in cassava research and development
   b. provision of opportunities for researchers to meet and communicate
3. Fostering of free exchange of information on cassava biotechnology research, including techniques, results, and materials

SETTING RESEARCH GOALS FOR CASSAVA BIOTECHNOLOGY

Biotechnology requires a large investment and is often long-term; consequently, careful priority setting for biotechnology is crucial. As with all agricultural research, the goal in cassava biotechnology is to generate appropriate, efficient and effective technology that can be adopted by as large a number of users as possible. In the case of cassava, the target group is the small-scale farmer and/or processor as well as urban consumers.

The first step in biotechnology research for cassava is the same as for all cassava research and development: to identify limitations to cassava production and utilization among the target groups who depend on the crop for food security, and to visualize new opportunities for cassava that could increase rural incomes or improve the availability of low cost, good quality food for urban areas.

The second step is to identify, among these research needs, those for which biotechnology can offer a relative advantage over other possible approaches. In this step, the biotechnology component of the research strategy must be integrated with other disciplines such as plant breeding, agronomy, food science, economics, sociology, and others, in order to develop appropriate and practical innovations.

Several meetings (IITA, 1989; CIAT, 1988; Amsterdam (DGIS), 1990; Cartagena, 1992; CIAT, 1992) and studies (Panman *et al.*, 1989; Henry, 1991) have used this approach to setting priorities and strategies for cassava biotechnology research. Participants in the process have been a broad group. Because the cassava research community is (still) relatively small, it is likely that at one point or another, and through various direct or indirect channels, most of the world's cassava researchers have contributed. Current CBN research priorities reflect the results of this process.

Table 2 shows one step in the process. It lists some key constraints to cassava productivity and use which could be addressed using biotechnology, such as viral diseases and insect pests and cassava quality constraints. The importance of each is indicated by world region. The Table also attempts to show how cassava production and/or marketing would be influenced by the potential biotechnology innovations.

The priorities in **Table 3** are divided into biotechnology applications and biotechnology tools. The applications are the ultimate goals and products of cassava biotechnology research. These applications include cassava quality and new products, production efficiency, integrated pest management, optimum management of cassava cyanogenesis, and others.

Since yield reductions from a range of viral diseases and insect pests can be as high as 70-80%, especially in Africa and Latin America, a biotechnological solution to these constraints would result in a very high increase in cassava yields, but with low direct advantage for the crop in the market. On the other hand, the relative impact of biotechnological innovations on cassava quality would be only slight in terms of yield increase, but would provide a large market advantage to cassava products. Other technologies will impact only on the marketing side of cassava. Current CBN research priorities **(Table 3)** reflect the results of this process.

Table 2. Relative importance of cassava constraints and opportunities for which biotechnology may have a relative research advantage, by region, and anticipated impact of biotechnological innovations on small-scale farmers and market value of cassava.

Biotechnology research topics	Importance by region			Impact of innovations	
	Africa	Latin America	Asia	Yield increase	Market advantage
Viral diseases	+++	+++	+	+++	+
Insect pests	+++	+++	+	+++	+
Cyanide toxicity	+++	+	++	0	++
Starch quality	++	++	+++	0	+++
Postharvest root deterioration	++	+++	+++	0	+++

+++ = high;
++ = medium;
+ = low;
0 = no change.
Source: Roca *et al.*, 1992.

The priorities in **Table 3** are divided into biotechnology applications and biotechnology tools. The applications are the ultimate goals and products of cassava biotechnology research. These applications include cassava quality and new products, production efficiency, integrated pest management, optimum management of cassava cyanogenesis, and others.

Biotechnology tools are listed second, as means to the ends, though in practice, development of the tools must precede all other cassava biotechnology research. Biotechnological tools for cassava include crop genome characterization and a molecular map of cassava, genetic transformation and regeneration of transformed plants, and useful genes and gene promoters ready for use when transformation protocols are ready. A second set of tools includes those related to germplasm conservation and use.

Priority setting for cassava biotechnology, as for all research, is a dynamic and continual process. This CBN list will be updated at two-year intervals as science advances, as economic situations change, and as new voices enter the process of setting research agendas. For example, perspectives of cassava farmers, processors, and consumers will be incorporated more directly in future cycles.

Table 3. Cassava biotechnology research priorities.

Biotechnology applications: For realizing cassava opportunities
Starch quantity and quality for diverse end uses
Other processes for innovative and improved products
Plant nutrient cycling efficiency
Productivity in suboptimal agroecological zones
(photosynthesis under stress, mycorrhizal interactions, bio-fertilizers)
Biotechnology applications: For solving cassava problems
Integrated pest management
Cyanogen biochemistry for optimal cassava production and use
Processing for enhanced cyanogen reduction
Waste management
Delayed postharvest deterioration
Development of true seed for cassava production
Biotechnological tools: For genetically improving cassava
Characterization of *Manihot* genomes
Molecular map of cassava
Cloning of useful genes and gene promoters
Regeneration and genetic transformation
Regulation of reproductive biology
Biotechnological tools: For conserving and exchanging Manihot genetic diversity
Diagnostic methods for clean germplasm transfer
Cryopreservation for long-term conservation
Tissue culture for conservation and micropropagation
Setting priorities for cassava biotechnology research
Socioeconomic studies:
Perspectives of small-scale farmers and processors
Data on cassava problems and opportunities
Interdisciplinary studies to clarify complex cassava issues:
Cyanogenesis
Postharvest deterioration of cassava
True seed instead of vegetative propagation.

CURRENT RESEARCH AND PROGRESS IN CASSAVA BIOTECHNOLOGY

Some work in cassava biotechnology, particularly in tissue culture and *in-vitro* conservation, had been started at CIAT as early as 1978. However, cassava biotechnology research began in earnest in 1988, when CBN was founded.

As was evident at the first International Scientific Meeting of the CBN, greatest progress to date has been in the development of biotechnology tools for cassava. Development of these tools has been emphasized as they are necessary before many biotechnology applications can proceed.

Biotechnology tools that are most advanced are those for conservation and use of genetic diversity of cassava and wild *Manihot* species. Micro-propagation and *in-vitro* conservation of cassava is in use in many countries, including Barbados, Brazil, Cameroon, China, Cuba, Indonesia, Nigeria, Panama, Peru, Samoa, Venezuela, Zaire, and others. Molecular markers are in use to identify duplicates in germplasm collections. Cryopreservation methods for low-cost, secure conservation of cassava genetic diversity have been developed at CIAT and ORSTOM and are now ready for long-term testing.

In the area of *Manihot* genome research, studies have shown that there is chromosomal compatibility among species, while molecular polymorphisms exists within and between species. Preliminary molecular phylogeny research indicates that northwestern South America may be a center of origin of cassava and that a close wild relative may be *M. aesculifolia*. These studies are now being extended to include the important Brazilian center of *Manihot* diversity.

A molecular map of cassava for gene tagging and efficient breeding is under construction, via collaborative interchange agreements. Genomic libraries and a mapping population have been generated and a framework map initiated. For speed, several types of molecular markers are being used in the initial mapping work: RFLPs obtained via total genomic DNA and cDNA (which contains only transcribed sequences), and RAPD primers. The framework map and the mapping population will be made available to cassava breeding programs and other researchers for completion and use.

Progress toward genetic transformation of cassava has been substantial. To date, regeneration has been achieved through somatic embryogenesis in a wide range of genotypes. The bottleneck has been regeneration of uniformly transformed plantlets from single transformed cells. No regeneration from callus or protoplasts has yet been reported. Embryo suspension culture studies are promising at this time, and the possibility of other single-cell based regeneration systems should be investigated.

Transformation of cassava cells has, however, been proven, and chimeric somatic embryos are regularly obtained. If funding for current cassava transformation research is maintained, transgenic plants are expected within a reasonable time frame.

Virus resistance through genetic transformation using the viral coat protein method has been shown to be highly effective against cassava common mosaic virus (CCMV) in test systems using *Nicotiana benthamii*, a tobacco species which is susceptible to cassava viruses. Effectiveness against African cassava mosaic virus (ACMV) in test systems is still being sought. Both coat protein genes will be tested in cassava itself when transformation is available.

