Cassava Breeding, Agronomy and Farmer Participatory Research in Asia

Proceedings of the Fifth Regional Workshop
held in Danzhou, Hainan, China, Nov 3-8, 1996

CATAS CIAT

The Nippon Foundation

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Technical Editor: R.H. Howeler

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R.H. Howeler

Harvest of Farmer Participatory Research (FPR) trials on erosion control in Bac Thai province of Vietnam.

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PREFACE

The Centro Internacional de Agricultura Tropical (CIAT), with headquarters in Colombia, has as its mission "to contribute to the alleviation of hunger and poverty in tropical developing countries by applying science to the generation of technology, leading to lasting increases in agricultural outputs while preserving the natural resource base". The ultimate goal is to reduce hunger and poverty through the development of sustainable agriculture, mainly by integrating programs on genetic improvement with those on natural resources management. The two programs are intimately linked, as sustainable land use and resource management will contribute to conserving biodiversity, which is a vital resource for crop improvement. Conversely, more productive germplasm will enable farmers to increase their yield and raise their income, giving them more resources and incentives to conserve the productivity of their soil and prevent erosion.

CIAT can not achieve this goal alone, but only in partnership with national and international research institutions. Moreover, in order to enhance the adaption of new technologies, CIAT also collaborates closely with extension organizations and strongly encourages farmer participation in technology development and dissemination.

Within the Consultative Group for International Agricultural Research (CGIAR), CIAT has 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, a network of cassava researchers in national research institutes and universities in Asia was established, with the objective of enhancing communication between researchers, both within and among countries, in order to increase the efficiency of cassava research with the goal of improving the productivity and utilization of the crop. This will ultimately contribute to increased incomes and improvements in the standard of living of cassava producers, processors and consumers.

To further enhance communication among cassava researchers in Asia, the CIAT Regional Office has organized Regional Cassava Workshops every three years. These workshops bring together many cassava researchers from different countries in Asia, who present the latest progress in their research, mainly in the areas of cassava breeding and soil/crop management or agronomy. The first workshop was held in Bangkok in 1984 to review the general situation of cassava in Asia, to identify the major constraints and set research priorities. The second workshop was held in Rayong, Thailand in 1987 to review the first year's results in cassava crop improvement and to summarize all agronomic research that had been conducted prior to that date by national programs. From this review it was concluded that future agronomic research in Asia should emphasize mainly the maintenance and improvement of soil fertility and the effective control of soil erosion. The third workshop was held in Malang, Indonesia in 1990. This workshop not only reviewed the recent progress in cassava breeding and agronomy, but also research on cassava utilization, both for human and animal consumption as well as for industrial usage. The fourth workshop was held in Trivandrum, Kerala, India in 1993 to review the latest progress in breeding and agronomy, as well as to discuss more effective ways to transfer the new technologies to farmers in order to achieve adoption and impact. In this workshop extension specialists from several countries were invited to share their experiences and to join the researchers in the cassava network. This will further enhance the adoption of many new cassava varieties that have recently been released, as well as that of new and more sustainable production practices. The workshop was also an opportunity to discuss a proposal, submitted for funding to the Nippon Foundation in Japan, to develop a Farmer Participatory Research (FPR) methodology, mainly to enhance the adoption of more sustainable management practices in cassava-based cropping systems in Asia. The Nippon foundation approved the project in late 1993 for a five-year period. It has funded all activities in the area of cassava soil/crop management research, farmer participatory research and training in FPR methodologies.

The fifth workshop was held at CATAS in Danzhou, Hainan, China in November 1996. Besides reviewing further progress in cassava varietal improvement and disemmination as well as agronomy research, it provided an opportunity to present and discuss the first results of the FPR projects conducted in several pilot sites in various countries in Asia. Based on these experiences future activities in the project were discussed. The papers presented in this 5th Regional Workshop are published in this Proceedings.

During the fifth Regional Workshop in China the Advisory Committee for the Asian Cassava Research Network met to discuss research priorities, the future outlook for cassava research in Asia, and to decide on the theme, location and time for the Sixth Regional Workshop. During this meeting the following members were elected:

Pham Van Bien	IAS, Vietnam:	Chairman
Kazuo Kawano	CIAT, Thailand:	Secretary
Zheng Xueqin	CATAS, China	
G.T. Kurup	CTCRI, India	
Soemarjo Poespodarsono	Brawijaya Univ, Indonesia	
Tan Swee Lian	MARDI, Malaysia	
Fernando Evangelio	PRCRTC, Philippines	
Charn Tiraporn	DOA, Thailand	
Reinhardt Howeler	CIAT, Thailand	

During the meeting it was decided to organize the sixth workshop in Ho Chi Minh city, Vietnam at the end of 1999.

CIAT wants to take this opportunity to express its gratitude to the Nippon Foundation and the Government of Japan for their financial support, not only for funding the collaborative research and extension activities reported here, but also the organization of the fifth Workshop in China. Without their financial support the Asian Cassava Research Network would not be sustainable.

We also like to thank all the members of the organizing committee, mainly from CATAS, for their hard work and dedication in organizing this event. In spite of unusually wet weather, they managed to organize an interesting field day to Kongba village in Baisha county. All workshop participants also much appreciated the excellent facilities and organization of the workshop, and especially, the delicious Chinese food. Many thanks to all for their hard work.

R.H. Howeler
CIAT, Bangkok
April 1998

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TRENDS, CONSTRAINTS AND OPPORTUNITIES OF THE ASIAN CASSAVA SECTOR: AN ASSESSMENT[1]

Guy Henry[2] and *Clair Hershey*[3]

ABSTRACT

This paper attempts to utilize past cassava production, utilization and market trends, integrated with regional macro-economic developments, together with a general summary of current cassava R&D advances, to analyze the principal cassava sector constraints and future opportunities, both at the country and regional level.

The first section shows where the major cassava production and utilization areas are and secondly assesses cassava area, yield and production trends from 1980-95 by region and specific countries (cases), explaining past trends due to a variety of factors, including climatological, biological, technological (R&D), political and macro-economic aspects.

The second section concentrates on the dynamics of cassava processing, products and markets, analyzing the major cassava product groups, i.e. cassava for fresh direct consumption, flours, dried cassava chips and pellets for animal feeds, and cassava starches. Evidence will be presented to show the significant increases of starch production *versus* relative declines in pellets. Macro-policy changes, expanded market demand, technology advances and relative price changes are some of the major factors explaining these recent developments.

The third section of the paper assesses regional, market (and country) cassava sector constraints which are stratified into four areas: (a) biological/technical aspects, (b) socio-economic aspects, (c) institutional aspects, and (d) political aspects. For some of the aspects quantitative evidence is presented; other aspects are more qualitatively assessed. After this, the most significant future opportunities are analyzed. These are grouped into three areas: (a) technological, (b) market, and (c) institutional/political.

The paper ends with the major conclusions and makes several recommendations.

CASSAVA PRODUCTION AND SYSTEMS TRENDS

The Asian continent currently produces about 46 million metric tons (t) of cassava on 3.5 million hectares (1996). As such, it occupies second place in terms of global cassava production, and first place in yield (13-14 t/ha). Two-thirds of total production originates in Thailand and Indonesia alone. Seven countries account for 99% of the region's production: Thailand, Indonesia, India, China, Vietnam, the Philippines and Malaysia (**Table 1**). About 40% of cassava is used for direct human consumption, especially in processed form. Most of the remainder is destined for animal feed or processed for starch (FAOSTAT, 1997).

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[1] This document draws significantly on papers treating the same subject by Henry and Gottret (1996) and Hershey *et al.* (1997).

[2] Economist, CIRAD-PROAMYL, Montpellier, France; formerly Economist, Cassava Program, CIAT, Cali, Colombia.

[3] Consultant, Manheim, PA, USA; formerly Plant Breeder, Cassava Program, CIAT, Cali, Colombia.

Table 1. Cassava area, yield and production in Asia in 1996.

	Area (ha)	Yield (t/ha)	Production (t)
Brunei	130	11.5	1,500
Cambodia	12,500	7.2	90,000
China	230,080	15.2	3,501,070
India	244,000	24.5	5,979,000
Indonesia	1,300,000	13.1	17,002,500
Laos	5,000	13.7	68,500
Malaysia	39,000	10.3	400,000
Maldives	8	2.5	20
Myanmar	7,300	9.3	68,000
Philippines	215,000	8.8	1,900,000
Singapore	1	10.0	10
Sri Lanka	32,000	9.1	290,000
Thailand	1,265,100	14.3	18,083,600
Vietnam	275,600	7.5	2,067,300
ASIA	**3,625,719**	**13.6**	**49,451,500**

Source: FAOSTAT, 1998

During the past decade, Asian cassava production experienced a growth rate of 0.30% per year. While cassava area experienced a decrease (-0.20%), yields increased at an annual rate of 0.50%. From the 1980s to the present, the main influences on cassava production and commerce were rapid growth in many Asian economies with accompanying changes in food consumption patterns; increased demand from industry for raw products such as starch; and increasing implementation of trade policies that reduced cassava's preferential treatment in European markets. Except for a few products such as *krupuk* in Indonesia, cassava generally enters markets where other calorie or industrial starch sources may readily be substituted. Future growth, therefore, is largely linked to cost competitiveness, or markets that require specific characteristics that only cassava provides.

Thailand, is a cassava processed-product export-led country. Nearly all cassava is grown on small farms of one to five hectares. Chipping and drying is done in nearby commercial drying floors, while processing for starch is generally done in large factories. The pellet export industry is heavily dependent on the middle-men who are usually owners of trucks or drying floors, who consolidate production from these small farms into processing and marketing channels. The various events that have led Thailand's cassava industrialization development are well described by Titapiwatanakun (1996), Henry and Gottret (1996), and Hershey *et al*. (1997). During the last decade, Thailand has experienced a major diversification of its cassava product and market mix. While up to the early 80's pellets represented 88% of cassava exports (almost entirely to the EU), the pellet share by 1992 was down to 72% and continues to decrease, in favor of starch. Furthermore, Thai starch factories are increasingly producing modified starches rather than lower valued native starch. Total production peaked at 24 million tons in 1989 and decreased to 18 million tons in 1996 (**Figure 1**).

For many years a single variety, Rayong 1, occupied almost 100% of the country's area. This began changing in the mid-1980s as new hybrids gained popularity due to market premium assigned to higher starch content. By 1996, new hybrids from the cassava programs of the Dept. of Agriculture and of Kasetsart University extended over about one-fourth of the total area. Private industry (mainly starch factories) and national extension services play an important role in promotion and distribution of new technology. Mechanized land preparation, fertilizer application, and mechanical or chemical weed control are now common.

Despite the adoption of new varieties, Thai cassava yields show only a 0.12% annual increase during the last decade (Henry and Gottret, 1996). This low figure is due to a large extent to a shift of cassava production to more marginal areas, and because of reduced fertilization as a consequence of depressed starch and pellet market prices. Reduced fertilization on soils that have been monocropped for many years will show adverse effects on yield, nothwithstanding improved varieties.

In **Indonesia,** the relatively stable area of planting across years is a function of market diversity and comparative advantage in upland environments not suited for rice. The multi-use characteristics are fully exploited and provide a range of market options to stabilize prices. The traditional products in the internal markets are *gaplek* (dried cassava chunks used in a variety of local dishes), and *krupuk*, a crispy snack wafer made from cassava starch.

Production systems in Indonesia are in general more complex than elsewhere in Asia. Intercropping is common, especially where there are not severe soil and water constraints. Common intercrops are upland rice, maize and various legumes. On the outer islands rainfall is usually less limiting, but poor soils are sometimes a constraint on the ability to intercrop cereals and legumes. On Java, farms are small and intensively managed, with few purchased inputs. The starch industry in Sumatra is based on large, vertically integrated plantations where moderate input levels are applied, and new high-yielding varieties planted. These industries have joined with the national program in supporting production research, which has benefitted surrounding small independent farmers as well as the plantations. The effects are becoming clear when analyzing production trends. Over the last decade, production grew with a healthy annual 1.2-1.4% (**Figure 1**), this growth being attributed to both increases in area (1.0%) and yield (0.36%) (Henry and Gottret, 1996). Nonetheless, large areas of Indonesia have suffered severe droughts during the past five years, and this is again the case in the 1997/98 season. Although this will much less effect cassava (relative to rice, etc.), production for 1998 is estimated to be down from earlier years (FAO, 1997).

Cassava cultivation in **India** is concentrated in the southern states of Kerala and Tamil Nadu. The country is distinguished by the world's highest average cassava yields, about 24 t/ha. These high yields are accomplished by intensive cultivation, and, in Tamil Nadu, by irrigation. In Kerala, much of the production is consumed as boiled roots, one of the few regions in Asia where this is common. Cooking quality is one of the principal criteria farmers use in selecting varieties for cultivation. In Tamil Nadu nearly all of the production is for starch and sago. Markets for fresh consumption have been slumped during several years, drawing attention to the need for product and/or market diversification. This trend has affected the planted area to cassava, which shows an annual decline of more than 2%. Hence, less area, but with increasing productivity.

China produces cassava in the southern provinces of Guangxi, Guangdong, and Hainan (and more recently in Yunnan). Most is planted with few production inputs on hillsides surrounding rice paddies. Historically cassava was a famine reserve crop, planted in marginal areas with high risk of crop failure. Production data from China are not very reliable, but according to FAO, area peaked at 245,000 ha in 1983. Although a minor crop in China as a whole, it is increasingly looked upon as an efficient producer of raw material for starch and on-farm pig feeding. Nonetheless, its area is under severe pressure from competing higher-value crops (fruit trees) and alternative land use.

Like Indonesia, **the Philippines** is a multi-island economy, but differs in that population is spread more uniformly across different islands. Cassava fits well within an agricultural policy that emphasizes self sufficiency in basic foods (except wheat), import substitution, and development of the small farm sector. Cassava is produced throughout the Philippines, but is more concentrated on the southern islands, especially the Visayas region and Mindanao. Most production is on small farms, although there are some large plantations supplying starch factories. Input use is low in comparison to other countries, and this is reflected in some of the lowest yields in Asia. Nonetheless, yields in the past ten years have climbed steadily from about 7 to about 9 t/ha, suggesting adoption of improved varieties and cultural practices. Cassava area has increased steadily, from about 200,000 ha in 1984 to 215,000 ha in 1996.