In the important area of cassava quality, significant progress has been made in understanding the biochemistry of cassava cyanogenesis. The gene has been cloned for linamarase, a key enzyme in the cyanogenesis pathway. New methods for determination of cyanogen content have been developed that are quicker, less expensive, and less toxic than former methods. Understanding of the implications of cyanogens for cassava production and use, crucial for cassava biotechnology research, has increased. There is now more information on the types of crisis circumstances likely to lead to cyanogen toxicity, and evidence for a possible association of cyanogenic glucosides with preferred cassava quality and with insect resistance.

A multidisciplinary proposal has been developed to address the production/marketing constraint of rapid post-harvest deterioration of cassava roots, a problem that four years ago was not sufficiently understood to be considered ready for a project. The project will integrate biotechnology and crop improvement via recent advances in molecular genetics.

CASSAVA BIOTECHNOLOGY RESEARCH IN ASIA: CURRENT RESEARCH AND POTENTIAL RESEARCH AREAS

What follows are a few examples of on-going work in cassava biotechnology in Asia, and suggested priority areas for new research, either specific to Asia or for which Asian scientists may have a regional advantage. The discussion is not presented as complete; indeed, a chief objective of CBN's participation in the present meeting is to strengthen the Network's contacts with cassava research in Asia and to learn more about cassava biotechnology, and biotechnology research capacity in Asia.

Biotechnology Tools for Cassava Research and Development

Regeneration.

Currently, at least two Asian laboratories, including the South China Institute of Botany and the Indonesian Institute of Sciences/CRIFC, are involved in the critical research on developing improved regeneration methods for cassava, a necessary requirement for a robust genetic transformation protocol.

Genome mapping, meiosis, and reproductive biology.

Areas where Asian researchers have an advantage and which could be important for cassava biotechnology are cytogenetics and cytology. For example, the linkage groups identified by cassava molecular mapping projects will eventually need to be located to chromosomes using triploid (or monoploid) genetic stocks. Such stocks are products of cytogenetic research and which do not presently exist for cassava.

Chromosome pairing in hybrids of cassava with wild *Manihot* species needs to be described in order to identify combinations with the best likelihood of genetic recombination. Reproductive biology of cassava, including pollen and seed biology and longevity, and the search for apomixis, is an almost unknown area requiring careful cytological research.

Biotechnology Applications for Cassava

As progress is made in the development of tools for cassava biotechnology, these tools can be applied toward solving problems and creating opportunities. Because applications of biotechnology to cassava are just beginning, there is great scope for work and creativity and more research is needed.

New processes and products.

At present, overall regional cassava production in Asia far exceeds total regional demand, with a high percentage of the total crop going for export. Cassava farmers and cassava-producing countries would benefit from increased regional and national research applying biotechnology toward opening new markets for cassava, via improved starch quality, improved processing methods, and other aspects of new product development. There is already significant research in this area at CTCRI in India, TISTR and Kasetsart University in Thailand, and others. An international collaborative project involving Mahidol University in Thailand is studying the biochemistry of cassava cyanogenesis.

Plant–environment interactions.

An area in which there is little research anywhere in the world is the application of biotechnology toward enhancement of plant-environment interactions of cassava, including nutrient cycling and tolerance to abiotic stresses. This is in part because little background research has been done on cassava crop ecology or plant physiology. A number of Asian institutions are doing such work, however, and their biotechnologist colleagues should encourage and follow this field-oriented work. Interdisciplinary groups of biotechnologists, physiologists, agronomists, and others may be able to identify specific intervention points where biotechnology could contribute to improving the productivity of cassava in unfavorable environments. This would enhance food security in areas where cassava has that role, and could permit sustainable production increases and reduced costs, thereby maintaining or enhancing cassava's competitivity and the opportunity for entering new markets.

OUTLOOK FOR CASSAVA BIOTECHNOLOGY

Experiences with other crops suggest that a genetic transformation protocol for cassava is not far off. The framework map to be used for gene tagging and locating major genes is expected to be completed in 1994.

The next phase of cassava biotechnology research will include identification and cloning of useful genes for applications such as starch quality; mapping for quantitative trait *loci*; and biochemical manipulations and novel processes for new products and waste management. Wise national regulations for environmental release of transformed plants, including cassava, will become critical to further progress.

Still somewhat far off may be biotechnological applications for understanding and manipulation of cassava physiology and plant/environment interactions, such as photosynthesis and soil nutrient cycling.

Also important in the future direction of cassava biotechnology will be continued socio-economic studies, which provide knowledge of the perspectives of small-scale cassava farmers and processors and of cassava problems and opportunities, and attention to world trade and economics.

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CONCLUDING REMARKS TO THE 4TH ASIAN CASSAVA RESEARCH WORKSHOP

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A great deal of progress, even socio-economic effects, were reported and significant learning took place during the Workshop. A great improvement was also noticeable in the quality of reporting and presentation of individual papers. Mutual understanding about the work and personalities of participants were much enhanced.

From all these it became clear, that while the era of cassava area expansion has ended, the production has to be sustained or slightly increased with higher production efficiency and slightly higher inputs. The goal of research should be to improve the people's living standard rather than the crop. Cassava for fresh human consumption has decreased in importance or is decreasing, while cassava for industrial processing is increasing. Two big issues for cassava's future are soil conservation and alternative markets.

In varietal improvement, yielding capacity and adaptation breeding is well in progress in many national programs and the efficient use of advanced germplasm provided by CIAT has been crucial in many instances. Further upgrading in yielding ability and further fine-tuning in adaptation are forthcoming. With this background, many national programs are passing to the stage of varietal release and dissemination. Overall, varietal development and dissemination channels are being well established.

In cultural management, many technical alternatives are now available for improved soil management. Which, or which combination of them, is implementable is yet to be defined through on-farm and farmer participatory research, which can be carried out only with more focus and concentration, strategically and geographically. A new network of agronomy research involving national research and extension programs as well as farmers would be necessary.

In the wake of an expected reduction in demand for cassava products in Europe, the need for developing new cassava uses and new marketing opportunities is imminent. More price competitiveness of cassava products is required for both international and domestic markets.

Different technology transfer methods are needed for varietal diffusion, soil management and utilization technologies. Different national program situations require different technology transfer schemes. Specific technology transfer methodologies have to be developed, particularly in the area of soil and crop management.

Thus, there are still a large number of problems to be solved; yet, we are giving answers to at least some of them. We hope we can come up with more solutions to these next time we meet at the 5th Workshop to be held in China. Finally, we would like to greatly thank our host and the Workshop Organizing Committee for the very successful organization of this Workshop.

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APPENDIX

Results of Soil Analyses in Asia

R.H. Howeler[1)]

The following tables present the analysis results of soil samples taken in various countries in Asia, mainly in soil fertility maintenance experiments. To facilitate interpretation of the results, Table 1 indicates the approximate classification of soil chemical characteristics according to the nutritional requirements of cassava.

Table 1. Approximate classification of soil chemical characteristics according to the nutritional requirements of cassava.

Soil parameter[1)]	Very low	Low	Medium	High	Very high
pH	<3.5	3.5 - 4.5	4.5 - 7	7 - 8	>8
Org. matter (%)	<1.0	1.0 - 2.0	2.0 - 4.0	>4.0	
Al-saturation (%)			<75	75 - 85	>85
Salinity (mmhos/cm)			<0.5	0.5 - 1.0	>1.0
Na-saturation (%)			<2	2 - 10	>10
P (μg/g)	<2	2 - 4	4 - 15	>15	
K (me/100g)	<0.10	0.10 - 0.15	0.15 - 0.25	>0.25	
Ca (me/100g)	<0.25	0.25 - 1.0	1.0 - 5.0	>5.0	
Mg (me/100g)	<0.2	0.2 - 0.4	0.4 - 1.0	>1.0	
S (μg/g)	<20	20 - 40	40 - 70	>70	
B (μg/g)	<0.2	0.2 - 0.5	0.5 - 1.0	1 - 2	>2
Cu (μg/g)	<0.1	0.1 - 0.3	0.3 - 1.0	1 - 5	>5
Mn (μg/g)	<5	5 - 10	10 - 100	100 - 250	>250
Fe (μg/g)	<1	1 - 10	10 - 100	>100	
Zn (μg/g)	<0.5	0.5 - 1.0	1.0 - 5.0	5 - 50	>50

[1)] pH in H_2O; OM by method of Walkley and Black;
Al saturation = 100xAl/(Al+Ca+Mg+K) in me/100g;
P in Bray II; K, Ca, Mg and Na in 1N NH_4-acetate; S in Ca-phosphate;
B in hot water; and Cu, Mn, Fe and Zn in 0.05 N HCl+0.025 N H_2SO_4

[1)] CIAT Cassava Asian Regional Program, Dept. Agric., Chatuchak, Bangkok, Thailand.