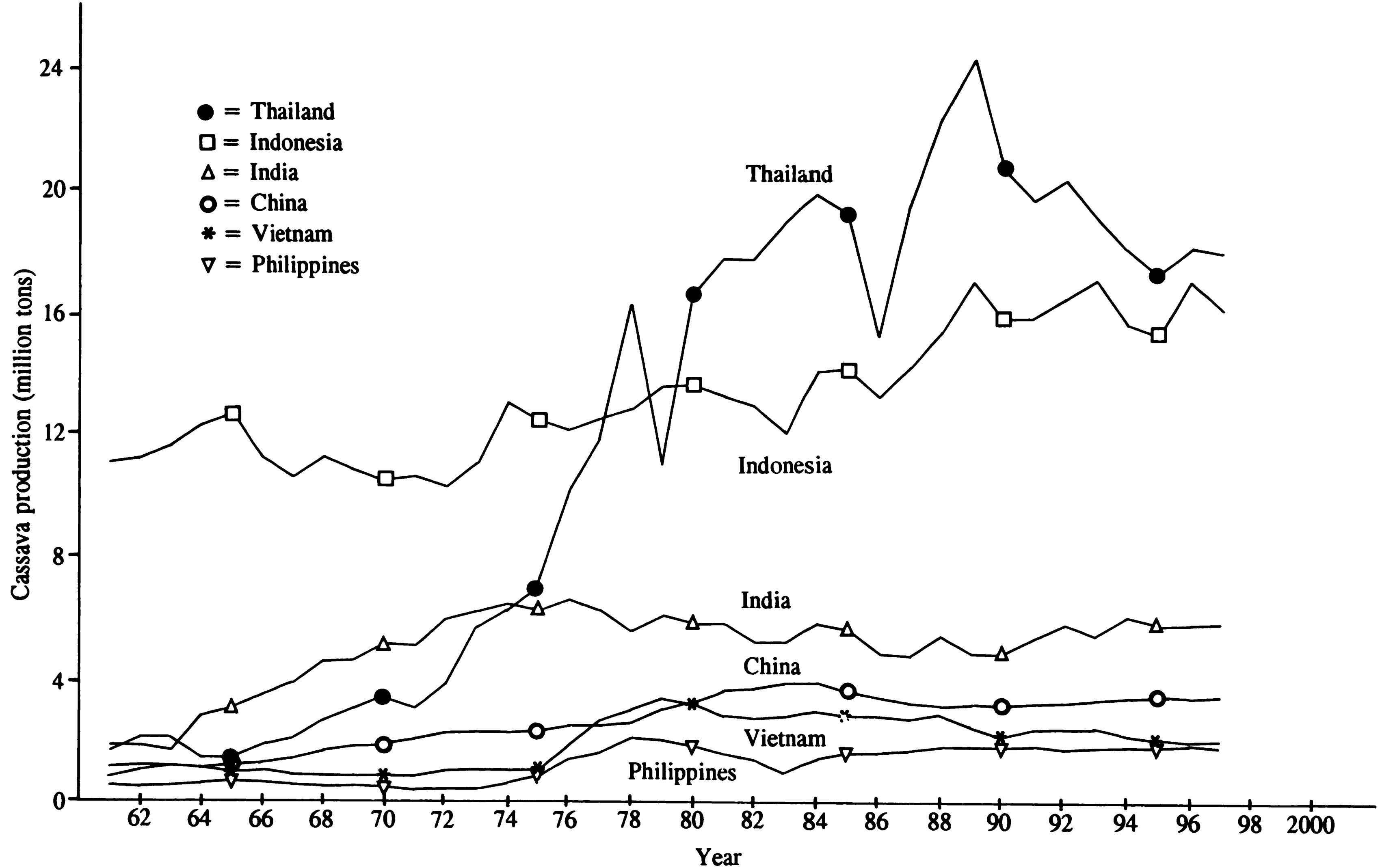

Figure 1. Cassava production trends in Asia's principal producing countries from 1961 to 1997.
Source: *FAOSTAT, 1998.*

In **Vietnam**, the area planted to cassava peaked in 1979 at 460,000 ha, but then declined to nearly half that level because of lack of markets and competition from other crops. It occupies the poor soils of mountainous and hilly areas, mainly in monoculture systems. Since many of these soils are highly erodible, their recuperation and conservation is currently a major research thrust. In early years, most of the plantings served as a food security crop, but human consumption now occupies only 10-20% of production. About 30% is used as animal feed, much of it on-farm for chickens and pigs, after chipping, drying and milling the roots. Industrial uses are on the increase as Vietnam undergoes rapid economic development. Industry now absorbs about 30-40% and this is rising. New varieties, mainly introduced from Thailand's breeding programs, and diffused with help from large-scale starch processors, are gaining popularity, especially in the South, for their high yield potential and high starch content. While cassava data do not show this yet, it is expected that these new varieties will increase yields significantly in the future. Cassava areas in Vietnam are shifting away from (semi)urban zones towards "waste lands" and more marginal areas. Due to high industral demand for cassava and changes in "land property" laws, the average cassava area (per farmer) in the South is increasing.

PRODUCT AND MARKET TRENDS

Diversity is the defining characteristic of cassava products and markets in Asia, both within and across countries. About 40% of cassava in the region is destined for human consumption (FAOSTAT, 1997). In Indonesia, the level is about two-thirds. Most of the remainder is processed for industrial purposes, principally chips for animal feed, and starch. Raw roots are not traded on any significant scale. The initial processing defines to some degree the market sector to which roots can be destined. This is unlike the grains such as maize which are traded as whole, unprocessed grain, to be converted into any number of products in the receiving country.

Fresh for Human Consumption

Outside of Kerala, India, and some poorer (isolated) districts of China and Vietnam, nearly all cassava for food is first processed; direct consumption of baked or boiled fresh roots is minor. This form of consumption is largely a rural practice, and often by households having their own backyard garden. Fresh consumption will decline with increasing incomes, urbanization, changes in dietary preferences and increasing opportunity cost for cassava from emerging alternative (processed) cassava markets. It must be noted, however, that cassava will remain a crop representing an on-farm reserve emergency crop (for human consumption) in times of rice shortfall, as for example, has been observed in Indonesia.

Chips and Pellets for Animal Feed

The cassava pellet industry peaked at the end of the 1980s. Since then total volume has decreased, mainly affecting Thailand[4] (**Table 2, Figure 2**). The reduced exports to the European Union (EU) have only partly been offset by a concerted effort to penetrate new, non-EU markets. During the early 90s a further shock was delivered to EU-destined cassava exports, as a result of changes in the Common Agricultural Policy (CAP), lowering internal EU feed grain prices. Nonetheless, although export prices (and profits) have been reduced significantly, Thai pellets still can compete with EU internal (barley) prices. Moreover, due to the 1997/98 baht devaluation, the pellet exports' price edge will gain. It is doubtfull that pellet production will significantly rebound in the future, since domestic competition for roots from the starch factories (who enjoy bigger margins) is very strong.

Table 2. World trade of cassava products (chips, pellets and starch).

	1992-94 Avg.	1994	1995	1996
	——million metric tons——			
World exports	**9.8**	**7.2**	**5.4**	**6.4**
-Thailand	8.3	5.9	4.1	5.0
-Indonesia	1.1	0.7	0.5	0.6
-China & Taiwan	0.3	0.4	0.4	0.4
-Others	0.1	0.1	0.4	0.4
World imports	**9.7**	**7.2**	**5.4**	**6.4**
-EU	6.5	5.2	3.2	3.8
-China & Taiwan	0.9	0.6	0.7	0.6
-Japan	0.5	0.3	0.4	0.4
-Korea, Rep. of	0.7	0.4	0.3	0.4
-Other	1.1	0.6	0.8	1.2

Source: FAO Commodity Market Review 1996-97

[4] For a complete treatise on this subject, see Titapiwatanakun (1996), Henry and Gottret (1996) and Hershey *et al.* (1997), among others.

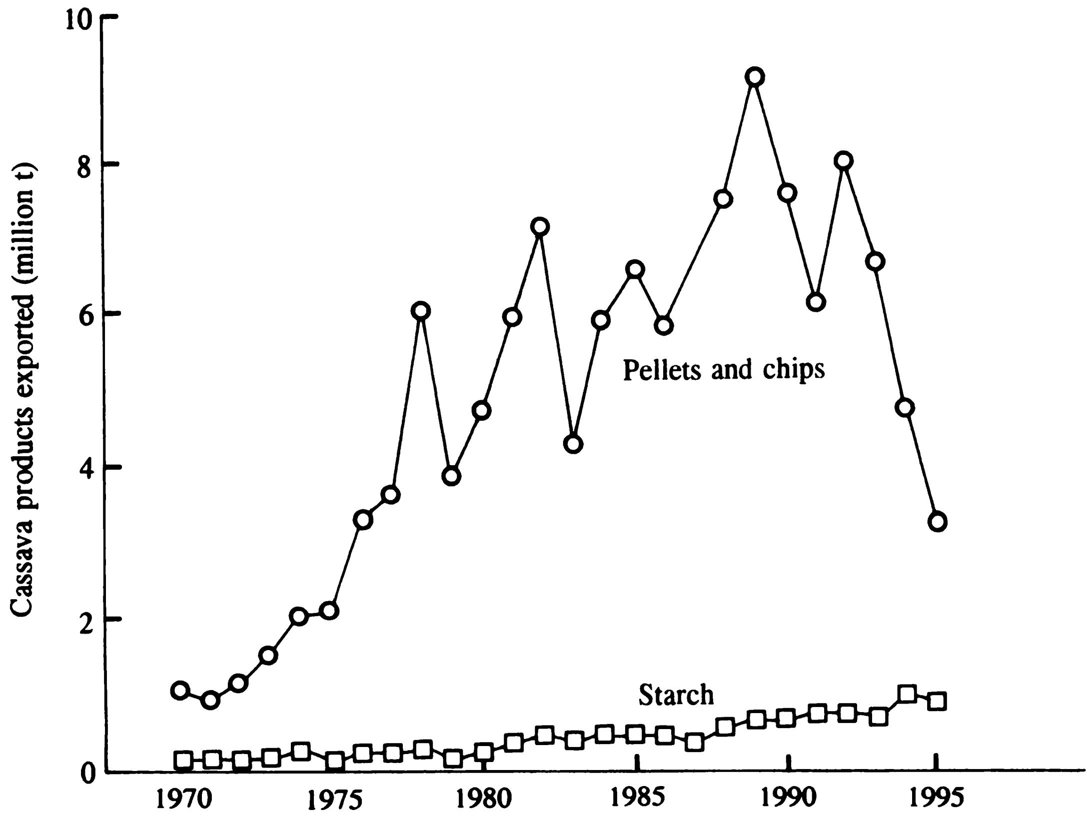

Figure 2. Exports of cassava products from Thailand between 1970 and 1995.
***Source:** Thai Tapioca Trade Association*

Starch

Starch for industry is classified as *native* or *modified*. The technology for modifying starches by physical, chemical or biological processes is highly advanced and evolving rapidly, and modified starches are absorbing an increasing market share. Starch-derived products include sweeteners (high fructose syrup, glucose syrup), dextrins, monosodium glutamate, pharmaceuticals and various chemicals. Starch is used in large quantities in the manufacture of paper, plywood, textiles, and as a filler/stabilizer in processed foods. New products from starch are continually entering the marketplace. Throughout the region, the industry is moving toward larger, more technologically advanced plants, and small, less efficient factories are closing. Furthermore, an increasing trend can be seen in Thailand, Vietnam and China of joint ventures with large international companies from US, Europe, Taiwan, Korea, Japan, etc. Multinational food companies with traditionally corn or potato starch based interest have started to aggressively diversify into cassava starch manufacturing.

Thailand is leading the Asian *starch boom* (**Figure 2**), surpassing Indonesia in recent years. Both export sales and domestic use have increased significantly. The focus for exports has been on modified starches, partly for the larger profit margins and partly to get around some of the import barriers imposed against native starch. Nonetheless, the increase in starch exports has not nearly kept pace with the decline in pellet exports. Private and public sectors are cooperating to identify and exploit internal growth markets for starch as a complementary strategy to export-orientation.

Indonesia's starch production is utilized mainly in internal markets. Nearly two-thirds goes into *krupuk*. Because of the specific starch characteristics required for this product, maize starch is not a competitor. This gives some insulation from the fluctuations of world starch prices. Growing demand in the near future is envisioned from paper, cardboard and plywood industries. Both China and Vietnam have significantly expanded and modernized their starch industries. Monosodium glutamate and glucose are rapidly growing markets in both countries. Foreign investors are drawn to the "newly opened" countries (Vietnam, Cambodia and Laos) to profit from the relatively cheap factors of production, land and labor, to invest in large-scale starch industries.

Flour

Cassava flours come in many forms. The most common is *gaplek* in Indonesia. Roots are peeled, chipped or sliced, and then dried. The dried chunks are ground or milled to a meal, which is used in a wide array of food preparations. It is consumed especially in times of rice scarcity, and partially substitutes for rice in rural daily diets. Cassava flour may partially substitute for wheat flour in bakery and other products. This is still minor in Asia, but is reported unofficially from several countries (Henry and Gottret, 1996).

CASSAVA DEMAND PROJECTIONS

Thailand's continuing campaign to reduce its dependency on the European animal feed market will dominate directions of the Asian cassava sector for the next decade. This will take several forms: introducing new production technologies to keep prices competitive with alternative energy sources; aggressively seeking new markets outside Europe; development of internal feed markets; and further diversification into starch and flour, with strong support for research on new processes and products. Other countries of the region, once with aspirations to penetrate export markets for pellets, are now recognizing that opportunities will depend very much on increasing production and processing efficiencies.

Prospects for starch vary widely depending on the specific market. For native starch, the different sources (maize, cassava, sweet potato, white potato) compete with one another on the basis of price. The markets for specialized starch are rather uncertain. On the one hand there is increasing demand, but on the other, there is a continually evolving technology for modifying starches to meet specific product properties. Ostertag (1996) suggests that most developing countries will use their resources most effectively by first concentrating on developing internal starch markets, in order to reduce the risks inherent in the export sector.

In a recent study of the major tropical root crops, Rosegrant and Gerpacio (1997) of the International Food Policy Research Institute (IFPRI) have projected cassava production and utilization in the year 2020, based on a model that takes into account virtually all the world's food production and consumption (International Model for Policy Analysis of Commodities and Trade (IMPACT). They foresee that moderate demand growth for cassava products in Asia through 2020 will sustain viable cassava-based development. The growth sectors vary within the region. In China, growth in feed demand will be among the strongest anywhere, at 2.08% per year, accompanied by a continuing trend for lower direct use as food. Southeast Asia should see healthy growth in all sectors, i.e. 1.4% in food, 0.13% for feed, and a total of 1.25% (including industrial use) (**Table 3**). The import demand in the non-cassava producing countries of East Asia will rise at 1.0% per year, providing some additional market possibilities.

SECTOR CONSTRAINTS AND OPPORTUNITIES

Various factors will define cassava's potential as a catalyst for further evelopment in Asia. These factors can be grouped in the domains of *policy, market economics, institutional issues and technology*. However, the majority of important constraints/opportunities deal with overlapping domains.

Policy

The policy arena more than any other will set the stage for cassava's role in Asia. Both agricultural policy as well as broader economic policies impact the cassava sector. Distortions in input and output markets, asset ownership, and other institutional and market distortions adverse to the poor must be minimized. Government policy interventions can be divided into direct (impacting on the cassava sector) and indirect policies. The former includes fertilizer subsidies, credits, crop substitution schemes, import tariffs and quotas, etc. The latter includes similar interventions but on other crops (cassava substitutes or complements), that in turn will have an effect on the cassava sector, such as interventions on feedgrains, foodgrains, etc. Furthermore, there exist domestic and foreign policies. For Asian cassava sectors, history has shown that direct and indirect foreign trade policies have had relatively more impact than any other interventions. There is no indication that this will be significantly different in the future.

Table 3. Projected production and utilization of cassava[a] in 2020.

	Growth rate for utilization 1993-2020 (%/year)			Utilization in 2020 (million t)	Production in 2020 (million t)
	Food	Feed	Total		
China	-1.27	2.08	1.19	3.9	4.2
India	1.00	0.00	1.00	7.6	7.8
Other East Asia	-0.95	1.09	0.63	3.5	0.0
Other South Asia	1.00	0.00	0.83	0.6	0.6
Southeast Asia	1.40	0.13	1.25	27.0	51.1
Latin America	0.26	1.26	0.78	39.3	40.5
Sub-Saharan Africa	2.51	0.29	2.47	166.0	166.0
Developing	2.01	1.18	1.88	248.8	271.1

Liberalized trade has become the economic mantra of the 1990s. The watershed Uruguay round of multilateral trade negotiations, under the auspices of the General Agreement on Tariffs and Trade (GATT), is a fundamental influence on the direction of the global economy. Trade liberalization will bring complex and unpredictable adjustments in the agricultural sector. The implementation of regional trade agreements is well-advanced in Asia. The Asia Pacific Economic Co-operation forum (APEC) has 18 members, which in total comprise half the world economy. Most of the major cassava-producing countries of the region (excepting India) are members. APEC aims to achieve free and open trade and investment by 2010 for its industrialized members and by 2020 for the others. Hence, the future implications include decreased barriers within the APEC trading bloc. This implies for example that protected markets like Japan, would be more accesible for starch exports. On the other hand, EU policies continue to evolve especially regarding Asian pellet exports, and this will be crucial for the future. Careful monitoring, anticipation and timely actions are important.

Market Economics

Stabilizing or increasing demand in an environment of freer trade will depend on the ability of the industry to respond quickly to shifts in product demand of traditional markets, and analysis and subsequent penetration of new markets.

The overwhelming preference for rice as the starchy staple, and the increasing demand for meat, will keep *per capita* cassava consumption levels low throughout Asia. This growth in meat consumption, however, is the basis for projecting strong potential to use cassava for on-farm feeding, or in balanced rations, for pigs and chickens. Already, a clear increasing trend is identified of on-farm pig feeding (including cassava chips or processing waste) in many sub-urban areas of southern China and Vietnam, to satisfy the rapidly growing demand for pork in urban populations.

Cassava's competitive position in national and international markets is closely linked to internal and world supplies and market prices of alternative commodities or products. Because of cassava's versatility, it may compete with a range of products in different markets. In the market for balanced feed rations, cassava in dried chip or pellet form competes mainly with sorghum or maize, and sometimes barley. In world markets, maize is the principal source of starch. In the principal cassava-producing countries of Southeast Asia, rice, maize and cassava production all increased three to five-fold in the past twenty-five years. Even this dramatic success, however, was not adequate for supplying the food needs of growing and somewhat more affluent populations. Grain imports, especially of wheat and maize rose from near zero in 1960 to 17 million tons in 1995. The challenge for cassava products will lie in remaining competitive following decreasing grain prices. This must be accomplished by reducing production and processing costs, but especially the former. The current devaluation of many national currencies in SE-Asia may have severe negative effects for their economic development, but it may be a blessing in disguise for their cassava product exports.

Besides price, fortunately, specific intrinsic cassava starch characteristics command a premium, or constitute an edge over potato or maize, in many upstream modified starch-based products. Although these industries are extremely competitive and secretive, they also can be very lucrative. The identification and penetration of these markets will take a concerted technology and marketing R&D effort.

Infrastructure

Subsistence farming requires virtually no infrastructure, no need for purchased inputs, and no need for highways for reaching markets. Commercial agriculture, on the other hand, depends heavily on infrastructure. The World Bank notes that rapid economic expansion and urbanization have outstripped the capacity of existing infrastructure, and created serious impediments to further investments and growth. Insufficient electricity generation capacity, outdated and inadequate telecommunications facilities, poor roads and inefficient ports are the most crucial infrastructure problems. Purchased inputs for agriculture are for the most part available, but may not be used on cassava because of other constraints. There is little likelihood of major investment in infrastructure aimed solely at supporting cassava development, but the general development of the region will bring benefits to cassava production, processing and marketing.

Technology Development

Technology development includes the identification, generation and adaptation of technology components suitable for alleviating the principal constraints of cassava production, processing and marketing domains. Besides the alleviation of constraints, technology must target opportunities that are presented through careful analysis.

Henry and Gottret (1996) and Van Norel (1997) analyzed and quantified the principal cassava production constraints in Asia. Hershey *et al.* (1997) adapted and summarized the results, shown in **Table 4**. Based on these and other findings, **Table 5** shows an assessment of expected impact on (a) income, equity and food security, and (b) the environment, by R&D intervention. As such, policy makers, investors and R&D agencies can more specifically target desired technology options.

Technology Transfer

Technology transfer for cassava is often a bottleneck to achieving impact. Transfer may fail either because the techniques are inappropriate or insufficient, or the technology itself may not be acceptable. Both have had a significant role in Asia; both are amenable to correction and improvement. In a well-functioning system, information flows both ways between the producer and the user of new technology. It is in this sense that technology transfer has an *integrative function* for the entire production, processing and utilization system.

Technology transfer is normally considered an institutional function, the act of moving technology from the hands of science to the fields or factories of end-users, by a public extension service, or by private companies aiming at making a profit. Few of the conventional resources or practices exist at adequate levels for cassava. Virtually all programs in Asia report that extension services for cassava do not function optimally, and some barely at all (CIAT, 1995). In this environment, many programs have used unconventional and creative means to fill the gap left by institutional deficiencies.

The Department of Agriculture in Thailand uses three separate channels for its highly successful transfer of new cassava varieties: direct transfer to farmers, mainly by way of on-farm regional trials and demonstration plots; through chip and starch factories, who promote new varieties to upgrade the quality of the raw product available; and the more traditional extension service methods. In Indonesia and especially in Vietnam, starch factories have also complemented the extension service to multiply and distribute new varieties. India has the most structured technology transfer system, and in general a better staffed public service sector than most countries. They have been able to achieve impact both with new varieties and agronomic practices.

The cassava sector has the opportunity to be at the forefront of designing and testing unconventional technology transfer systems. The lack of institutional resources has already motivated public and private partnerships, and an array of other means to get technology to end-users. A survey of methods that have succeeded and those that have failed, and brainstorming about future planning, could be a highly useful exercise for Asia, and with implications elsewhere.

Table 4. Cassava constraints analysis for Asia, with comparison to global[1].

Constraints	Yield gain in affected area(%)	Area affected (%)	Total yield gain (%)	Total yield gain ('000 tons)	Total yield gain as % of global[2]
Soil Management			**35**	**17,067**	**36**
Low soil fertility	32	68	22	10,690	32
Soil erosion	17	60	10	5,039	43
Surface temperature	11	26	3	1,338	62
Crop Management			**21**	**10,291**	**22**
Sub-opt. land preparation	8	33	3	1,262	22
Quality of planting material	17	48	8	3,958	19
Inadequate spacing	8	47	4	1,853	30
Weeds	18	37	7	3,218	23
Intrinsic varietal traits			**24**	**11,384**	**31**
Low yield potential vars.	26	89	24	11,384	31
Climate			**11**	**5,153**	**25**
Drought	16	58	9	4,496	26
Low winter temperature	0	8	1	658	54
Diseases			**2**	**929**	**3**
Root rots	6	5	0	151	5
Bacterial blight	6	19	1	553	6
Anthracnose	2	15	0	132	5
ICMV	6	3	0	92	1
Other leaf/stem pathogens	0	82	2	1,042	30
Pests			**3**	**1,478**	**7**
Green and red spider mites	6	38	2	1,112	9
Mealybug	2	2	0	16	0
Whitefly	4	3	0	51	10
Termites	2	3	0	33	5
Mammalian pests	5	2	0	46	3
Scale insects	5	9	0	211	52
Tipacola plagiata	11	0	0	9	100
Total potential production increase		**96**	**46,301**	**23**	
Post-harvest			**21**	**9,923**	**32**
Quality	22	60	13	6,390	31
Processing	15	24	4	1,806	30
Product marketing	20	18	4	1,727	47
Total cassava sector			**116**	**56,224**	**24**

[1] Other constraints with near zero potential yield gain are excluded from the table.
[2] Total yield gain in Asia as percent of global yield gain.
***Source:** adapted from Henry and Gottret, 1996.*

Table 5. Examples of technologies and methodologies to alleviate poverty, enhance food security and protect the environment.

Situation	Description or cause	Technology or methodology available	Positive impact of technology on[1)]: Income, equity or food security	Positive impact of technology on[1)]: The environment	Remaining constraints or opportunities
Marginal and fragile production environments	Low soil fertility; acid soils	Fertilizer application; use of animal and green manures	***	**	Credit for input purchases; high labor demand
		Adapted and nutrient-efficient germplasm; cropping systems management	**	**	Effective varietal distribution; farmer participatory research
	Steep slopes; erodible soils	Fertilizer; minimum tillage; contour-ridging; live barriers; high yielding early-vigor varieties; mulching; closer spacing	*	***	Farmer education on consequences of erosion; Short-term profitability as incentive for adoption
	Low or erratic rainfall	Drought tolerant germplasm; soil/water conservation (e.g. mulches)	**	*	Mulch availability and transport costs
Intrinsic varietal traits	Low yield potential	High-yielding hybrids	***	*	Effective varietal distribution; fine-tuning for specific environments and markets
	Low multiplication rate	Stem treatment and storage technology; rapid propagation techniques	**		Rapid propagation methods appropriate for commercial scale application
Biological constraints	Native or introduced pests or diseases	IPM (host plant resistance, biological control, chemical control, crop management)	*	*	Monitoring potential threats of new introductions or outbreaks; Contingency plans
	Weeds	Mechanization; herbicides	*		Credit for input purchases; mechanical weed control adapted to small farms; herbicide-resistant varieties

1) * = low; ** = moderate; *** = high

Table 5 (Cont.)

Situation	Description or cause	Technology or methodology available	Positive impact of technology on[1)]: Income, equity or food security	Positive impact of technology on[1)]: The environment	Remaining constraints or opportunities
Processing constraints	Low processing efficiency	Mechanization; high-starch varieties	**		
	Pollution from products and waste-water	Microbial treatment, recycling; water treatment; value added re-processing		***	Economic wastewater treatment; selection of efficient microbes; new uses for byproducts
	Low or variable product quality	Stable varieties; crop management; harvest and post-harvest management	**		Economical pre- and post-harvest management practices; extended shelf life by genetic means
	Convenience; ease of handling	Processing to reduce bulkiness, add value, and extend storage	**		Cassava-based convenience foods; transfer technologies developed elsewhere
Marketing constraints	Low product demand; low prices	Value-added products	***		Analytical methods to anticipate market shifts; develop new value-added products
	Transportation and market channels underdeveloped	Processing to transform product to higher value (e.g. reduce water content)	**		Infrastructure development; new value-added products
	Irregular product supply to fill demand	Coordinated harvests among growers; conversion to more storable intermediate products	**		Varieties of differing maturities; long-term storage technology (genetic or management)

[1)] * = low; ** = moderate; *** = high

Integrating the System and the Actors

Basic economic theory and experience show that changes in production, processing and marketing of cassava need to be integrated and coordinated to provide broad benefits across the system. Increased production in a constrained market simply depresses prices for producers. Expanded markets without ability to increase production capacity can restrain market growth due to excessive price increases. New or more efficient processing may be needed to fit the demands of new markets, or to process increased volumes of raw materials. Unless the integration of these phases are anticipated during the technology development process, the products of research and development will not be implemented in an optimal manner.

Both producers and consumers hope for some imbalance in the supply/demand dynamics. Naturally, these hopes extend in different directions, i.e. producers want excess demand to raise farm-level prices, and consumers hope for excess supply to depress prices. At the same time, both recognize their own long-term financial health depends on that of the other, i.e. supply and demand are in dynamic balance.

Even though the markets for cassava are much better developed in Asia than in either Africa or Latin America, attention to the continued balance in production, processing and marketing is warranted. The integration of actors -- R&D institutions, farmers, processors, marketers and consumers -- does not always develop optimally in a *laissez faire* atmosphere. The integrated project experiences in Latin America are a valuable lesson with high potential for application in Asia as production systems and markets undergo rapid changes (Ospina *et al.*, 1996).

Instutional Aspects

While the preceeding section treats the integration of stakeholders at the sector level, a similar integration is required at the the institutional level. Who are the main players or stakeholders here? They include foremost: national governments, (national and international) R&D agencies and networks, extension services, private sector, NGOs, farmer/processor/trader associations or representative bodies, and donor agencies. Because of different goals, several of these stakeholder groups may have different priorities and interests. However, the challenge lies in integrating these different actors around a common cause and action agenda, whereby individual tasks should be divided according to relative comparative advantages. A case in point is the on-going IFAD spearheaded *Global Cassava Strategy* process. Since 1996, a series of activities co-conducted by a large variety of principal cassava stakeholders (national and international) are gearing towards the formulation and implementation of a globally acceptable co-owned cassava strategy. As such, the final (end of 1998) result is expected to be a common cassava agenda (globally and regionally) that will be shared and acted upon by àctors on the demand side (demands and opportunities of the sectors) and the supply side (governments, R&D agencies, networks, donors, ...).

Information Management and Communications Technology

Asia as a whole has relatively advanced communications systems. This can have a large impact on integrating the components of a research and development system, especially if policymakers, researchers, development specialists, farmers, processors, marketers, and industry managers are all linked together. The internet makes this possible in ways that were not remotely possible just a decade ago. A very important use of the internet is to diffuse information regarding technology, technology generators and diffusers, farm and market products, volumes and prices, financing opportunities, etc. On the one hand, improved and timely information diffusion will strengthen marketing efficiency and technology diffusion, on the other hand, it offers an opportunity to better integrate (supply and demand of) the different actors in the cassava arena.

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PROGRESS IN CASSAVA BREEDING AT THE CHINESE ACADEMY OF TROPICAL AND AGRIC. SCIENCES (CATAS)

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ABSTRACT

During the past 16 years the Chinese Academy of Tropical and Agricultural Sciences (CATAS) has made good progress in developing improved cassava varieties for China. Several improved varieties have been released in south China, of which cv. SC124, with high yield and good cold resistance, is already being planted on a large scale, mainly in Guangxi and Yunnan provinces. SC8002, which is characterized by a high yield potential and tolerance to cold, has mainly been released in Guangdong province, while SC8013, with high yield and good wind resistance, is being multiplied for planting in the typhoon affected areas of Hainan and Zhanjiang district of Guangdong. The release of these new varieties will improve the present situation of dependence on only two varieties, and will promote varietal comparisons, as well as stimulate the development of cassava production in China.

In recent years, a large F_1 population and its progeny clones have been produced from true seeds, which were mainly introduced from CIAT/Colombia and from the Thai-CIAT program. Up to 1995, a series of breeding materials with different characters have been evaluated and selected; out of these, three new varieties have been released, more than 30 accessions have been used as cross parents, and 15 promising clones have been recommended for testing in Regional Trials. In 1996, 316 clones were tested at the Single-row Trial, 63 clones were further evaluated at the Preliminary Yield Trial, and 54 clones were included in the Advanced Yield Trials. Most of the clones in the Regional Trial and the Advanced Yield Trial were characterized by high yield and high dry matter content (especially clones OMR33-10-4 and OMR34-11-3 have very high dry matter content); their performance at the later stages is closely being watched. Also, some good clones were selected from the Preliminary Yield Trial in 1995/96, such as ZM9315, ZM93255, ZM9317, ZM93236 etc., and OMR36-63-6, OMR36-40-9, OMR36-05-9 etc. from the Single-row Trial; these showed significantly higher yields compared with the check variety, SC205, while their root dry matter contents were higher than 40%, the harvest indices were over 0.62 and they had good wind resistance.