Table 2. Soil samples taken in China.

Sample no.	Sample location and description	Date	Lab series
Hainan-1	SCATC - date of planting trial	Feb'91	S-198
Hainan-2	SCATC - pasture intercrop trial	Jan'90	S-34
Hainan-3	SCATC - erosion control trial	Jan'90	S-34
Hainan-4	SCATC - erosion control trials	Feb'91	S-198
Hainan-5	SCATC - breeding trial - very vigorous growth	Aug'90	S-212
Hainan-6	SCATC - burned soil used as fertilizer	Jan'91	S-198
Hainan-7	Qifeng village - erosion control trial	Apr'88	S-324
Hainan-8	Nada - farmer's field - cassava under rubber - SC205	Sept'87	S-976
Hainan-9	Nada - farmer's field - coarse soil, Mabihong variety	Sept'87	S-976
Hainan-10	Jalay - farmer's field - dark red sticky clay, P-def.	Sept'87	S-976
Hainan-11	Chengmai - farmer's field - dark red sticky clay,P-def.	Sept'87	S-976
Hainan-12	SCATC - NPK trial before planting Av. 4 Reps	Feb'92	S-891
Hainan-13	SCATC - variety trial	Feb'92	S-891
Hainan-14	SCATC - NPK trial - Av.$N_0P_0K_0$ - before 2nd planting	Feb'93	S-891
Hainan-15	SCATC - FPR demonstration plot	Mar'94	S-891
Hainan-16	Qiongzhong - farmer's field on steep slope	Mar'94	S-891
Guangxi-1	Wuming state farm, vigorous cassava SC201	Sept'87	S-976
Guangxi-2	Wuming state farm, poor cassava with K-deficiency	Sept'87	S-976
Guangxi-3	Liuzhou, Xing Xing state farm	Sept'87	S-976
Guangxi-4	Guilin, Lu Dang state farm - yellow brown clay	Sept'87	S-976
Guangxi-5	Guixian, Xijiang state farm - heavy yellow clay	Jan'88	S-976
Guangxi-6	Guixian, 30 km south, farmer's field - purple red soil, high K	Jan'88	S-976
Guangxi-7	Yulin, 15 km south, farmer's field, red soil	Jan'88	S-976
Guangxi-8	Lu Chiang, Wuxing state farm, yellow clay	Jan'88	S-976
Guangxi-9	Ming Yang state farm-NPK trial before planting	Apr'88	S-324
Guangxi-10	Nanning - GSCRI, NPK trial - $N_0P_0K_0$	Jan'90	S-34
Guangxi-11	Nanning - GSCRI, NPK trial - $N_0P_0K_0$ before 2nd planting	Apr'90	S-210
Guangxi-12	Nanning - GSCRI, erosion trial before planting	Jan'90	S-34
Guangxi-13	Nanning - GSCRI, NPK trial - $N_0P_0K_0$ before 4th planting	Mar'92	S-583
Guangxi-14	Nanning, GSCRI, NPK-trial-$N_0P_0K_0$ before 5th planting	Feb'93	S-891
Guangxi-15	Nanning, GSCRI, NPK-trial-$N_0P_0K_0$ before 6th planting	Feb'94	S-891
Guangdong-1	Guangzhou, about 30 km NE, farmer's field	Oct'88	S-324
Guangdong-2	Si Feng, about 60 km NE of Guangzhou, farmer's field	Oct'88	S-324
Guangdong-3	Guangzhou, UCRI - outside NPK trial	Jan'90	S-34
Guangdong-4	Guangzhou, UCRI, NPK trial, $N_0P_0K_0$ before 2nd planting	Mar'90	S-212
Guangdong-5	Guangzhou, UCRI, NPK trial, $N_0P_0K_0$ before 3rd planting	Mar'91	S-198
Guangdong-6	Guangzhou, UCRI, NPK trial, $N_0P_0K_0$ before 4th planting	Mar'92	S-583
Guangdong-7	Guangzhou, UCRI, NPK trial, $N_0P_0K_0$ before 5th planting	Feb'93	S-891
guangdong-8	Guangzhou, UCRI - proposed site for erosion trial	Mar'94	S-891

Table 3. Chemical and physical characteristics of cassava soils in China.[1)]

	Chemical characteristics														Physical characteristics			
		%	ppm	me/100g				ppm							%			
Sample no.	pH	OM	P	Al	Ca	Mg	K	S	B	Zn	Mn	Cu	Fe		Sand	Silt	Clay	Texture[2)]
Hainan-1	4.5	1.9	11.2	0.56	0.70	0.15	0.09		0.45	0.53	23	1.36	51		53.1	18.9	28.0	s.c.l.
-2	5.1	1.8	3.8		0.36	0.22	0.09		0.82	1.17	51	0.16	21		55.3	15.2	29.4	s.c.l.
-3	4.9	2.6	5.8		0.43	0.25	0.11		0.90	1.09	55	0.18	26		40.0	17.8	47.2	clay
-4	4.6	3.1	5.0	1.48	0.45	0.24	0.14		0.95	1.17	77	0.65	30					
-5	4.8	1.8	20.0	0.81	0.86	0.15	0.09											
-6	6.0	3.2	83.0		2.26	1.00	1.16		1.90	4.24	104	0.24	73					
-7	5.4	2.4	4.8	0.30	1.52	0.83	0.36		0.59	1.08	130	0.28	16		51.3	14.0	34.7	s.c.l
-8	4.7	2.3	2.7		0.70	0.32	0.10			1.92	44	0.57	23		24.6	20.1	55.3	clay
-9	5.9	1.5	21.1		3.31	0.41	0.12			2.64	22	0.26	18		55.1	13.9	31.0	s.c.l.
-10	5.0	2.0	4.0		0.42	0.18	0.08			1.40	40	1.00	11		18.1	14.1	67.8	clay
-11	5.0	1.5	5.9		0.87	0.49	0.11			1.18	57	0.56	11		35.9	11.8	52.3	clay
-12	4.6	2.3	28.7	0.70	0.65	0.11	0.12	-	0.30	0.52	20	0.32	18		56.3	18.2	25.5	s.c.l.
-13	4.6	2.6	27.5	0.67	0.81	0.14	0.12	-	0.24	0.53	25	0.18	23		55.4	19.9	24.7	s.c.l.
-14	4.7	2.2	31.6	0.57	0.63	0.13	0.11	-	-	-	-	-	-		-	-	-	-
-15	4.6	2.3	7.9	0.74	0.25	0.09	0.10	-	0.39	0.30	12	0.07	10		60.6	13.8	25.7	s.c.l.
-16	4.5	4.8	2.2	4.36	0.52	0.39	0.07	-	0.40	0.75	15	0.04	19		25.5	24.2	50.3	clay
Guangxi-1	5.6	3.0	5.6	-	5.73	0.93	0.35			1.39	59	0.52	9		23.0	20.7	56.2	clay
-2	5.3	2.9	3.4		1.22	0.30	0.11			1.00	16	0.45	12		12.2	16.9	71.0	clay
-3	5.4	2.1	18.3		1.44	0.52	0.29			2.55	44	0.77	11		3.7	18.9	77.4	clay
-4	5.3	2.4	25.4		2.56	1.00	0.44			1.28	8	0.68	23		13.4	34.0	52.6	clay
-5	6.4	3.1	145.0		9.00	3.20	0.24			6.61	41	0.72	10		33.8	18.6	47.5	clay
-6	7.1	1.8	199.0		9.10	1.98	0.37			2.86	36	0.11	1		23.2	44.9	31.8	c.l.
-7	5.5	1.8	7.4		5.15	1.15	0.15			1.23	36	1.11	18		5.8	23.3	70.9	clay

Table 3. (continued).

	Chemical characteristics														Physical characteristics			
		%	ppm	me/100g				ppm							%			
Sample no.	pH	OM	P	Al	Ca	Mg	K	S	B	Zn	Mn	Cu	Fe		Sand	Silt	Clay	Texture[2]
Guangxi-8	5.3	1.4	3.4		1.31	0.20	0.05			1.08	6	0.81	39		53.4	12.6	33.9	s.c.l.
-9	6.1	1.6	39.5	-	3.57	0.34	0.14		0.60	1.33	24	0.72	24		22.4	45.3	32.4	c.l.
-10	5.0	2.4	15.7		2.20	0.42	0.14		0.38	1.11	8	0.62	78		29.6	32.6	37.8	c.l.
-11	5.1	2.2	28.2	1.35	2.81	0.39	0.16		0.48	1.15	6	0.69	50		26.7	44.9	28.3	c.l.
-12	4.9	2.8	4.9		2.47	0.76	0.09		0.26	1.20	10	0.96	53		10.6	28.2	61.1	clay
-13	4.8	2.5	16.6	1.86	2.70	0.57	0.19	27.9	0.56	0.86	8	0.66	47		29.3	33.9	36.8	c.l.
-14	5.0	2.9	15.3	1.54	2.67	0.50	0.18											
-15	5.1	3.0	19.5	1.38	2.41	0.48	0.15											
Guangdong-1	4.7	1.1	7.0	0.90	0.41	0.06	0.09		0.17	0.53	7	0.69	23		65.2	11.8	23.0	s.c.l.
-2	4.8	0.9	28.4	0.30	1.00	0.21	0.15		0.16	1.50	21	0.62	21		67.8	15.6	16.6	s.l.
-3	5.6	1.6	3.9		4.33	0.27	0.09		0.24	2.10	6	0.71	18		39.9	20.4	39.7	c.l.
-4	5.6	1.0	4.2	0.07	4.17	0.20	0.10		0.72	1.40	4	0.59	14		46.7	37.8	15.5	loam
-5	5.4	1.4	2.9		4.50	0.23	0.10		0.97	2.01	4	0.90	17		42.7	20.8	36.5	c.l.
-6	5.5	1.6	2.5	0.13	4.54	0.26	0.10	48.2	0.39	1.89	4	0.99	10		46.8	18.3	34.9	s.c.l.
-7	5.3	2.0	2.8	0.12	3.81	0.24	0.10		-	1.76	5	1.33	12		22.1	36.9	41.0	clay
-8	4.9	4.5	-	1.19	1.12	0.18	0.08		0.64	1.57	6	0.78	71		50.7	9.8	39.5	s.c.

[1] See Table 2 for description of samples
[2] s.c.l. = sandy clay loam, c.l. = clay loam, s.l. = sandy loam, s.c. = sandy clay

Table 4. Soil samples taken in India, Sri Lanka, Myanmar and Malaysia.

Sample no.	Sample location and description	Date	Lab series
India-1	Kerala, Trivandrum CTCRI, long-term NPK trial	1977	CTCRI
India-2	Tamil Nadu, Coimbatore, farmer's field	Sept'91	S-198
India-3	Tamil Nadu, Coimbatore, farmer's field, grey sandy clay	Sept'91	S-198
Sri Lanka-1	Matale, farmer's field near Galewela	Nov'90	S-232
Sri Lanka-2	Kandy, CARI, long term NPK trial, $N_0P_0K_0$, Rep I	Sept'91	S-198
Sri Lanka-3	Kandy, CARI long term NPK trial, $N_0P_0K_0$, Rep II,III	Sept'91	S-198
Sri Lanka-4	Kegalla, Wagolla station, long-term NPK trial, $N_0P_0K_0$	Sept'91	S-198
Sri Lanka-5	Badulla, Girandurakotta station, NCVT trial	Sept'91	S-198
Myanmar-1	Ayeyarwady, Kyonpaw township, farmer's field	Nov'89	S-34
Myanmar-2	Ayeyarwady, Layemyet township, farmer's field	Nov'89	S-34
Myanmar-3	Ayeyarwady, Henzada township, farmer's field	Nov'89	S-34
Myanmar-4	Yangon, Hlengu, FVRDC station	Nov'89	S-34
Malaysia-1	Johor, Pontian Peat Station, NPK trial, $N_0P_0K_0L_0$, 5th year	May'88	S-324
Malaysia-2	Johor, Pontian Peat Station, NPK trial, $N_2P_2K_2L_0$, 5th year	May'88	S-324
Malaysia-3	Johor, Pontian Peat Station $N_2P_0K_2L_0$, 8th year, very poor cassava	Oct'91	S-198
Malaysia-4	Johor, Pontian Peat Station $N_2P_0K_2L_0$, 8th year, very good cassava	Oct'91	S-198
Malaysia-5	Selangor, Kundang Tin Tailing Research Station	Mar'88	S-34
Malaysia-6	Perak, Ipoh, farmer's field with tin tailing soil	Oct'91	S-198

Table 5. Chemical and physical characteristics of cassava soils in India, Sri Lanka, Myanmar and Malaysia[1].

	Chemical characteristics													Physical characteristics			
		%	ppm	me/100g				ppm						%			
Sample no.	pH	OM	P	Al	Ca	Mg	K	B	Zn	Mn	Cu	Fe		Sand	Silt	Clay	Texture[2]
India-1	4.7	1.2	25.0		0.24	0.24	0.18		0.82		0.50						g.s.c.
-2	6.9	1.2	41.3	-	22.14	5.15	0.61	1.26	1.17	88	0.38	8		49.8	18.5	31.6	s.c.l.
-3	7.3	1.7	165.0	-	22.09	5.61	0.62	1.31	0.15	12	0.19	5		56.7	14.5	28.8	s.c.l.
Sri Lanka-1	6.4	2.5	21.9	-	5.32	0.98	0.40	1.03	2.15	81	2.96	23		57.9	14.9	27.2	s.c.l.
-2	5.8	3.0	29.3	-	0.67	0.36	0.39	1.44	1.32	127	2.32	16		43.3	13.5	43.2	clay
-3	5.5	2.9	13.5	-	1.61	0.68	0.62	1.18	1.88	177	3.16	24		43.3	13.5	43.2	clay
-4	5.6	2.4	35.0	-	4.17	1.72	0.08	0.59	4.64	56	2.38	31					
-5	5.9	1.4	6.6	-	3.36	0.84	0.18	0.69	1.27	36	1.26	20		64.3	12.6	23.1	s.c.l.
Myanmar-1	5.5	2.5	17.5		6.13	4.42	0.11	0.56	1.60	69	1.80	70		7.5	54.6	37.9	si.c.l.
-2	5.5	2.4	14.0		6.11	3.89	0.14	0.18	2.20	65	1.47	47		11.0	51.4	37.6	si.c.l.
-3	5.7	2.4	80.0		5.01	3.13	0.36	0.20	2.15	49	1.20	77		17.0	54.0	29.0	si.c.l.
-4	5.1	2.1	22.4		0.83	0.42	0.13	0.22	1.15	13	0.47	60		44.0	36.6	24.3	loam
Malaysia-1	3.5	47.5	13.2	6.2	13.96	1.96	0.14		5.25	33	0.98	12					
-2	3.4	49.7	7.8	3.2	11.05	1.19	0.14		5.17	17	0.23	29					
-3	3.1	81.3	8.2	6.5	3.05	0.79	0.19	5.10	5.81	8	0.34	21		69.8	10.1	20.0	s.c.l.
-4	3.4	91.3	20.3	4.5	5.99	1.76	0.55	4.60	48.23	24	0.21	50		69.8	10.1	20.0	s.c.l.
-5	5.5	0.5	2.3	-	0.12	0.03	0.01	0.20	0.92	1	5.88	7		82.1	5.8	12.1	sandy loam
-6	5.8	0.8	3.5	-	0.61	0.05	0.05	1.44	1.68	16	0.34	6		80.5	4.3	15.2	loamy sand

[1] See Table 4 for description of samples.
[2] g.s.c. = gravelly sandy clay; s.c.l. = sandy clay loam; si.c.l. = silty clay loam

Table 6. Soil samples taken in Indonesia.