High-yield, high dry matter content and good wind resistance are still our major objectives in cassava breeding. From our experience we are convinced that it is impossible to make any major breakthrough in our breeding program by just using our native genetic resources. There are two ways for us to realize our objectives in the future: 1) selection from the hybridizations between our local germplasm and those from CIAT/Colombia or the Thai-CIAT program, such as ZM9036, ZM8803, ZM9057 etc.; and 2) the comprehensive evaluation and direct selection of the seed materials introduced from CIAT/Colombia or the Thai-CIAT program. While the importance of the former scheme is increasing, up to now, many of the good clones with high yield, high dry matter content and high harvest index were selected from this latter source. As such, the materials introduced from CIAT/Colombia or the Thai-CIAT program and their hybrids with the local genetic materials are playing an important role in cassava varietal improvement in China.

INTRODUCTION

Cassava is the fourth most important crop in southern China, following rice, sugarcane and sweet potato. It is used mainly as animal feed and for starch

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manufacturing, which both play an important role in the agricultural economy. Cassava production makes full use of available land resources, especially in upland and hilly areas, as well as in marginal areas with poor soils. In recent years, cassava production and its economic value have increased due to the rapid development of the animal feed and starch industry, as well as to improvements in marketing channels for cassava products. More and more attention has been paid to the release and planting of new varieties and the use of good cultivation technologies. Considerable progress has been made in cassava varietal improvement at the Chinese Academy of Tropical and Agricultural Sciences (CATAS), with CIAT's cooperation and support. A national cassava network, including cassava breeding, selection, testing and extension, has been established. New varieties, such as SC124, SC8002 and SC8013 have been released in different regions of the country because of their high yield potential. In addition, many promising clones are constantly being selected from F_1 seedling populations and from their progenies. Some of these with high yield, high root dry matter content and wide adaptability will be further tested, and when approved, will be released and extended as new improved varieties in the future.

VARIETAL IMPROVEMENT AT CATAS

Collection, Evaluation and Utilization of Cassava Germplasm

In China, all cassava varieties that are now planted at a large scale were introduced from abroad. Some local clonal progenies, which had evolved through natural or artificial selection from natural crosses, also exist, but these are very limited and scattered, with less than 20 accessions in total. Therefore, cassava germplasm in China can mainly be attributed to direct introductions or to cross breeding of local with introduced germplasm. Over the years, CATAS has introduced more than 30 accessions from CIAT/Colombia or from the Thai-CIAT program, and a number of cross parents from CIAT's breeding materials have also been evaluated and are now being conserved. A cassava germplasm bank has been set up at CATAS, which presently has more than 120 accessions; their major characteristics have been evaluated, and are being catalogued and documented. This forms the foundation for cassava breeding and is a source of genetic diversity for selecting cross parents. From the materials of CIAT/Colombia or the Thai-CIAT program, a group of special germplasm has been evaluated and selected: Nanzhi 188 and CM3044-2 were found to be male-sterile, CM3993-9 and SM614-1 have high dry matter content, while MCol 22 and CM1585-13 are characterized by short plant height, wind-resistance and abundance of female flowers. Thus, materials from CIAT or the Thai-CIAT program have not only played an important role in cassava breeding, but are also a useful genetic resource in China. CATAS has developed some promising clones, such as ZM9036, ZM9057, ZM9079, ZM9111, ZM9315 etc, through hybridization between local materials with those from CIAT or from the Thai-CIAT program.

Multiplication and Extension of Improved Varieties

With the further development of the animal feed and starch processing industries, as well as the starch-based chemical industry, demand for cassava roots have dramatically increased in China. Therefore, the release and rapid multiplication of improved varieties, so as to increase cassava yields, is very important to satisfy producers' and consumers' needs. CATAS has bred and recommended new varieties, such as SC124 and SC8002, which have high yield and are cold tolerant, as well as SC8013 with high yield and wind resistance. These varieties have been tested and released in Guangdong, Guangxi, Hainan and Yunnan provinces.

In recent years, the new variety SC124 was mainly released in Guangxi and has also been introduced and recommended to Jiangxi, Guizhou, and Sichuan provinces. It is estimated that in 1995 a total of 8000 ha were planted with this variety. In 1992, SC124 was also introduced into the districts of Honghe, Yuxi and Simao of Yunnan province to be demonstrated in a total area of 1.6 ha under different soil conditions; this resulted in a significant increase in yield. According to the report of the Cassava Feed Resource Development and Utilization Group of Jinping County of Yunnan, its average yield was 45 t/ha, while the highest yield was 85.7 t/ha, which was about three times higher than that of the local variety. This was mainly attributed to the high yield potential of this variety in regions that are not affected by typhoons. Up to 1996, SC124 has been extented to 6775 ha in Yunnan province only.

In 1994, the improved varieties SC8002 and SC8013 from CATAS were recommended for further testing and release in China. Results of tests and demonstrations at different locations over the years indicate that both SC8002 and SC8013 have high yield potential and wide adaptability (**Table 1**). SC8002 had an average yield of 33.7 t/ha in 12 locations, outyielding the check varieties SC205 and SC201 by about 22 and 36%, respectively. The leaf life of SC8002 was 5.8 and 5.9 days longer than those of SC205 and SC201, respectively (**Table 2**). Meanwhile, its cold resistance was only slightly lower than that of SC124. This variety has been further tested and released in Guangdong, Guangxi, Hainan and Yunnan provinces with a potential extension area of 4000 ha. However, the planted area in 1996 was estimated at 1300 ha.

The new variety SC8013 has very good wind resistance and had a mean yield of 37.9 t/ha in nine different locations, outyielding SC205 and SC201 by about 38 and 53%, respectively. Its leaf life was 6.1 and 6.2 days longer than those of SC205 and SC201, respectively (**Table 2**). In addition, its dry matter content was higher than those of the check varieties. This is a breakthrough in breeding for wind resistance in China, as it provides a good possibility for high and stable yields of cassava also in typhoon affected areas. It will be further extended in Hainan and in Zhanjiang district of Guangdong with a potential area of 3400 ha, of which 600 ha will be planted in 1996. This variety is now being tested for rapid multiplication using the shoot propagation system.

Regional Trials of Promising Clones

CATAS has established a national cassava network in China, including experiment stations in Guangdong, Guangxi and Hainan provinces, to conduct the Regional Trials. During 1992-1995, 22 promising clones have been evaluated in Regional Trials, and those found to have high yield and wide adaptability, such as OMR33-10-4, ZM9036, ZM9057, SM1542-3 and SM1592-3 have been selected for further testing (**Table 3**).

Table 1. Fresh root yield (t/ha) of SC8002 and SC8013 in comparison with those of two local varieties in different regions of southern China.

Location	SC8002	SC8013	SC205	SC201
Hongxing State-farm, Guangdong	31.7	36.6	24.1	-
Lecheng Agri-technical station, Guangdong	33.8	-	29.7	26.4
Qiongzhong, Hainan	-	46.3	31.5	-
Fengshun, Guangdong	31.7	58.5	30.0	-
Qinzhou, Guangxi	30.6	-	-	28.9
Wuxuan, Guangxi	-	40.2	-	20.6
Dingan, Hainan	-	20.2	-	11.7
Wuming, Guangxi	-	57.6	-	44.4
Zengcheng, Guangdong	30.7	-	-	23.9
Boluo, Guangdong	33.4	-	-	30.0
Guangning, Guangdong	36.4	-	19.7	-
Jiexi, Guangdong	43.8	-	28.8	-
Zijin, Guangdong	49.5	-	21.4	-
Baisha, Hainan	22.5	26.0	21.3	-
Nanning, Guangxi	23.3	22.5	-	21.4
Guilin, Guangxi	-	-	-	-
CATAS	37.0	33.2	41.5	15.5

Among the clones listed in **Table 4**, SM1592-3 and SM1542-3 are progenies from the F_1 population of 1992, and their yields were the highest among 24 clones that were included in the Advanced Yield Trial in 1994. Root dry matter contents of these two clones were above 38%. Results of the Regional Trials conducted in 1995 again indicate that these two clones showed good yield performance; they need to be further evaluated in the future. OMR33-10-4, ZM9036 and ZM9057, which are clonal progenies from the F_1 population of 1990, also continued to show high yield potential and high root dry matter content under different conditions over the years (**Tables 4 and 5**).

Table 2. Leaf life and various root characteristics of SC8002 and SC8013 in comparison with those of two local cassava varieties as determined in different regions of southern China.

Variety	Average leaf life (days)	Fresh root yield (t/ha)	RDMC[1)] (%)	Starch content (%)	HCN (mg/kg) (fresh wt.basis)
SC8002	77.9	33.7	38.6	29.9	44.6
SC8013	78.2	37.9	41.9	32.0	32.5
SC205	72.1	27.5	38.1	30.2	63.4
SC201	72.0	24.7	37.7	30.3	128.2

[1)]RDMC= root dry matter content.

The weight of roots of F_1 seedlings OMR33-10-4, ZM9036 and ZM9057 were 3.8, 5.8 and 4.3 kg, respectively. They have shown good performance and stable high yields as well as high root dry matter contents at the CATAS experimental station. During 1992-1995, their average yield were 34.4, 19.8 and 20.9% higher than SC205, respectively. Of these clones, OMR33-10-4 has a significantly higher yield potential than SC205, outyielding the latter by up to 78% in term of dry yield; also, it has better wind resistance. This clone was selected by farmers who participated in the FPR project at the pilot sites of Hainan. It is therefore being further propagated, hoping that it will become a new variety with high yield and good quality (high RDMC) in south China.

Evaluation and Selection of Clones

For more than 16 years CATAS researchers have been cross breeding cassava. From 1992 to 1995 CATAS introduced and produced 560 cross parents as well as 23,060 true seeds, of which 17,477 seeds and 216 parents came from CIAT/Colombia and the Thai-CIAT program. From these, 11,092 plants have been produced for the F_1 population and 1648 good plants have been selected. In 1996, 316 clonal selections were included in the Single-row Trial, 63 clones in the Preliminary Yield Trial, 54 clones in the Advanced Yield Trial, and 15 promising clones were recommended to be further tested in Regional Trials throughout southern China.

Table 3. Average results of evaluations of promising cassava clones in Regional Trials conducted in varions locations during 1992-1995.

Clones	No.of locations	Fresh root yield(t/ha)	Dry root yield(t/ha)	Root dry matter content(%)
ZM9057	6	38.2	14.5	38.0
SM1592-3	8	37.6	13.5	36.0
ZM9036	5	32.8	12.8	39.1
OMR33-10-4	6	29.4	11.7	39.7
SM1542-3	6	27.8	10.1	36.4
SC205	6	28.1	10.9	38.9
SC201	5	28.3	10.3	36.5

Table 4. Average fresh and dry root yields of three promising clones in comparison with those of the check variety SC205 in Regional Trials conducted in 1992 to 1995.

Clones	1992		1993		1994		1995		
	Fresh (t/ha)	Dry	Fresh (t/ha)	Dry	Fresh (t/ha)	Dry	Fresh (t/ha)	Dry	RDMC (%)
OMR33-10-4	30.8	12.7	41.9	16.1	28.1	10.8	23.8	9.0	38.3
ZM9036	24.1	10.4	31.3	12.3	28.1	11.1	24.2	9.6	39.6
ZM9057	27.0	11.3	33.6	12.6	31.2	11.6	23.6	8.6	37.2
SC205	23.7	8.5	31.4	11.6	21.0	8.0	23.8	8.3	36.6

Table 5. Fresh root yields (t/ha) of three promising clones and of the local check varieties in Regional Trials conducted in different locations. Data are average yields for 1992 to 1995.

Locations	OMR33-10-4	ZM9036	ZM9057	SC205	SC201	SC102
Baisha, Hainan	28.1	36.0	34.0	25.5	-	-
Qiongzhong, Hainan	43.5	47.0	66.3	52.6	-	-
Dingan, Hainan	24.4	20.6	23.8	-	-	10.0
Xuwen, Guangdong	35.0	-	31.0	28.9	-	-
Lurong, Guangxi	25.3	16.1	24.5	-	13.6	-
Nanning, Guangxi	18.5	20.9	13.1	-	16.6	-
Wuxuan, Guangxi	31.7	55.4	28.6	35.0	-	-
Danzhou, Hainan	28.1	25.4	24.2	25.3	-	-

Results of the Advanced Yield Trial in 1994 and 1995 indicate that some good clones, such as OMR34-11-3, SM1542-3, SM1691-3, ZM9111, ZM9244, ZM9281 etc, which were selected from Preliminary Yield Trials in 1993 and 1994, showed higher yield potential compared with SC205 (**Table 6**); of these, OMR34-11-3, SM1542-3 and ZM9111 had better comprehensive characteristics. Especially OMR34-11-3 has good plant type, high harvest index, high RDMC, good wind resistance, while both its yield and RDMC were the highest in the Preliminary Yield Trial of 1993 and the Advanced Yield Trial of 1994. It is a very interesting clone. ZM9079, ZM9066, ZM9045 etc, also showed very high yield potential, but these will need to be further tested. Some clones with high RDMC, such as ZM9315, ZM9317, ZM93255, ZM93236, OMR36-63-6, OMR36-40-9 and OMR36-05-9 were selected from the Single-row and Preliminary Yield Trials in 1995 (**Tables 7** and **8**).

Table 6. Yield parameters and other characteristics of lines selected from the Advanced Yield Trial conducted in CATAS in 1995.

Clones	Dry root yield(t/ha)	Fresh root yield(t/ha)	RDMC (%)	Plant type	Root shape
OMR34-11-3	10.7	27.3	39.2	4.5	4.0
ZM92157	10.0	29.4	34.1	4.0	4.0
ZM9266	9.6	27.5	34.8	5.0	3.5
SM1595-2	9.6	31.6	30.5	5.0	5.0
ZM9111	9.5	28.4	33.5	5.0	4.3
SM1691-3	9.1	25.0	36.5	5.0	4.5
SM1542-3	8.4	23.8	35.3	5.0	4.3
SC205	8.2	23.2	35.6	5.0	4.0

DISCUSSION

Breeding Efficiency Using Germplasm of Different Origin

All breeding materials used at CATAS originated from CIAT/Colombia, the Thai-CIAT program, or from locally produced true seeds. The material from CIAT/Colombia showed a wide genetic variability and, in general, had very strong vigor with early and prolific branching. Many high yielding clones, such as CM4031-2 and CM4040-1 were produced from this material; however, in general, their root dry matter content was low. But in recent years, some of these clones are characterized by high yield as well as high RDMC, such as SM1542-3, SM1592-3 and SM1691-3. Undoubtedly, these materials will always be an important source of genetic variability for cassava breeding programs in China.

From our experience in recent years, we believe that the materials from the Thai-CIAT program have shown over the years a high selection efficiency and a very high

RDMC, whether they are individuals or populations. The two promising clones, OMR33-10-4 and OMR34-11-3, are typical representatives of this. Seven clones were selected from the Single-row Trial of 1995, of which five clones originated from this material (**Table 8**). Among the 17 clones with more than 40% RDMC, a harvest index of more than 0.60, and strong resistance to wind, 13 came from Thai-CIAT materials. This is a very clear indication that the materials from the Thai-CIAT program have shown a very high selection efficiency. They will play an ever more important role in cassava varietal improvement in China, especially in increasing cassava root dry matter content.