Sample no.	Sample location and description	Date	Lab series
E. Java-1	Malang, Jatikerto station	Oct'86	S-436
E. Java-2	Malang, Jatikerto station, breeding trial, poor growth cassava	Mar'87	S-650
E. Java-3	Malang, Jatikerto station, breeding trial, vigorous growth cassava	Mar'87	S-650
E. Java-4	Malang, Dampit village, farmer's field	Oct'86	S-436
E. Java-5	Madura, west of Sampang, farmer's field	Mar'91	S-198
E. Java-6	Madura, near Kedungdung, farmer's field	Mar'91	S-198
E. Java-7	Madura -5 km west of Ketapang, red soil	Mar'91	S-198
E. Java-8	Kediri, Tarokan village, NPK trial, $N_0P_0K_0$	Mar'90	S-34
E. Java-9	Kediri - Bulusari, NW of Kediri, vigorous cassava, sandy loam	May'88	S-324
E. Java-10	Kediri - Wates - 23 km N of Kediri, red clay loam	May'88	S-324
E. Java-11	Malang, Jatikerto, NPK trial, $N_0P_0K_0$ Av. 3 Reps - 5th planting	Feb'93	S-891
E. Java-12	Tulungagung, Pelem, on-farm fert. trial, Av. no fert.	Feb'93	S-891
E. Java-13	Tarokan, above erosion control trial, no fertilizers	Feb'94	S-891
E. Java-14	Ponorogo, farmers field near Sawa, cassava on terraces	Feb'94	S-891
Yogyakarta-1	Wonosari, Playen, spacing trial in farmer's field, black soil	Nov'87	S-976
Yogyakarta-2	Wonosari, Playen, fert. trial in farmer's field, red soil	Nov'87	S-976
Yogyakarta-3	Wonosari, Playen, fert. trial red soil, A_1 treatm. 3rd year	Mar'90	S-34
Yogyakarta-4	Wonosari, Playen, fert. trial red soil, B_1 treatm. end 3rd year	Aug'90	S-212
Yogyakarta-5	Wonosari, Playen, NPK trial on black soil, $N_0P_0K_0$	Mar'91	S-198
Yogyakarta-6	Wonosari, Playen, NK timing trial, 3 1/2 months after planting	Mar'91	S-198
Yogyakarta-7	Wonosari, Semanu, farmer's field	May'88	S-324
Yogyakarta-8	Wonosari, Baron, farmer's field, near limestone rocks	May'88	S-324
Yogyakarta-9	Wonosari, Playen, NPK trial - $N_0P_0K_0$ Av. 3 Reps - 2nd planting	Feb'93	S-891
C-Java-1	Karangpucung, 60 km west of Purwokerto	May'88	S-324
W-Java-1	Bandung, Nagrek, 50 km SE Bandung	May'88	S-324
W-Java-2	Ciangur, Ciranjang, 60 km SE Bogor	May'88	S-324
W-Java-3	Cibinong, Jasinga, 40 km W. Bogor, 250 masl. red soil	Oct'86	S-436
Lampung-1	Tamanbogo - Spacing trial before planting	Nov'87	S-976
Lampung-2	Umas Jaya - NPK trial before planting	Mar'87	Bogor
Lampung-3	Umas Jaya - Erosion trial before planting	June'87	Bogor
Lampung-4	Umas Jaya - F_1 selection field	May'87	S-650
Lampung-5	Tamanbogo - NPK trial, $N_0P_0K_0$ Av. 3 Reps - 2nd planting	Feb'93	S-891
Lampung-6	Tamanbogo - NPK trial, $N_0P_0K_0$ Av. 3 Reps - 3 rd planting	Feb'94	S-891
S. Sumatra-1	Palembang - Sepakat Siantar plantation, grey clay loam	May'88	S-324
S. Sumatra-2	Palembang - Sepakat Siantar plantation, yellow clay loam	May'88	S-324

Table 7. Chemical and physical characteristics of cassava soils in Indonesia[1].

Sample no.	Chemical characteristics												Physical characteristics			
		%	ppm	me/100g				ppm					%			
	pH	OM	P	Al	Ca	Mg	K	B	Zn	Mn	Cu	Fe	Sand	Silt	Clay	Texture[2]
E-Java-1	5.5	1.5	2.8	0.20	4.90	2.80	1.43		5.72	41	4.49	56	24.3	30.5	45.2	clay
-2	5.9	1.0	1.6	-	7.52	2.90	1.16	0.68	2.13	61	4.51	43				clay
-3	5.7	1.5	10.4	-	4.33	1.90	0.87	0.43	2.10	62	6.81	66				clay
-4	5.6	1.6	5.3	0.20	5.40	1.80	0.62		3.43	21	4.49	53	38.4	31.8	29.8	c.l.
-5	6.5	1.0	14.8	-	22.61	1.58	0.21	0.79	0.70	29	0.81	13	35.9	27.3	36.7	c.l.
-6	5.3	2.0	3.8		27.88	0.65	0.34	0.97	0.85	16	0.38	14	5.4	29.4	65.1	clay
-7	6.3	2.6	14.1	-	17.11	2.07	0.19	1.76	0.97	54	0.68	4	24.2	24.2	51.6	clay
-8	5.8	1.6	4.8	-	18.90	6.00	0.13	0.36	5.98	3	0.69	65				
-9	5.9	1.0	50.8	-	8.24	1.97	0.36	0.50	1.66	28	2.01	40	51.8	20.5	27.6	s.c.l.
-10	6.2	1.0	2.8	-	7.21	2.17	0.12	0.76	1.16	32	1.98	30	23.0	16.4	60.5	clay
-11	5.7	1.6	2.9	0.06	6.67	2.95	0.83	0.37	1.74	53	5.03	51	28.2	34.1	37.7	c.l.
-12	7.0	1.6	11.0	0.04	20.60	0.83	0.35	0.39	0.04	3	0.08	<1	39.1	26.0	34.9	c.l.
-13	5.7	2.8	3.4	0.05	8.63	3.35	0.15	0.61	1.03	73	1.73	24	32.3	17.3	50.4	clay
-14	5.7	2.7	5.0	0.12	31.15	11.50	0.33	0.33	0.50	34	0.60	11	23.3	25.6	51.1	clay
Yogyakarta-1	6.0	2.6	20.3	-	26.00	4.91	0.60		1.62	157	0.73	3	11.9	21.7	66.3	clay
-2	5.7	1.8	2.0	-	18.20	3.53	0.27		1.13	58	1.36	5	0.8	19.1	80.1	clay
-3	5.9	3.0	5.8	-	22.00	3.01	0.32	0.91	1.46	48	1.46	7	3.5	16.0	80.5	clay
-4	5.8	2.4	2.3	0.06	20.20	3.27	0.23	0.44	1.28	112	1.42	6	1.3	20.9	77.8	clay
-5	5.4	2.6	2.2		21.75	3.14	0.23	0.72	0.97	29	1.55	10	10.4	25.1	64.4	clay
-6	5.4	2.7	8.5		18.68	3.68	0.21	1.13	1.52	38	1.84	8	11.2	27.6	61.2	clay
-7	6.8	1.1	2.1	-	34.90	4.08	0.07	0.40	0.67	21	0.74	3	10.4	15.6	74.1	clay
-8	6.8	1.9	6.3	-	17.60	1.05	0.45	1.39	0.99	13	1.08	2	1.1	20.3	78.6	clay
-9	5.5	3.0	1.6	0.05	20.69	3.11	0.12	0.31	1.55	43	1.60	11	8.0	24.3	67.7	clay

Table 7. (continued).

	Chemical characteristics												Physical characteristics			
		%	ppm	me/100g				ppm					%			
Sample no.	pH	OM	P	Al	Ca	Mg	K	B	Zn	Mn	Cu	Fe	Sand	Silt	Clay	Texture[2]
C-Java-1	5.8	1.3	11.7	-	33.60	8.33	0.56	0.36	0.97	32	2.32	18	11.4	26.5	62.1	clay
W-Java-1	6.1	2.9	4.5	-	9.09	3.18	0.63	1.28	3.55	68	5.80	98	19.6	28.0	52.4	clay
-2	5.5	2.8	2.4	0.10	5.88	2.89	0.16	0.78	3.52	63	4.61	14	2.1	18.5	79.4	clay
-3	4.7	3.9	2.1	7.10	1.00	0.70	0.20		7.46	33	1.11	24	8.7	12.1	79.2	clay
Lampung-1	5.1	2.8	2.6		1.66	0.76	0.15		1.14	17	0.43	40	43.0	15.7	41.1	clay
-2	4.6	2.1	4.0	0.91	1.73	0.37	0.19		1.40	10	1.10	108	54.6	17.7	27.6	s.c.l.
-3	5.1	2.2	7.1	0.27	2.97	0.50	0.12		0.95	28	1.60	46	61.7	11.8	26.4	s.c.l.
-4	4.9	2.7	54.5	0.60	2.00	0.52	0.22	0.54	1.02	20	0.73	56				clay
-5	4.7	3.5	4.3	1.48	0.96	0.35	0.08	0.40	1.10	14	0.38	31	39.7	17.5	42.8	clay
-6	5.1	3.4	3.5	1.31	1.32	0.53	0.06	0.38	0.33	12	0.27	29	41.7	14.7	43.6	clay
S-Sumatra-1	5.1	5.8	7.1	2.20	0.70	0.23	0.09	0.17	0.64	8	0.26	8	32.6	38.6	28.8	c.l.
-2	4.2	3.3	2.3	4.70	0.34	0.12	0.11	0.37	0.56	11	0.67	95	16.2	40.4	43.3	si.c.

[1] See Table 6 for description of samples.
[2] s.c.l. = sandy clay loam, c.l. = clay loam, si.c. = silty clay

Table 8. Soil samples taken in the Philippines.

Sample no.	Sample location and description	Date	Lab series
Leyte-1	Baybay, ViSCA - breeding trial in lowland	Apr'87	S-650
Leyte-2	Baybay, ViSCA, NPK trial under coconut, $N_0P_0K_0$	Apr'90	S-34
Leyte-3	Hindang village, farmer's field on hillside	Apr'90	S-34
Leyte-4	Baybay, ViSCA, NPK trial under coconut, $N_0P_0K_0$ before 5th cycle	May'93	S-891
Bohol-1	Ubai, Bohol Experiment Station, regional trial	May'88	S-324
Bohol-2	Ubai, Bohol Experiment Station, NPK trial, $N_0P_0K_0$	Apr'90	S-34
Bohol-3	Ubai, Bohol Experiment Station, NPK trial, $N_0P_0K_0$ before 2nd planting	June'91	S-198
Bohol-4	Ubai, farmer's field near Bohol Exp. Station,	June'91	S-198
Bohol-5	San Miguel, farmer's field between S. Miguel and BES	May'88	S-324
Bohol-6	Dagohoy, farmer's field between Dagohoy and Carmen	May'88	S-324
Bohol-7	Carmen, black soil south of Carmen with Fe deficiency	May'88	S-324
Bohol-8	Ubai, Bohol Experiment Station, NPK trial, $N_0P_0K_0$ before 5th cycle	July'93	S-891
Negros Oc.-1	La Carlotta city, La Granja, NPK trial, $N_0P_0K_0$	Apr'90	S-34
Negros Oc.-2	La Carlotta city, NPK trial, $N_0P_0K_0$ residue removed, before 3rd planting	June'91	S-198
Guimaras-1	Mirasol Developm. Corp., field near motor pool	June'91	S-198
Surigoa Norte-1	Tubod, cassava field of Tubod Farmer's Coop.	Sept'93	S-891
Misamis Orient-1	Lagonglong-Lumbo, Upper Poblacion	Sept'93	S-891
Misamis Orient-2	Lagonglong-Lumbo, Lower Poblacion	Sept'93	S-891
Misamis Orient-3	Lagonglong-Banglay-mountain side	Sept'93	S-891
Misamis Orient-4	Risal, Claveria, cassava field, dark red soil	Sept'93	S-891
Bukidnon-1	Liboran, Baungon, near Philagro Industrial Corp.	Sept'93	S-891
Lanao Sur-1	Malabang, Matling plantation, lot 114, virgin black soil	Apr'90	S-34
Lanao Sur-2	Malabang, Matling plantation, lot 144, average cassava soil	Apr'90	S-34
Sulu-1	Jolo, farmer's field, dark clay, intercropped cassava	May'88	S-324
Sulu-2	Jolo, farmer's field, cassava under coconut	May'88	S-324
Sulu-3	Jolo, farmer's field, cassava with K deficiency	May'88	S-324

Table 9. Chemical and physical characteristics of cassava soils in the Philippines[1].

	Chemical characteristics												Physical characteristics			
		%	ppm	me/100g				ppm					%			
Sample no.	pH	OM	P	Al	Ca	Mg	K	B	Zn	Mn	Cu	Fe	Sand	Silt	Clay	Texture
Leyte-1	6.4	1.6	29.8	-	20.90	7.60	0.80	0.33	1.39	36	2.22	14				clay loam
-2	5.1	2.8	1.7		2.92	2.52	0.15	0.33	0.95	49	2.09	52	21.6	25.5	52.9	clay
-3	5.4	2.5	3.6		19.36	11.09	0.18	0.24	1.12	27	1.58	17	24.4	28.0	47.5	clay
-4	5.0	4.4	2.4	0.75	2.76	2.28	0.15									
Bohol-1	6.3	1.3	5.0	-	4.95	0.83	0.10	0.59	0.52	9	1.20	43	36.1	42.0	21.9	loam
-2	5.7	1.8	9.1	-	2.97	0.90	0.08	0.29	1.60	12	1.09	50	41.8	36.4	21.8	loam
-3	5.5	1.7	3.8	-	3.25	1.04	0.10	0.82	0.68	18	0.89	29	41.6	37.8	20.5	loam
-4	5.2	2.4	4.4	-	1.95	1.60	0.14	0.81	0.32	34	1.19	63	51.9	28.8	19.2	loam
-5	5.8	1.8	4.3	-	3.78	1.11	0.16	0.35	0.82	13	1.64	112	42.3	33.1	24.5	loam
-6	5.2	3.5	1.7	1.40	11.18	4.98	0.59	0.26	2.24	104	3.19	19	24.1	30.5	45.4	clay
-7	8.0	4.6	5.0	-	48.00	1.18	0.17	0.24	0.31	0	0.09	0	24.1	25.6	50.2	clay
-8	5.6	1.8	3.5	0.05	2.81	0.79	0.06									
Negros Oc.-1	5.4	1.7	2.5		4.11	1.27	0.16	0.17	3.55	289	4.53	22	25.2	21.2	53.6	clay
-2	6.0	2.2	4.0		4.25	1.40	0.28	0.56	2.68	74	7.68	54	25.0	24.0	50.9	clay
Guimaras-1	5.2	2.6	5.6		1.26	0.41	0.10	0.63	1.38	105	2.20	27	36.8	37.6	25.5	loam
Surigao N.-1	5.1	5.0	3.4	2.51	1.68	1.10	0.28		1.88	289	1.88	13	26.1	31.5	42.4	clay
Misamis O.-1	6.0	1.8	15.5	0.04	10.90	5.06	0.70	0.41	1.40	24	3.38	19	43.4	14.4	42.2	clay
-2	6.7	5.6	41.0	0.04	10.69	7.36	3.90	0.25	2.33	46	0.49	2	30.8	48.3	20.9	loam
-3	7.0	1.5	209.0	0.04	5.93	2.43	2.01	0.20	3.05	26	2.74	11	65.1	15.6	19.3	sandy loam
-4	5.2	6.6	3.1	0.44	2.38	1.08	0.83	0.47	3.44	111	5.98	13	-	-	-	-

Table 9. (continued).