Table 7. Yield parameters and other characteristics of lines selected from the Preliminary Yield Trial conducted at CATAS in 1995.

Clones	Dry root yield(t/ha)	Fresh root yield(t/ha)	RDMC[1/] (%)	Harvest index	Plant type	Root shape
ZM93253	11.4	33.8	33.7	-	5	4
ZM9315	11.3	28.1	40.2	0.48	3	3
ZM93255	11.0	27.3	40.5	0.48	2	3
ZM9317	10.9	27.5	39.7	0.54	3	4
ZM93236	10.5	28.2	37.4	0.51	5	4
SC205	10.1	27.7	36.3	0.50	3	3

[1/] RDMC = root dry matter content

The locally produced materials can not be ignored, as they are still an important resource for cassava breeding in China. But it is very difficult to make any breakthrough by using only the limited native genetic resources. Therefore, in order to widen the genetic variation and make faster progress, a combination of utilizing native germplasm with those coming from abroad, so as to produce better cross parents, should be most successful. Some elite clones, such as ZM9036, ZM9111, ZM9315, ZM9137, ZM93253 and ZM93236 were selected from the hybrids between the native materials with those introduced from CIAT/Colombia or the Thai-CIAT program. Obviously, the materials from CIAT/Colombia and Thai-CIAT will be an indispensable source of germplasm, and these will greatly affect the impact of cassava breeding in China, both now and in the future.

Table 8. Yield parameters of lines selected in the Single-row Trial conducted at CATAS in 1995.

Clones	Dry root yield(t/ha)	Fresh root yield(t/ha)	RDMC (%)	Harvest index
OMR36-63-6	17.1	40.4	42.3	0.63
OMR36-05-9	14.4	35.4	40.8	0.67
OMR36-40-9	13.4	32.0	41.8	0.59
ZM9454	12.8	30.0	42.5	0.52
OMR36-11-3	12.6	36.0	35.0	0.55
OMR36-05-7	12.3	33.8	36.4	0.63
ZM9495	12.2	34.0	35.9	0.57
SC205[1)]	12.1	34.4	35.2	0.61

[1)]the highest yield in the Single-row Trial

Relationship Between Root Yield, Harvest Index, Biomass and Root Dry Matter Content

As Dr. Kawano has stated, "cassava harvest index is hereditary, and there is a close relationship between root yield and harvest index". From **Figure 1** we can see that cassava root yield in CATAS was strongly and positively related to harvest index. It means that high yielding clones can usually be selected from those having high HI and strong vigor.

Biomass is a function of the clone's native vigor, but is also seriously affected by the soil and climatic conditions. Kawano (1987) reported that both biomass and harvest index were naturally very important to fresh root yield, especially in poor soils. **Figure 2** shows that there was a strong positive correlation between fresh root yield and biomass under the conditions of CATAS. That means that low biomass production or low HI immediately disqualifies any clone from the selection. Yet, either high biomass or high HI alone are not a guarantee for high yield, especially at very high yield levels. Thus, only a good combination of these two characters can lead to high yields.

Root dry matter content of cassava is also an hereditary character, but has no clear relationship with fresh root yield. However, from **Figure 3** we can see that fresh root yield and RDMC are not contradictory characters either. This means that selection for both high yield and high RDMC is a realistic objective. Our experience at CATAS has proven this point, i.e., clones having both high yield and high RDMC have been selected, such as OMR33-10-4, OMR34-11-3, ZM9036, ZM9111 and ZM9315.

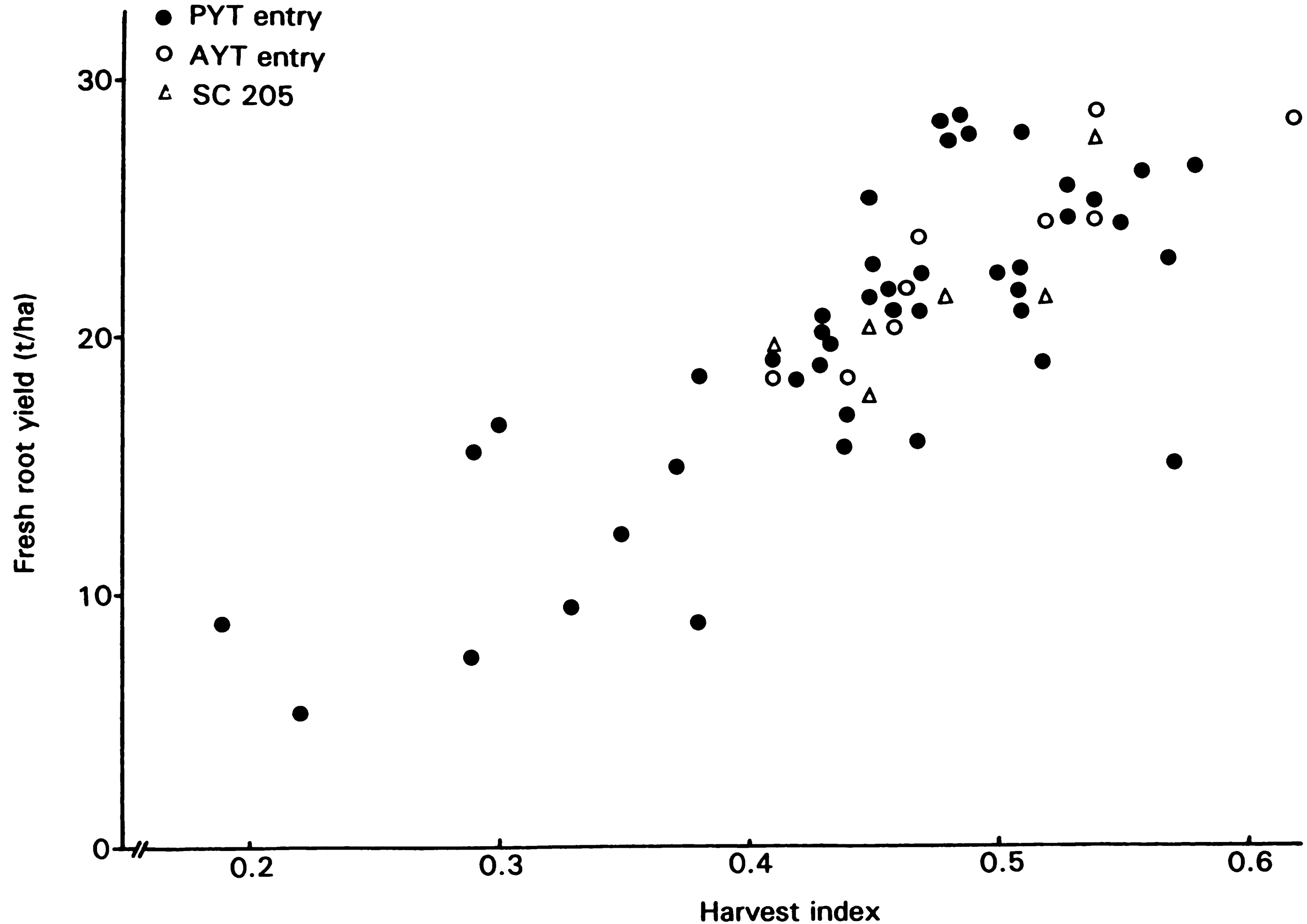

Figure 1. Relationship between harvest index and root yield among Advanced and Preliminary Yield Trial entries at CATAS, Hainan, China, 1995/96.

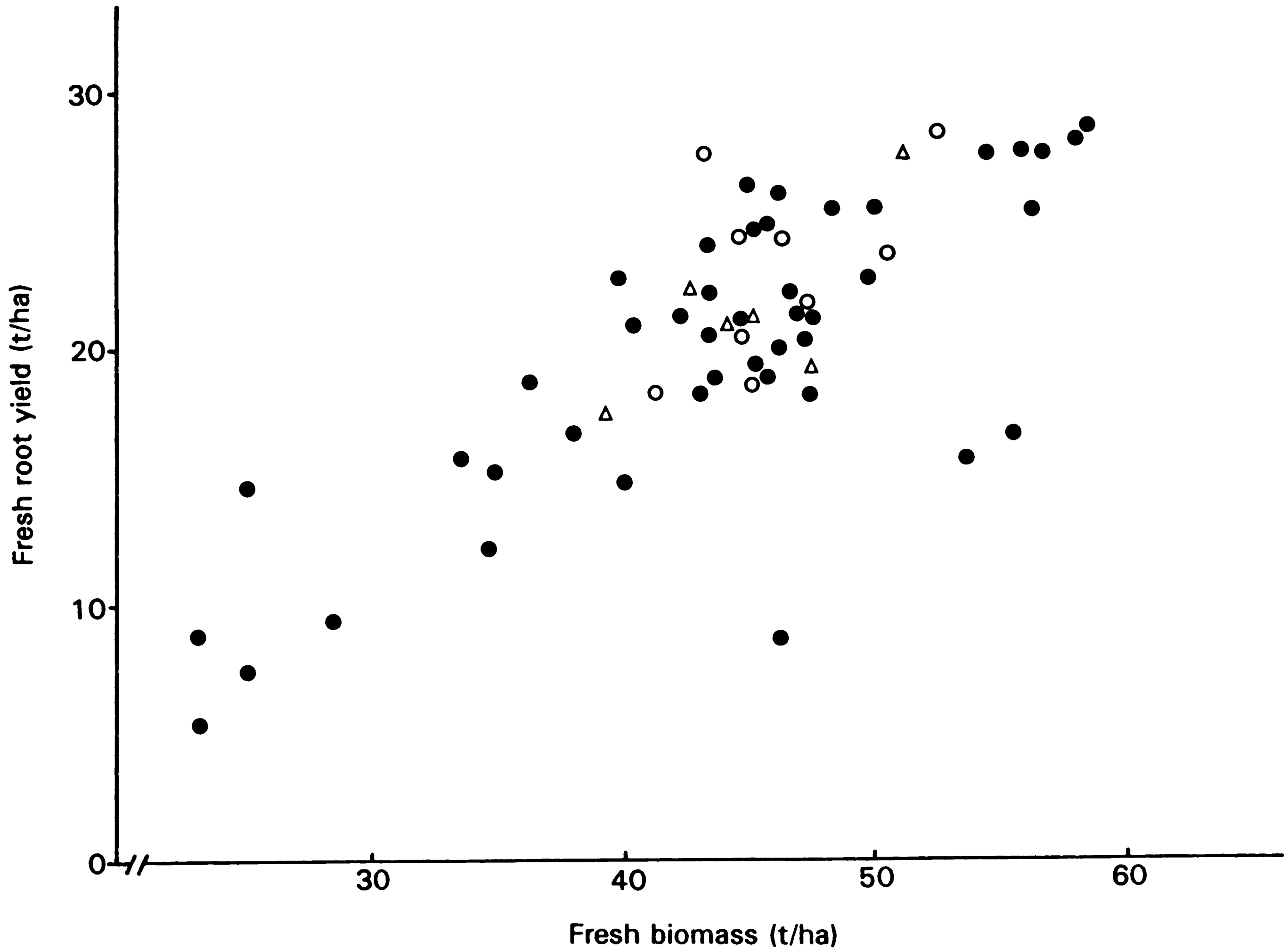

Figure 2. Relationship between biomass and root yield among Advanced and Preliminary Yield Trial entries at CATAS, Hainan, China, 1995/96.

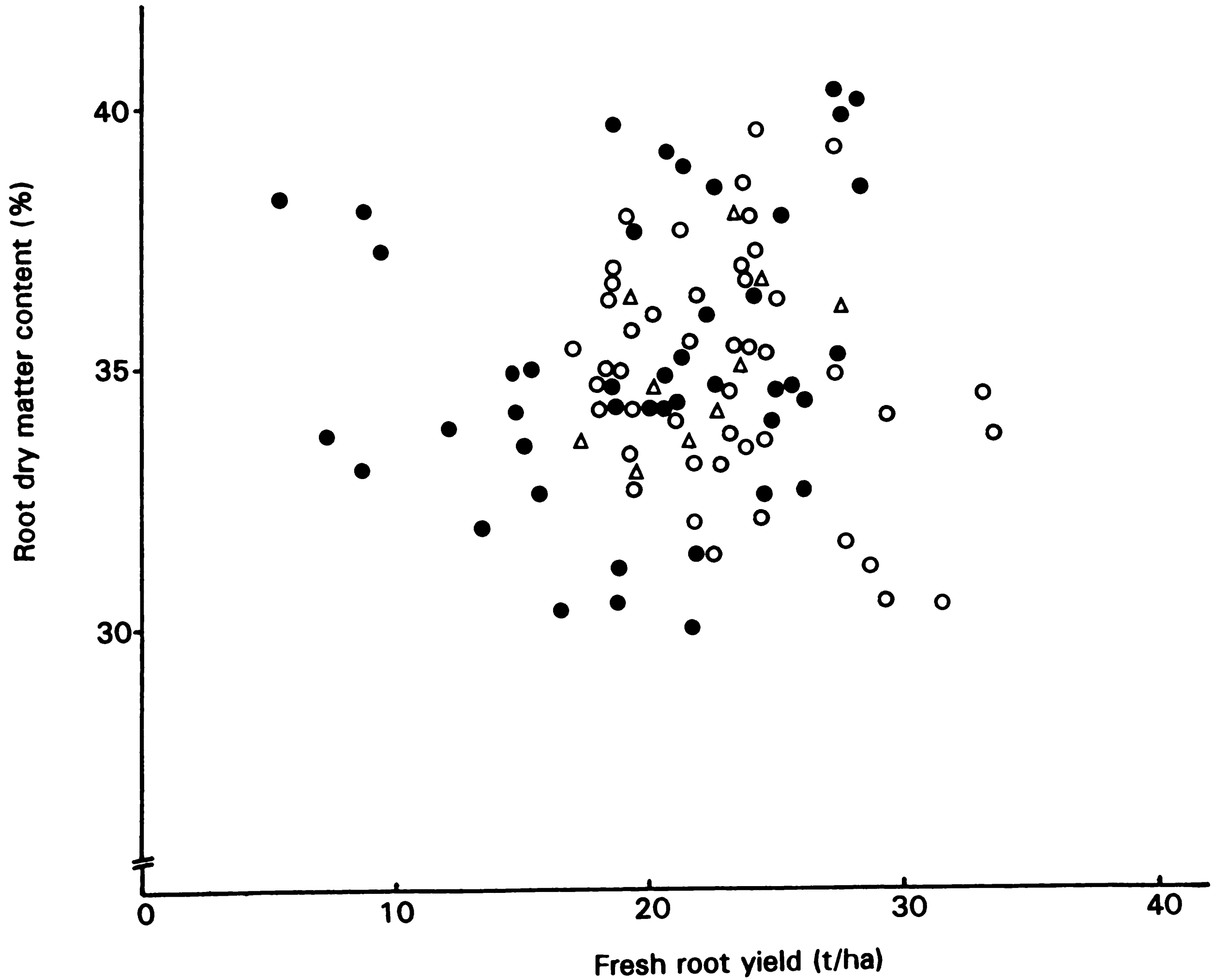

Figure 3. Relationship between fresh root yield and root dry matter content among Advanced and Preliminary Yield Trial entries at CATAS, hainan, China, 1995/96.

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CASSAVA VARIETAL IMPROVEMENT AND DISSEMINATION IN GUANGXI

Tian Yinong and Lee Jun[1]

ABSTRACT

The Guangxi Subtropical Crops Research Institute (GSCRI) began their cassava varietal introduction and improvement program in 1981. Since 1985, GSCRI has introduced cassava hybrid seeds as well as promising clones by tissue culture from CIAT/Colombia, from the Thai-CIAT program, as well as from other institutes. Through continuous selection and experiments, several promising clones, such as SM1113-1, SM1600-1, CM5443-1, SM1741-8 etc. have been identified, and these have been tested to a certain extent in on-farm trials. Since their release and dissemination these clones have awakened great interest by both farmers and starch factories. Some of them have now spread to other provinces. In China, high yield and high starch content of cassava varieties are still the most important factors in raising the comprehensive benefits resulting from cassava production. This is also the only way to change the stagnated position of cassava production, which in the past increased mainly by increasing the area planted. At the moment, many local governments of the principal cassava growing areas are conscious of this and have started to spend money on the introduction and dissemination of new higher-yielding varieties.

INTRODUCTION

In recent years, the cassava planting area and total production in Guangxi province of China have greatly increased (**Table 1**), the average annual rate of increase from 1991 to 1995 being 6.4 and 17%, respectively. This is the result of the continuous development of cassava processing, the products of which have had a good market. In many areas farmers have adopted new cropping systems and have increased their production investment, resulting in an increase in cassava root yield, as well as the income derived from growing cassava (**Tables 2, 3** and **4**).

The cassava growing area in Guangxi is mainly concentrated in Yulin, Wuzhou, Nanning and Liuzhou districts, which are located in the middle and eastern parts of the province (**Figure 1**). The cassava area and production in these four districts account for 55 and 50% of the total in Guangxi, respectively, and the cassava processing industry is also mainly established in these areas, except for Yulin district. The natural conditions in these areas are comparatively favorable and communications are well-developed. But they also have a solid industrial foundation, so these areas developed rapidly and all these districts belong to the economically developed areas of Guangxi. But, being a low-value crop, cassava is also partly being replaced by other crops. Thus, the main cassava area in Guangxi seems to be moving to the western and northern parts from the eastern and middle parts (**Figure 2**). The data of cassava area for the most recent years in different districts of Guangxi have shown this. The western and northern parts of Guangxi include the two districts of Baise and Hechi; these are mainly hilly and mountainous areas, with low fertility soils and poor natural conditions, so they are the two less-developed districts

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of Guangxi. For a long time there were very few processing factories and farmers planted cassava usually on steep slopy land without any investment in production, so that yields were very low. The roots were mostly used for feeding livestock. In recent years, the government has given some "assistance projects" to this area and several starch (or alcohol) factories were built one after another, while some cassava production bases have been set up. They have introduced some new cassava varieties and adopted new production technologies, so the yield of cassava increased markedly. Compared with 1990, the cassava area in these two districts in 1995 had increased more than 20,000 ha, and total production increased 356,106 t. They account for 34% of the total increase in area and 18% of the total increase in cassava production in Guangxi. In 1995, the cassava area and production in these two districts accounted for 17.5 and 15% of the total in Guangxi, respectively, while in 1990 this was only 12 and 12%.

Cassava Varietal Improvement at the Guangxi Subtropical Crops Resarch Institute (GSCRI)

SC201 and SC205 are the two most important varieties, which are estimated to account for 85% of the total cassava growing area in Guangxi. These two varieties were introduced into Guangxi about 60 years ago. Since cassava has not been an important commodity in the past, farmers did not pay any attention to adopt new varieties or new production technologies. This is the reason that yields in Guangxi were low for a long time. In the 1980s, although several new cassava varieties were introduced, few of these were really adapted to the conditions of Guangxi. Because only 1-2 cassava varieties were used until the beginning of the 1990s, there was little potential to increase farmers' income. Moreover, the harvest period is short and is mainly concentrated in Dec and Jan, so except in these two months, only dried chips can be used for processing. In view of this, many starch factories appealed to agricultural institutes to introduce or improve new cassava varieties with high yield and high starch content, and they have been willing to fund some of the research.

Table 1. Cassava planted area, yield and production in various districts or cities of Guangxi province in China from 1993 to 1995.

	Planting area (ha)			Yield (t/ha)			Production(t)		
District/city	1993	1994	1995	1993	1994	1995	1993	1994	1995
Nanning city	14,148	16,271	22,678	15.30	17.73	19.26	216,420	288,438	436,872
Liuzhou city	4,590	4,554	4,527	8.60	8.62	10.28	39,470	39,261	46,527
Guilin city	2,786	2,953	3,099	10.47	11.44	13.10	29,170	33,777	40,614
Wuzhou city	3,497	3,438	3,987	7.76	8.81	10.00	27,140	30,303	39,873
Beihai city	8,451	9,075	10,789	27.21	26.00	27.72	229,950	235,983	299,127
Nanning district	34,740	36,231	41,126	8.53	12.96	13.30	296,420	469,506	546,843
Liuzhou district	24,967	23,693	25,331	6.32	6.98	7.96	157,710	165,504	201,681
Guilin district	7,715	9,078	10,150	10.11	11.14	12.76	77,980	101,163	129,522
Wuzhou district	34,519	35,169	38,667	13.34	17.33	14.26	460,490	609,339	551,289
Yulin district	37,563	39,701	43,037	13.03	12.81	12.71	489,690	508,665	547,017
Baise district	11,913	12,521	24,811	10.48	10.80	13.44	124,850	135,255	333,543
Hechi district	18,905	19,404	23,078	7.77	8.07	12.72	146,880	156,663	233,097
Qinzhou district	15,263	15,498	19,264	11.62	12.98	15.59	177,340	201,228	300,327
Fang cheng city	-	1,690	2,365	-	9.88	12.30	-	16,692	29,079
Total	**219,057**	**229,276**	**272,911**	**11.29**	**13.05**	**13.69**	**2,473,430**	**2,991,777**	**3,735,411**

***Source:** Guangxi Statistical Bureau, 1996.*

Table 2. The yield and gross income from planting different cassava varieties in Laibin county of Liuzhou district, Guangxi, China in 1995.

Variety	Fresh root yield (t/ha)	Price roots (yuan/t)	Stem yield (t/ha)	Price stems (yuan/t)	Gross income (yuan/t)
SC201 (local)	22.5	360	25.4	200	13,180
SC205*(new)	26.3	370	21.5	430	18,976
SC124 (new)	30.0	360	25.6	1100	38,960

* SC205 is a new variety for Laibin county but is common in southern Guangxi

Table 3. Comparison between several crops in terms of gross and net income in Laibin county of Liuzhou district Guangxi, China in 1995.

	Yield (t/ha)	Price (yuan/t)	Gross income (yuan/t)	Net income (yuan/t)
Cassava	22.5	360	8,100	3,600
Orange	22.5	1900	42,750	33,000
Sugarcane	60.0	270	16,200	7,200
Mango	7.5	3200	24,000	16,800

Table 4. Comparation between several intercropping systems in terms of gross income in Laibin county of Liuzhou district, Guangxi, China in 1995.

	Cassava fresh root yield (t/ha)	Price roots (yuan/t)	Intercrop yield (t/ha)	Price intercrops (yuan/t)	Gross income (yuan/ha)
Cassava+Watermelon	22.5	360	30.0	400	20,100
Cassava+Peanut	24.8	360	1.9	3,200	15,008
Cassava+Watermelon seeds	21.8	360	0.5	14,000	14,848

Source: Laibin State Farm

The Guangxi Subtropical Crops Research Institute (GSCRI) began their cassava varietal introduction and improvement program in 1981. At that time, they were mainly working on the introduction of promising clones or new varieties from other Chinese institutes, which were tested in the Institute and then distributed to State Farms. Since 1985, GSCRI has introduced cassava hybrid seeds as well as promising clones by tissue culture from CIAT/Colombia, from the Thai-CIAT program, as well as from other institutes. In the last decade, GSCRI has introduced a total of 23,733 cassava hybrid seeds from 432 parent combinations (**Table 5**).

In consideration of the natural conditions of cassava production in Guangxi and based on the demands from farmers and starch factories, the general objectives of the cassava varietal introduction and improvement program in Guangxi are to develop promising clones with the following characteristics:

- High root yield and high harvest index
- High root starch content
- Non-branching growth habit
- Tolerance to wind
- Good root shape
- Early harvestability

During the past ten years, GSCRI has made good progress in developing improved cassava varieties (**Table 6**). Through continuous experimentation and selection, four promising clones have now been identified, i.e. SM1113-1, SM1600-1, CM5443-1 and SM1741-8 (**Table 7**). These four promising clones were higher yielding than the local varieties SC201 or SC205 at three locations (Nanning, Mingyang and Laibin). The yields of clone SM1113-1 at Nanning, Mingyang and Laibin were 23.2, 52.5 and 28.4 t/ha, respectively. The yields of clone SM1600-1 at Nanning and Laibin were 24.9 and

40.7 t/ha, respectively. The yields of clone CM5443-1 at Nanning and Laibin were 29.5 and 34.0 t/ha, respectively; and the yields of clone SM1741-8 at Nanning and Laibin were 32.2 and 36.0 t/ha, respectively. The root dry matter content of clone SM1113-1 is also very high (Table 8).

Cassava Varietal Dissemination in Guangxi - Channels and Procedures

The channels for cassava varietal dissemination in Guangxi are as followed:

- Committee of Science and Technology
- Extension Station of Agricultural Technology
- State Farm (starch factory)
- New Technology Development Company
- Private enterprises

As the department responsible for science and technology, the Committee of Science and Technology is not only in charge of carrying out policies of the government in the countryside, but also plays a very important role in disseminating the achievements of science and technology. It is the key unit for spreading new technologies from scientific institutes to rural areas. The local Extension Station of Agricultural Technologies is the unit responsible for spreading agricultural technologies directly to farmers, but normally they work by introducing new high yielding technologies to agricultural communities.

State Farms are separate units with all these functions. There is an Agricultural Research Team (ART), which is composed of technical staff whose members have graduated from an Agricultural School or University (College). State Farms tend to have a lot of land. So, in general, State Farms are not only a good experimental site, but are also an ideal place for scaling-up agricultural production. Trials conducted in State Farms normally conform to the standard.

New Technology Development Company is a new organization, which has expanded rapidly in recent years; most of these are operated by the government and are especially engaged in the introduction and dissemination of technologies.

The private entrepreneurs are people who achieve success during the rapid development of a modern economy; among them are many who are operating in agricultural production. They are not only businessmen but also producers, and they have not only capital but also flexible management strategies which allows them to easily adopt new things and take advantage of their conditions to quicken the tempo of agricultural development.

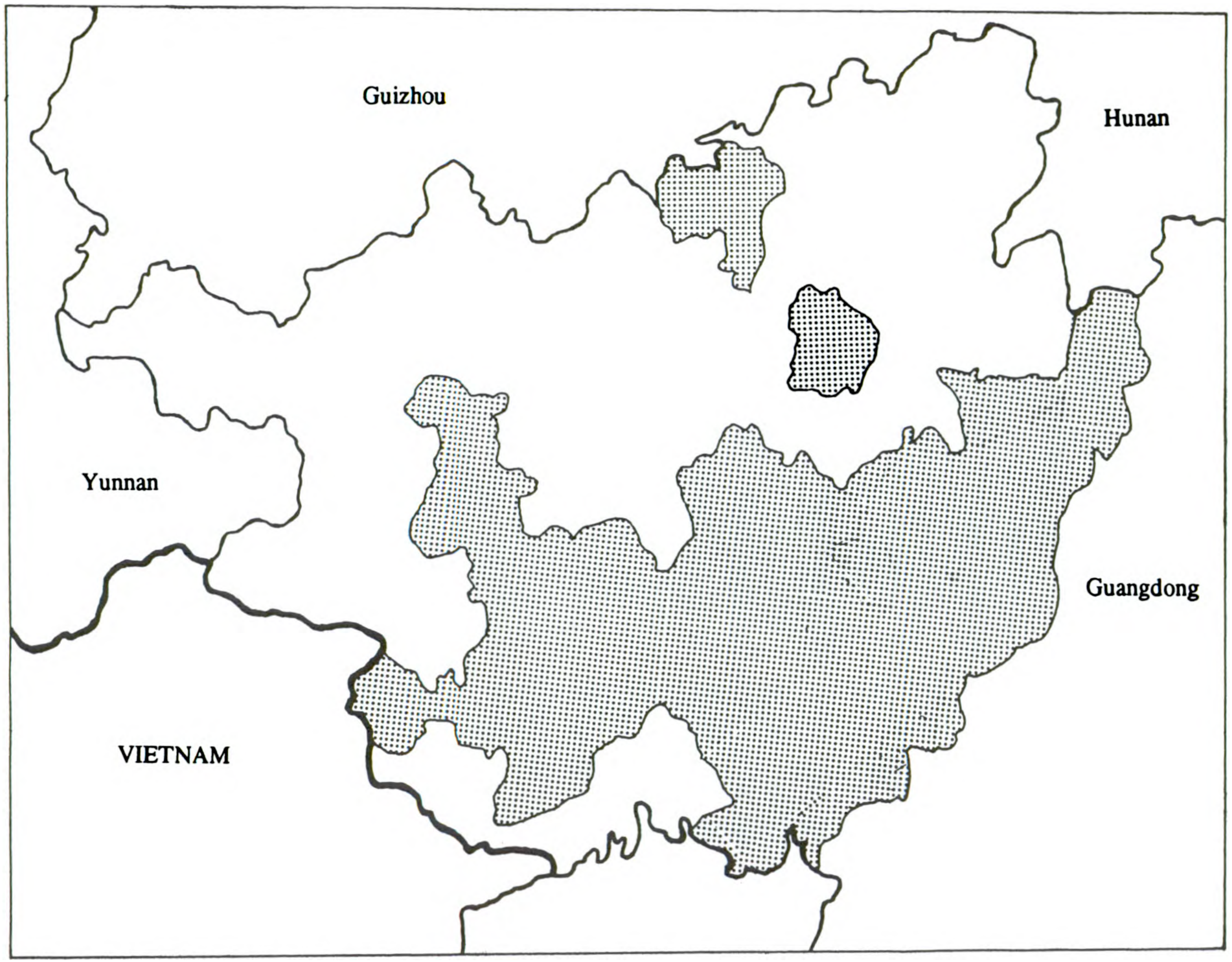

Figure 1. The main cassava growing areas in Guangxi in 1991.