Sample no.	Chemical characteristics												Physical characteristics			
		%	ppm	me/100g				ppm					%			
	pH	OM	P	Al	Ca	Mg	K	B	Zn	Mn	Cu	Fe	Sand	Silt	Clay	Texture[2]
Bukidnon-1	5.8	6.1	4.0	0.05	7.93	2.29	0.37	0.44	2.18	93	3.85	5	13.4	27.5	59.1	clay
Lanao Sur-1	5.6	2.8	32.7	-	1.96	0.77	0.23	0.32	0.46	6	1.38	23	68.7	17.9	13.4	sandy loam
-2	5.7	4.2	15.9	-	6.49	6.06	0.66	0.58	1.79	107	3.49	42	42.4	35.7	21.8	loam
Sulu-1	7.1	4.6	17.7	-	16.40	2.11	0.48	0.39	9.75	25	0.65	2	24.1	29.7	46.2	clay
-2	5.9	5.0	3.2	-	6.11	2.10	0.25	0.70	5.63	56	2.71	5	24.3	26.9	48.8	clay
-3	5.2	0.6	5.2	0.4	2.48	1.52	0.12	0.45	2.71	76	2.92	7				

[1] See Table 8 for description of samples.

Table 10. Soil samples taken in Thailand.

Sample no.	Sample location and description	Date	Lab series
Rayong-1	Rayong Field Crops Research Center	Feb'87	S-649
Rayong-2	Rayong FCR-Center-former ant hill	Feb'87	S-649
Rayong-3	Ban Chang - farmer's cassava field	Feb'87	S-649
Rayong-4	Pluak Daeng - outside erosion trial	Oct'88	S-324
Chon Buri-1	Sri Racha station, date planting trial	Jan'88	S-976
Chon Buri-2	Sri Racha station, erosion trial	Jan'88	S-976
Prachin Buri-1	Khaw Hin Sorn-erosion trial	Sept'92	S-583
Prachin Buri-2	Kabinburi FCR-Station-variety trial good growth	Oct'93	S-891
Prachin Buri-3	Kabinburi FCR-Station-variety trial bad growth	Oct'93	S-891
Prachin Buri-4	Kabinburi FCR-Station-secondary forest	Oct'93	S-891
Prachin Buri-5	Kabinburi FCR-Station-near forest, very hard soil	Oct'93	S-891
Phitsanulok-1	East of Phitsanulok-teak plantation	Sept'92	S-583
Phitsanulok-2	E. Phitsa. -teak plantation near factory	Sept'92	S-583
Phitsanulok-3	E. Phitsa.-mango plantation near factory	Sept'92	S-583
N. Ratchasima-1	Banmai Samrong FCR-Station-long term NPK trial - $N_0P_0K_0$, tops removed	May'87	S-649
N. Ratchasima-2	Banmai Samrong FCR-Station-long term NPK trial- $N_8P_8K_8$, tops removed	May'87	S-649
N. Ratchasima-3	Banmai Samrong FCR-Station-long term NPK trial-Fe deficient plants	Oct'92	S-583
N. Ratchasima-4	Banmai Samrong FCR-Station, NPK trial $N_0P_0K_0$ - Av. 4 Reps	Oct'92	S-583
N. Ratchasima-5	Banmai Samrong FCR-Station, NPK trial $N_1P_1K_0$ - Av. 4 Reps	Oct'92	S-583
N. Ratchasima-6	Banmai Samrong FCR-Station, NPK trial $N_1P_1K_1$ - Av. 4 Reps	Oct'92	S-583
Khon Kaen-1	Khon Kaen FCR-Center - long term NPK trial - $N_0P_0K_0$, tops removed	May'87	S-649
Khon Kaen-2	Khon Kaen FCR-Center - long term NPK trial - $N_8P_8K_8$ tops removed	May'87	S-649
Khon Kaen-3	Ban Phai, farmer's field	May'87	S-649
Khon Kaen-4	Khon Kaen FCR-Center - $N_0P_0K_0$ tops removed, Av. 4 Reps	Oct'92	S-583

Table 10. (continued)

Province	Sample location and description	Date	Lab series
Khon Kaen-5	Khon Kaen FCR-Center - $N_1P_1K_0$ tops removed, Av. 4 Reps	Oct'92	S-583
Khon Kaen-6	Khon Kaen FCR-Center - $N_1P_1K_1$ tops removed, Av. 4 Reps	Oct'92	S-583
Maha Sarakham-1	Maha Sarakham FCR-Station - regional trial	May'87	S-649
Maha Sarakham-2	Maha Sarakham FCR-Station - regional trial, vigorous cassava	Oct'87	S-976
Roi Et-1	Roi Et FCR-Station - regional trial	May'87	S-649
Roi Et-2	Roi Et FCR-Station - regional trial, poor cassava	Oct'87	S-976
Kalasin	Kalasin FCR-Station - regional trial	May'87	S-649
Ubon Ratchathani	Farmer's cassava field	Oct'87	S-976

Table 11. Chemical and physical characteristics of cassava soils in Thailand.[1)]

	Chemical characteristics													Physical characteristics			
		%	ppm	me/100g				ppm						%			
Sample no.	pH	OM	P	Al	Ca	Mg	K	S	B	Zn	Mn	Cu	Fe	Sand	Silt	Clay	Texture[2)]
Rayong-1	5.0	1.4	53.0	0.20	1.57	0.51	0.34		1.00	1.09	24	0.48	29				s.c.
-2	6.3	1.2	44.0	-	2.48	1.02	0.52		1.30	2.01	63	0.92	21				
-3	5.6	0.4	11.8	-	0.30	0.07	0.07		0.37	0.87	36	0.28	14				
-4	6.1	0.7	7.0	-	1.12	0.17	0.08		0.28	0.56	26	0.41	10	67.5	14.7	17.8	s.c.
Chon Buri-1	5.4	0.5	8.0		0.35	0.19	0.21			1.55	30	0.77	10	69.2	13.8	17.1	s.c
-2	5.2	0.6	8.7		1.02	0.46	0.34			1.14	50	0.20	7	67.8	13.1	19.1	s.c
Prachin Buri-1	6.2	1.6	7.4	0.03	2.13	0.34	0.22	19.6	0.50	1.10	33	0.20	9	69.5	13.9	16.6	s.c
-2	5.6	1.4	3.0	0.34	0.78	0.25	0.06		0.37	0.39	9	0.63	48	50.8	32.1	17.1	loam
-3	5.9	1.8	4.5	0.05	1.38	0.24	0.07		0.11	0.51	12	0.40	17	55.7	27.3	16.9	s.l.
-4	5.7	2.0	3.4	0.29	0.90	0.26	0.04		0.40	0.30	12	0.42	18	52.1	31.4	16.4	loam
-5	5.5	1.8	24.1	0.70	0.52	0.11	0.07		0.22	0.21	7	0.52	22	59.0	20.2	20.8	s.c.l.
Phitsanulok-1	6.9	1.2	8.7	0.03	6.57	2.04	0.10	26.7	0.54	2.07	138	1.10	46		41.5	31.7	c.l.
-2	5.1	2.4	4.0	1.32	1.46	0.41	0.10	11.9	0.34	0.87	74	1.12	162	26.8	34.5	28.9	c.l.
-3	5.4	1.3	9.2	0.23	4.53	0.91	0.12	17.9	0.40	1.47	77	1.20	46	36.6			
N. Ratchas.-1	6.9	0.9	38.6	-	4.57	0.92	0.40		0.52	1.49	59	0.56	11				c.l.
-2	7.2	1.2	179.0	-	7.33	0.80	0.45		0.67	37.90	67	3.57	22				c.l.
-3	7.0	1.7	92.0	0.03	8.99	0.93	0.57	13.8	0.46	1.40	46	0.30	2				
-4	7.0	1.2	31.0	0.03	5.52	0.77	0.30	8.1	0.44	1.52	34	0.50	7	54.6	23.3	22.1	s.c.l.
-5	6.7	1.6	60.0	0.03	5.63	0.77	0.28	11.5	0.51	2.47	29	0.68	8	50.7	25.8	23.5	s.c.l.
-6	6.4	1.0	44.2	0.19	4.48	0.72	0.29	12.7	0.43	0.76	30	0.33	8	53.5	24.4	22.1	s.c.l.