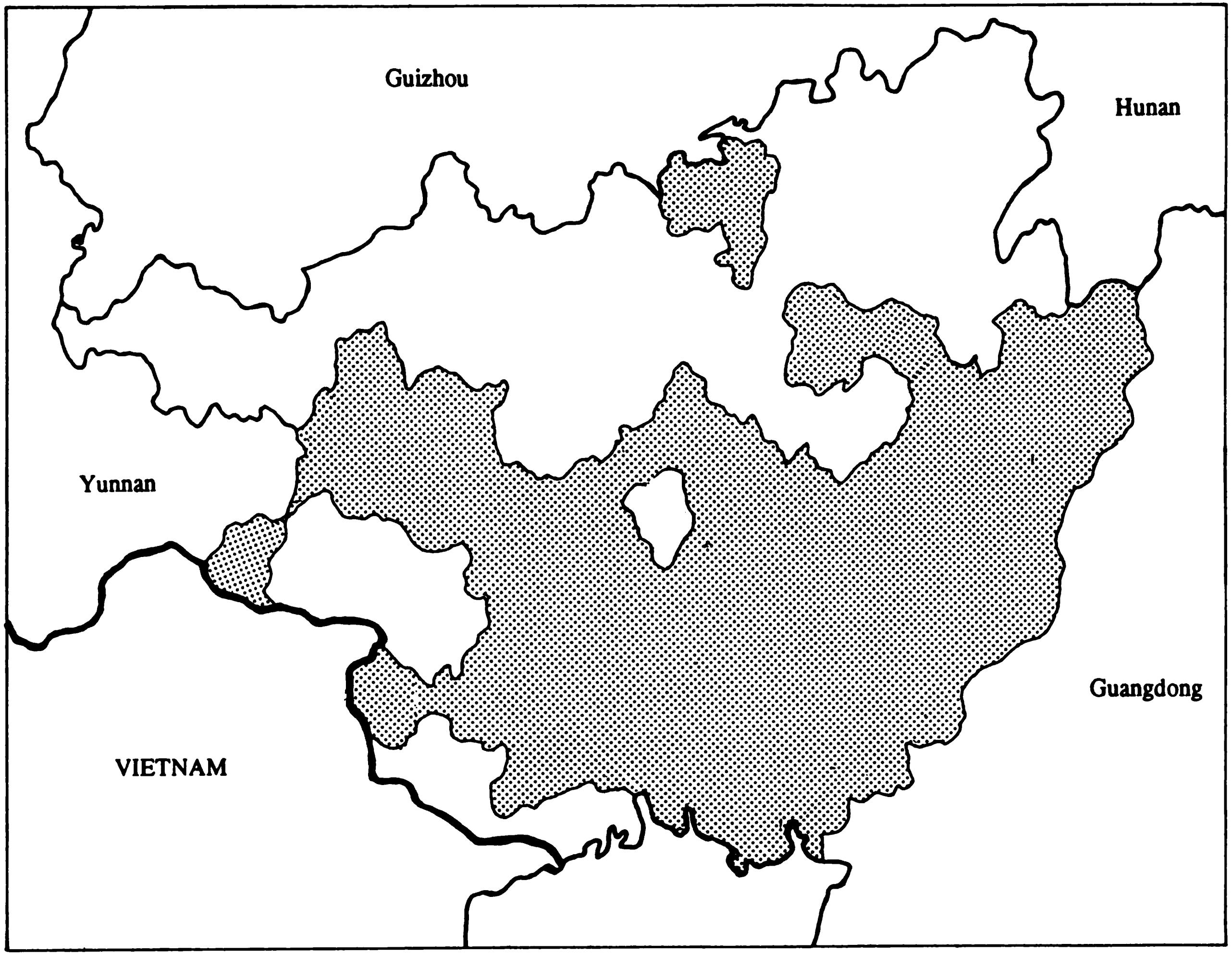

Figure 2. The main cassava growing areas in Guangxi in 1996.

Table 5. Number of cassava hybrid seeds supplied by CIAT to GSCRI in Guangxi, China, from 1985 to 1996.

Year	No. of seeds	No. of crosses	Source
1985	1,500	30	CIAT/Colombia
1986	1,800	36	CIAT/Colombia
1987	-	-	-
1988	1,950	32	CIAT/Colombia
1989	2,250	45	CIAT/Colombia
1990	3,350	59	CIAT/Colombia, Thai-CIAT program
1991	1,560	51	CIAT/Colombia
1992	1,500	21	CIAT/Colombia
1993	2,189	35	CIAT/Colombia
1994	2,550	47	CIAT/Colombia, Thai-CIAT program
1995	2,000	30	CIAT/Colombia
1996	3,084	46	CIAT/Colombia, Thai-CIAT program
Total	23,733	432	

Table 6. Number of entries of cassava evaluated at various stages of selection by GSCRI, Nanning, Guangxi, China, from 1985 to 1996.

Selection trial	Year											
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
F1 seedling Trial	104	242	-	387	890	922	1047	605	1296	551	629	960
Single-row Trial		49	27	34	53	212	262	48	32	21	47	58
Preliminary Yield Trial		18	8	4	19	32	23	38	22	15	21	17
Advanced Yield Trial			3	3	6	2	2	6	7	7	10	10
Regional Trial				1	1					2	3	4
On-farm Trial											3	4

Table 7. Promising clones selected at GSCRI in Nanning, Guangxi, China, from 1987 to 1995.

Clones	Parents	Main features
SM1113-1	MCol 2215	high yield, high starch content, good plant type, high HI
SM1600-1	MPar 126	high yield, high HI, good plant type
X3		high yield, good plant type, high HI
CM5443-1	MBra 35xCM523-7	high yield
SM1741-8	MPar59	high yield

Table 8. Yield and oher traits of promising clones in GSCRI in Nanning, Guangxi, China, 1992-1994.

Clones	Fresh root yield (t/ha)	Root DM content (%)	Dry root yield (t/ha)	Harvest index
SM1113-1	23.2	39.5	9.2	0.65
SM1600-1	24.9	34.3	8.5	0.64
X3	22.7	32.4	7.4	0.66
SC201(local)	20.0	36.5	7.3	0.54
SC124(new cv.)	22.4	35.5	8.0	0.57

The procedures for cassava varietal dissemination in Guangxi are shown in **Figure 3**. The Guangxi Subtropical Crops Research Institute normally disseminates improved cassava clones through State Farms or starch factories (most starch factories are owned by State Farms). Promising clones are first sent to the representative State Farms (mostly located in the eastern, southern or middle part of Guangxi, but also in the northern part) to conduct on-farm yield trials. An agronomist from the Agriculture Research Team (ART) is appointed by the Farm to be responsible for the trial; data on cassava biological characters are taken regularly. During the harvest, the whole staff of the ART comes to evaluate the trial in the field. The characters evaluated include: fresh root yield, starch content, plant type, root shape, harvest index, germination, wind tolerance, etc. In the second year, the experiment is expanded. During the harvest the local government invites representative farmers from nearby villages to participate in the field day and to evaluate the new varieties. Then, these farmers may take some planting material of the selected varieties to be multiplied and planted in a demonstration trial in their own villages, so as to step-by-step disseminate these to other growers. Another case is as follows: since the harvested roots are mainly for selling to starch factories, there is a special relationship between farmers and starch factories. Actually, farmers get much informations and advice about growing cassava from starch factories; in other words, the farmers trust the starch factory. So it should be affirmed that the dissemination of cassava improved varieties through starch factories is one of the most rapid and effective channels.

Distribution of Promising Clones Selected by GSCRI

Since 1994 GSCRI has successfully recommended several promising cassava clones to farms and starch factories. In 1994, GSCRI cooperated with Mingyang starch factory, the biggest cassava starch factory in China, in conducting a Regional Yield Trial at the State Farm in which the factory is located. The results show that SM1113-1 produced a very high yield of 52.5 t/ha in a sandy clay soil, 53% higher than that of SC205; and the starch content of SM1113-1 was 2% higher than that of SC205. In March, 1995, upon the invitation of Laibin State Farm, we set up an On-farm Yield Trial there. From the time of planting until harvest, the leadership of this Farm attached great importance to the trial. On Dec 1995, with the support of CIAT and the Guangxi Starch Association, we held a very successful "field day" on cassava varietal improvement. More than 40 participants (mainly farmers) from farms, institutes, starch factories, etc. attended the field day. They carefully evaluated all promising cassava clones in this trial in terms of yield, starch content, plant type, harvest index, wind tolerance, etc. The results of this trial indicate that some new cassava clones, such as SM1113-1, SM1600-1, etc. not only produce higher fresh root yields but also have a higher starch content than SC201, which is the most important variety that has been used in Guangxi for a long time. Other biological characters, such as plant type, root shape, etc., were also better than SC201. All the participants, including specialists of the Guangxi Starch Association and farmers, highly appreciated the progress made by the GSCRI cassava program. After this field day, many farms and starch factories in Guangxi province wanted to introduce these cassava clones. In 1996 we distributed these clones to Xingan county in the north, to Qinzhou city in the south and to Baise in the northwestern part of Guangxi, as well as to Shimao and Zhenyuan of neighboring Yunnan province.

We believe that the identification of above-mentioned promising clones will greatly help the development of the cassava starch industry in Guangxi, as well as the development of the agricultural economy of these mountainous areas. Since their release and dissemination, these clones have awakened great interest by both farmers and starch factories and even by the government. As of 1996, the national Ministry of Agriculture and the Guangxi provincial Science and Technology Committee have supported programs on cassava varietal improvement and dissemination at GSCRI. In view of the history and the present situation of cassava production in China, high-yielding and high-starch content cassava varieties are still the most important factors in raising the comprehensive benefits resulting from cassava production. This is also the only way to change the stagnated position of cassava production, which in the past increased only by increasing the area planted. At the moment, many local governments of the principal cassava growing areas are conscious of this and have started to spend money on the introduction and dissemination of new higher-yielding varieties.

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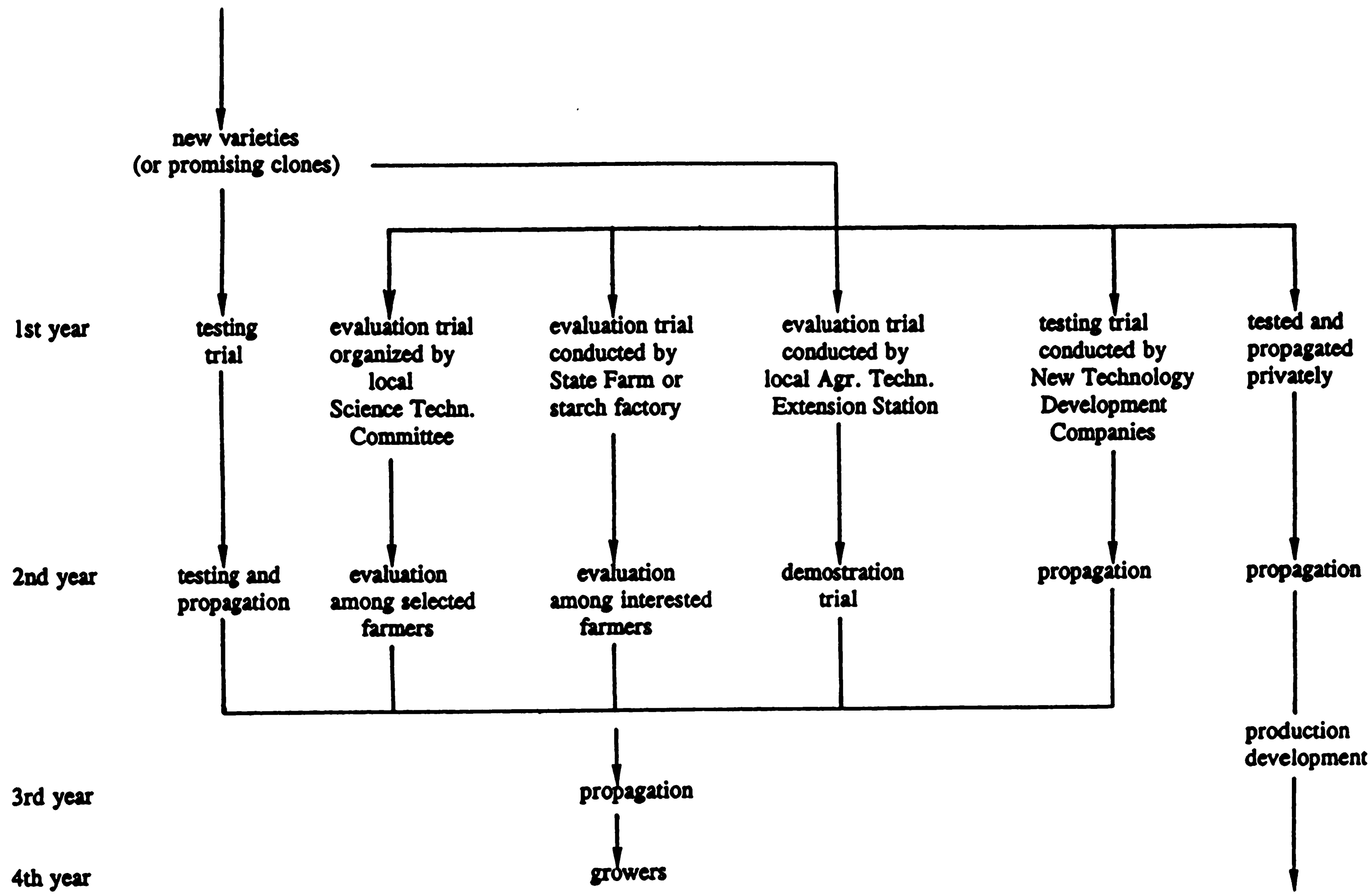

Figure 3. Procedure of cassava varietal varietal dissemination in Huangxi, China

BREEDING AND VARIETAL IMPROVEMENT IN THAILAND

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ABSTRACT

In Thailand cassava breeding is the responsibility of the Rayong Field Crops Research Center of the Department of Agriculture (DOA), and of Kasetsart University (KU). From 1975 to 1992, six cultivars have been released for industrial use, i.e. Rayong 1, Rayong 3, Rayong 60, Rayong 90, Sri Racha 1 and Kasétsart 50. All these recommended cultivars are widely adopted by farmers, but the area planted with improved cultivars was increasing only slowly due to the low multiplication rate of cassava. Therefore, in 1992 the Government approved the allocation of 11 million US dollars for the DOA and the Department of Agricultural Extension (DOAE) to rapidly multiply stakes of those cultivars and distribute those to the farmers, in order to replace about 240,000 ha of Rayong 1 with new high-yielding cultivars by the year 1996. According to the most recent survey by DOAE, this target has been well accomplished before the end of the project period.

During the past three years, the cassava breeding program in Thailand continued to emphasize selection for high yield and high dry matter content, as well as some other desirable traits, especially high total plant weight and harvest index, and good plant type, germination and survival under stressful conditions. One of our successes has been the release of another industrial cultivar, Rayong 5, in October 1994. Rayong 5 is superior to Rayong 1 in many aspects. It has been well adopted and is spreading rapidly in many parts of the country.

For Thai cassava breeders it seems to be increasingly more difficult to produce new clones that can surpass the exellent cultivars KU 50 and Rayong 5; however, some of our new clones, such as CMR33-57-81 and CMR33-53-181 appear quite promising, and CMR33-57-81 may be released as Rayong 7 in the next 2-3 years.

INTRODUCTION

Cassava in Thailand is produced mostly for export in the form of hard pellets, chips and starch, and the major markets are in the EU countries. During the past ten years (1985-1994) there has generally existed a situation of overproduction, since the demand for cassava roots was less than 20 million tons, while the supply was usually over 20 million tons. The Government was well aware of this problem and became even more concerned when the EU's CAP Reform was gradually implemented between 1993 and 1995. In 1992, the Thai Government established the policy to reduce the cassava planting area from 1.5 million ha to 1.28 million ha by encouraging farmers to replace cassava with fruit trees, fast growing trees, pastures and livestock.