Table 11. (continued)

	Chemical characteristics													Physical characteristics			
		%	ppm	me/100g				ppm						%			
Sample no.	pH	OM	P	Al	Ca	Mg	K	S	B	Zn	Mn	Cu	Fe	Sand	Silt	Clay	Texture[2]
Khon Kaen-1	4.6	0.4	10.7	0.60	0.36	0.19	0.08		0.34	0.79	27	0.23	4				s.l.
-2	4.8	0.6	30.3	0.30	0.49	0.18	0.08		0.68	0.51	19	0.23	4				s.l.
-3	6.0	0.5	5.3	-	1.63	0.24	0.13		0.53	1.21	16	0.34	16				s.l.
-4	5.0	1.3	6.6	0.79	0.59	0.14	0.03	7.7	0.49	0.44	21	0.73	5	64.8	15.4	19.8	s.l.
-5	4.6	1.3	52.2	0.94	0.41	0.09	0.03	14.7	0.55	0.74	9	0.45	7	67.3	13.2	19.5	s.l.
-6	4.8	1.2	44.7	0.60	0.35	0.08	0.06	9.8	0.46	0.62	11	0.47	7	69.3	13.6	17.1	s.l.
Maha Sarak.-1	5.8	0.5	19.6	-	0.76	0.18	0.08		0.38	0.99	44	0.28	8				s.l.
-2	6.4	0.4	69.0	-	1.26	0.20	0.08			3.44	19	0.31	5	76.4	8.8	14.8	s.l.
Kalasin-1	5.2	0.5	75.0	0.10	1.65	0.05	0.08		0.42	1.60	14	0.35	8				s.l.
Roi Et-1	5.4	0.5	78.0	0.10	0.68	0.09	0.08		0.75	1.54	26	0.43	43				s.l.
-2	5.5	0.4	63.0	-	0.46	0.07	0.07			1.73	15	0.50	53	72.6	11.3	16.1	s.l.
Ubon Rat.-1	5.7	0.4	104.0	-	0.83	0.19	0.13			2.78	21	0.50	7	69.2	14.3	16.5	s.l.

[1] See Table 10 for description of samples.
[2] s.c.l. = sandy clay loam, c.l. = clay loam, s.c. = sandy clay, s.l. = sandy loam

Table 12. Soil samples taken in Vietnam.

Sample no.	Sample location and description	Date	Lab series
Dong Nai-1	Hung Loc Exp. Center - cultivar trial	Sept'88	S-324
Dong Nai-2	Hung Loc Exp. Center - method of planting trial, very poor cassava	Oct'89	S-34
Dong Nai-3	Hung Loc Exp. Center - NPK trial, $N_0P_0K_0$	Oct'89	S-34
Dong Nai-4	Hung Loc Exp. Center - variety trial near house, good cassava	Oct'89	S-34
Dong Nai-5	Hung Loc Exp. Center-NPK trial (new location) $N_0P_0K_0$	Aug'90	S-212
Dong Nai-6	Trang Bom commune	Sept'88	S-324
Song Be-1	Thuan Giao Agr. Station - grey podzolic sandy soil	Sept'88	S-324
Song Be-2	Lai Uyen Station - NPK trial, $N_0P_0K_0$	Oct'89	S-34
Song Be-3	Lai Uyen Station - legume intercrop trial	Oct'89	S-34
Song Be-4	Farmer's field near Lai Thieu	Sept'88	S-324
Song Be-5	Thuan An, Song Be Extension office, NPK trial, $N_0P_0K_0$	Sept'92	S-583
Tay Ninh-1	Hoa Thangh, farmer's cassava field	Mar'91	S-198
Ho Chi M.-1	Cu Chi district, Nhi Xuan Research Station, acid sulfate soils	Sept'88	S-324
Ho Chi M.-2	Cu Chi district, Pham Van Coi state farm	Sept'88	S-324
Bac Thai-1	Agric. College#3 - variety trial	Oct'89	S-34
Bac Thai-2	AC#3, - NPK trial, $N_0P_0K_0$ before 2nd planting	Mar'91	S-198
Bac Thai-3	AC#3, - NPK trial, $N_0P_0K_0$ before 3rd planting	Feb'92	S-198
Bac Thai-4	AC#3, - NPK trial, $N_0P_0K_0$ before 3rd planting	Feb'92	S-583
Ha Son Binh	Chuong My district, Thanh Binh, farmer's cassava field	Nov'91	S-198
Ha Tay-1	Thach That district, Dong Truc, farmer's field	Oct'92	S-583
Ha Tay-2	Xuan Mai Experiment Station	Oct'92	S-583

Table 13. Chemical and physical characteristics of cassava soils in Vietnam.[1]

	Chemical characteristics														Physical characteristics			
		%	ppm	me/100g				ppm							%			
Sample no.	pH	OM	P	Al	Ca	Mg	K	S	B	Zn	Mn	Cu	Fe		Sand	Silt	Clay	Texture[2]
Dong Nai-1	5.3	2.6	15.8	0.30	3.66	0.80	0.28		0.52	1.87	65	1.21	22		1.2	15.8	83.0	clay
-2	5.1	2.0	3.5		2.37	0.61	0.27		0.38	0.98	89	1.08	15					
-3	5.0	2.1	5.0		1.68	0.54	0.28		0.36	0.66	74	0.96	21		5.8	12.7	81.5	clay
-4	5.2	2.4	7.9		3.85	0.77	0.19		0.50	3.33	73	2.18	16		4.5	15.3	80.2	clay
-5	4.7	2.9	18.4	2.01	1.14	0.40	0.19		0.45	1.08	67	0.78	11		6.7	19.8	73.5	clay
-6	4.5	3.5	5.0	2.30	1.05	0.48	0.29		0.37	1.64	115	1.54	22		11.0	18.3	70.7	clay
Song Be-1	6.2	0.9	25.7		1.57	0.21	0.11		0.64	2.17	4	0.52	25		72.8	10.6	16.7	s.l.
-2	4.7	1.5	8.7		0.43	0.22	0.06		0.45	0.45	3	0.26	24		64.1	15.1	20.8	s.c.l.
-3	4.6	1.6	10.8		0.25	0.18	0.04		0.49	0.33	2	0.28	27		62.6	13.9	23.4	s.c.l.
-4	4.3	0.6	24.6	0.40	0.70	0.09	0.04		0.20	1.45	2	0.70	37		73.3	10.1	16.7	s.l.
-5	4.4	1.6	47.5	0.99	0.52	0.07	0.06	29.3	0.33	0.75	1	0.39	62		66.9	12.4	20.7	s.c.l.
Tay Ninh-1	4.6	1.4	27.0	0.40	0.14	0.03	0.06		0.63	0.40	2	0.19	27		70.4	14.3	15.3	s.l.
Ho Chi Minh-1	4.6	7.8	24.5	1.00	2.40	2.46	0.81		1.07	13.50	19	0.79	38		13.5	23.9	62.6	clay
-2	5.0	1.6	56.0	0.40	1.21	0.15	0.11		0.59	12.30	2	9.12	58		65.0	10.6	24.4	s.c.l.
Bac Thai-1	5.2	1.6	15.1		2.22	0.11	0.08		0.36	0.26	1	0.33	30		55.5	18.9	25.5	s.c.l.
-2	4.5	2.5	9.1	1.76	1.26	0.05	0.03		0.51	0.75	3	0.59	124		57.4	20.8	21.8	s.c.l.
-3	4.6	2.0	9.7		1.25	0.06	0.04		0.69	0.70	2	0.39	122		58.8	17.6	23.6	s.c.l.
-4	4.5	2.3	13.9	1.87	1.17	0.08	0.05	35.8	0.37	0.65	2	1.02	136		59.3	18.9	21.8	s.c.l.
Ha Son Binh-1	4.7	2.7	11.7	0.64	2.14	0.82	0.49		0.47	2.66	30	1.25	23		21.5	17.6	60.9	clay
Ha Tay-1	5.4	2.4	25.5	0.25	3.28	0.96	0.09	35.5	0.25	1.50	148	1.76	43		9.4	41.4	49.1	si.c.
-2	4.4	4.5	64.5	2.39	0.85	0.23	0.12	34.5	0.29	2.27	64	3.20	42		33.1	25.3	41.6	clay

[1] See Table 12 for description of samples.
[2] s.c.l. = sandy clay loam, si.c. = silty clay, s.l. = sandy loam

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