In 1995 the area under cassava was reduced to 1.3 million ha and the production was only 18 million tons. However, contrary to expectations, the cassava root price went up to 1.20 baht per kilogram, which had never happened before. It looked as if the Government had been successful in reducing the cassava planting area, but in fact the drastic decline in cassava area was a direct result of the low cassava root price during the

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previous two years, 1993 and 1994. In response to the attractive price of cassava in 1995, it can be predicted that the cassava planting area will rapidly increase again after this year.

While the Government tried to decrease the cassava planting area during the past few years, at the same time it encouraged farmers to change from the local cultivar, Rayong 1, to the newly released cultivars, in order to improve the efficiency of production. The Department of Agriculture (DOA) and the Department of Agricultural Extension (DOAE) of the Ministry of Agriculture and Cooperatives initiated a five year project, starting in 1992, to rapidly multiply stakes of the improved cultivars and to distribute these to the farmers. The project's target is that Thailand will have an area under new improved cultivars of about 240,000 ha by the year 1996. According to the DOAE statistics, this target has already been accomplished during the 1995/96 planting season. The national average yield is expected to increase from 13.75 t/ha to 14.68 t/ha at the end of the project.

CASSAVA VARIETAL IMPROVEMENT

Background

Since 1975 and until 1992, the Rayong Field Crops Research Center of the Field Crops Research Institute of DOA, and Kasetsart University (KU) have released six cultivars for industrial use and one cultivar for direct human consumption. The background and the outstanding characteristics of those cultivars are described in **Table 1**.

Breeding Objective

The main objectives of cassava breeding in Thailand is to improve root yield and dry matter content (or starch content) in order to satisfy the needs of the farmers and the factories. It was suggested by Kawano (1988) and Rodjanaridpiched *et al.* (1995) that cassava yields should be improved through the simultanious improvement of total biomass and harvest index. Aside from the above important characteristics, the following characteristics are also our breeding and selection criteria:

- early harvestability
- good plant type (tall and non- or less-branching)
- good stake quality (germination and storage duration)
- good root shape with white flesh
- tolerant to major pests and diseases

Table 1. Background and outstanding characteristics of seven released cultivars.

Cultivar	Year Released	Parents	Background and outstanding characteristics
Rayong 1	1975	unknown	Selected from local land race. Exellent agronomic traits. Relatively high yield. Moderately resistant to major pests and diseases. Well adapted to low inputs.
Rayong 3	1983	(F) MMex 55 (M) MVen 307	Selected from CIAT F1 hybrid seeds. High dry matter content.
Rayong 60	1987	(F) MCol 1684 (M) Rayong 1	Selected from CIAT F1 hybrid seeds. High fresh yield. Recommended for early harvesting. Excellent agronomic trails.
Sriracha 1	1991	(F) MCol 113xMCol 22 (M) Rayong 1	Selected from KU F1 hybrid seeds. Excellent agronomic traits. High dry matter content.
Rayong 90	1991	(F) CMC76 (M) V43	Selected from DOA F1 hybrid seeds. High dry matter content. Relatively high yield.
Kasetsart 50	1992	(F) Rayong 1 (M) Rayong 90	Selected from KU F1 hybrid seeds. High yield and high dry matter content. Well adapted to unfavorable conditions.
Rayong 2	1984	(F) MCol 113 (M) MCol 22	Selected from CIAT F1 hybrid seeds. Recommended for human consumption. Relatively high yield, and carotene andvitamin A contents. Low HCN content.

Recent Progress

During the past three years, the DOA has released one industrial cultivar called Rayong 5, and has tested two promising clones, i.e. CMR33-57-81 and CMR33-53-181, in farmers' fields.

Rayong 5, previously identified as CMR25-105-112, was obtained from a cross between 27-77-10 and Rayong 3, made in 1982 at the Rayong Field Crops Research Center. It was released by DOA on October 28, 1994. It is one of the attempts to improve cassava cultivars through an improvement of the top parts along with the roots. **Table 2,** in which data from hundreds of trials are compiled, indicates that Rayong 5 is higher in total plant weight and harvest index, and has higher root yields than Rayong 1, Rayong 3, Rayong 60 and Rayong 90.

Rayong 5 is now widely adopted by cassava growers due to its high yield and other outstanding properties, such as ease of harvest due to its good root shape and root formation, good germination and drought tolerance. **Table 3** shows the yields of Rayong 5 when planted in the early rainy season and in the late rainy season, compared with those of Rayong 1. Its fresh root yield, dry root yield and dry matter content were higher than those of Rayong 1 by 20, 31 and 9% in the early rainy season plantings, respectively. For the late rainy season plantings, its fresh root yields was higher than Rayong 1 by 28%, partly due to the better survival of plants of Rayong 5 during the dry season.

Promising clones

It seems to be increasingly more difficult for Thai cassava breeders to create new cassava clones that are superior to the already existing excellent cultivars Kasetsart 50 and Rayong 5. However, two promising cassava clones, CMR33-57-81 and CMR33-53-181, were selected by the Rayong Field Crops Research Center staff from crosses made in 1990.

Table 2. Yield parameters of Rayong 5 compared with all previously released cultivars. Data from Regional Yield Trials and On-farm Trials conducted from 1988 to 1993.

	R5	R1	R3	R60	R90	KU50
Top yield (53 trials)						
Total plant weight (t/ha)	39.8	38.6	30.1	37.4	37.3	39.4
Leaf and stem weight (t/ha)	14.3	16.2	11.1	13.8	13.7	14.6
Harvest Index	0.64	0.58	0.63	0.63	0.63	0.63
Root yield (120 trials)						
Fresh root yield (t/ha)	27.6	22.7	19.9	26.5	24.7	25.3
-Relative to R1 (%)	121	-	88	117	109	111
Dry matter content (%)	34.8	32.3	35.3	32.5	36.0	35.5
Dry root yield (t/ha)	9.7	7.4	7.1	8.7	8.9	9.1
-Relative to R1 (%)	131	-	96	117	120	123

Table 3. Average yield of Rayong 5 and Rayong 1 when planted in the early rainy season and in the late rainy season from 1988 until 1993.

	Rayong 5	Rayong 1	% Relative to R1
Early rainy season planting (78 experiments)			
Fresh root yield	26.9	22.5	119
Dry matter content (%)	34.8	31.8	
Dry root yield (t/ha)	9.4	7.2	130
Late rainy seaon planting (42 experiments)			
Fresh root yield (t/ha)	29.0	22.6	128
Dry matter content (%)	35.0	33.2	
Dry root yield (t/ha)	10.3	7.7	134

CMR33-57-81 was obtained from a cross between Rayong 1 and Rayong 5, while CMR33-53-181 was obtained from crossing OMR26-14-9 with Rayong 1. The progenies were evaluated in eight Regional Trials and in 15 On-farm Trials during the 1994/95 and 1995/96 seasons. The trials were conducted in two major cassava planting areas of the country, the Northeastern region (Nakon Ratchasima, Khon Kaen, Maha Sarakarm, Kalasin, Roi Et, Mukdahan and Sakhon Nakon provinces), and the Central Region (Rayong, Chonburi, Chantaburi, Prachinburi and Suphanburi provinces).

The data from 11 trials in the Central Region and 12 trials in the Northeastern Region during the 1994/95 and 1995/96 seasons are presented in **Table 4**. Considering the fresh root yield, dry matter content, dry root yield, total biomass and harvest index of the two promising clones and the check varieties, i.e. Rayong 1, Rayong 90 and Rayong 5, from each region and the average of the two regions, the following conclusions could be drawn:

- CMR33-57-81 and CMR33-53-181 produced higher fresh root yields, dry root yields and total biomass than Rayong 1, Rayong 90 and Rayong 5 in both regions, while maintaining a high harvest index at the same level as that of Rayong 5.
- CMR33-57-81 performed excellently in the Northeastern Region, while CMR33-53-181 performed very well in the Central Region.
- The root dry matter contents of the two promising clones are higher than that of Rayong 1, but not as high as those of Rayong 90 and Rayong 5.

CMR33-57-81 and CMR33-53-181 are now in the On-farm Trials and are expected to be released specifically for each region in the next 2-3 years.

Activities through CIAT

Since 1985 the DOA has provided cross-pollinated (CMR) and open-pollinated (OMR) F_1 seeds to CIAT for distribution to other cassava producing countries in Asia.

From 1985 to 1993 74,568 F_1 seeds were provided to CIAT and another 27,570 seeds were provided during the past three years (**Table 5**). Kawano (1993) indicated that the Thai breeding materials were well-adapted to the semi-arid and seasonally dry lowland tropics; therefore, they are offering excellent selection opportunities in most national cassava breeding programs in Asia.

Table 4. Fresh root yield, dry matter content, dry root yield, total biomass and harvest index of CMR33-53-181 and CMR33-57-81 compared with check varieties in Regional and On-farm Trials during 1994/95-1995/96.

	Central Region (11 trials)	Northeastern Region (12 trials)	Average (23 trials)
Fresh root yield (t/ha)			
CMR33-53-181	32.9	32.0	32.4
CMR33-57-81	28.9	36.0	32.6
Rayong 1	24.3	25.4	24.9
Rayong 5	27.4	28.5	28.0
Rayong 90	28.1	24.9	25.2
Dry matter content (%)			
CMR33-53-181	31.9	34.4	33.2
CMR33-57-81	31.3	34.8	33.2
Rayong 1	30.0	32.9	31.5
Rayong 5	33.3	35.4	34.4
Rayong 90	34.2	34.6	34.3
Dry root yield (t/ha)			
CMR33-53-181	10.3	11.1	10.7
CMR33-57-81	9.0	12.6	10.9
Rayong 1	7.1	8.6	7.9
Rayong 5	9.0	10.2	9.6
Rayong 90	8.5	8.8	8.6
Total biomass (t/ha)			
CMR33-53-181	44.6	52.7	49.0
CMR33-57-81	37.8	55.1	47.2
Rayong 1	39.0	46.7	43.2
Rayong 5	37.4	49.3	43.9
Rayong 90	37.8	44.0	41.1
Harvest Index			
CMR33-53-181	0.69	0.63	0.66
CMR33-57-81	0.72	0.67	0.69
Rayong 1	0.60	0.56	0.58
Rayong 5	0.69	0.61	0.65
Rayong 90	0.67	0.59	0.63

In May 1995, Thailand had an opportunity to be the host of a Workshop on Cassava Breeding Methods and Practices, organized by CIAT for Asian cassava researchers. The workshop provided the participants with ample opportunities for learning from the Thai varietal improvement and dissemination programs and for sharing experiences among each other.

Table 5. Number of cassava F1 hybrid seeds exchanged between CIAT and the DOA.

	Year	Number of seeds
Hybrid seeds introduced from CIAT	1975-1993	137,448
	1994	9,843
	1995	11,964
	1996	9,781
	Total	**169,036**
Hybrid seeds provided to CIAT	1985-1993	74,568
	1994	7,678
	1995	11,223
	1996	8,669
	Total	**102,138**

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VARIETAL IMPROVEMENT AND DISSEMINATION BY KASETSART UNIVERSITY, THE THAI TAPIOCA DEVELOPMENT INSTITUTE, AND THE DEPT. OF AGRICULTURAL EXTENSION

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ABSTRACT

For decades a cassava yield stagnation has been observed in Thailand. In addition, current prices of cassava roots and products are highly fluctuating, as they depend on the European Union market's price of cereals, the subsidy of which will be relaxed and will soon disappear. Since 1992 the Thai government has been implementing a policy of reducing the cultivated area, while maintaining the quality and total production of cassava, by the replacement of the traditional local variety, Rayong 1, by higher yielding new varieties. The objective of this paper is to describe the varietal improvement of cassava by Kasetsart University (KU), as well as the cooperative multiplication and dissemination of new, improved cultivars to farmers by KU, the Thai Tapioca Development Institute (TTDI) and the Department of Agricultural Extension (DOAE). Two popular cassava cultivars, Kasetsart 50 and Rayong 5, were officially released in 1992 and 1994, respectively. Subsequent breeding efforts at KU have concentrated on the cross between Rayong 5 and Kasetsart 50. The preliminary results shows that several F_1 clones from the cross had potential dry root yields 10-30% higher than those of the parents. These promising clones have harvest indices and root starch contents similar to those of the parents, but have a significantly higher total biological yield.

Regarding varietal dissemination, in 1994 KU produced 750,000 long stems, and in 1995 1.5 million long stems of Kasetsart 50, for the DOAE to distribute to cassava farmers for further multiplication and distribution. Participating farmers received free cassava stems and 15-15-15 fertilizer at the rate of 625 kg/ha. In 1994, the multiplication area was 5,440 ha involving 2,458 farmers from 25 provinces. Additionally, in 1995, there were 3,899 participating farmers from 22 provinces, who multiplied cassava in 6,274 ha.

In 1993, the TTDI was founded as a foundation, with an initial trust fund of US$24 million. Later, in 1995 TTDI cooperated with KU in distributing 1.79 million stems of Kasetsart 50 to 1,198 cassava farmers from 11 provinces, while 5.97 million stems of Kasetsart 50 and 484,000 stems of Rayong 5 were distributed in 1996 to 4,243 cassava farmers from 23 provinces. Subsequently, in 1995, farmers who planted Kasetsart 50 indicated very satisfactorily performance of this new variety. An average yield of 26.47 t/ha was obtained by 26 surveyed farmers who planted Kasetsart 50, as compared with the national average yield of 14.6 t/ha.

INTRODUCTION

Thailand is the world's leading cassava pellet and starch exporter. Around 4.7-7.3 million metric tons of cassava pellet, and about 500,000-700,000 tons of starch were exported during 1990-1994. The major importer of cassava pellets is the European

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Union (EU). Since 1993 the EU has started to reduce the high support price of its cereals; this will inevitably reduce the price of Thai cassava roots in the EU market.

In order to safeguard the Thai cassava farmers two policies have been launched. First, to decrease the cassava planted area by replacing cassava with fast-growing trees, fruit trees and pastures, and secondly, to increase cassava productivity through cultivar replacement. The traditional Rayong 1 cultivar is to be replaced with new, high-yielding cultivars, such as Kasetsart 50 and Rayong 5.

Two institutes have conducted cassava breeding research, i.e. the Rayong Field Crops Research Center (RFCRC) under the Field Crops Research Institute (FCRI) of the Department of Agriculture (DOA), Ministry of Agriculture and Cooperative (MOAC), and Kasetsart University (KU). Besides the farmers own efforts, a large-scale multiplication, promotion and distribution project has been conducted by both the Department of Agricultural Exptension (DOAE) and the Thai Tapioca Development Institute (TTDI). Since 1994, the adoption rate of new cassava cultivars has been increased at a dramatic rate.

VARIETAL IMPROVEMENT BY KASETSART UNIVERSITY

RFCRC is the major Center for cassava breeding in Thailand. Several new varieties have been released by RFCRC, namely, Rayong 1 in 1975, Rayong 3 in 1983, Rayong 60 in 1987, Rayong 90 in 1989, and Rayong 5 (formerly called CMR25-105-112) in 1994. The breeding program at Kasetsart University is relatively small. Nevertheless, the variety Sriracha 1 was released in 1990, and in cooperation with RFCRC and the Centro Internacional de Agricultura Tropical (CIAT), Kasetsart 50 was released in 1992. Details of these varieties were summarized by Rojanaridpiched *et al.* (1995).

Rayong 1 is a selection from a local land race. It has excellent agronomic triats, 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 farmer conditions. More than 1 million ha were planted with Rayong 1 every year. Thus, it can be stated that Rayong 1 is the most successful cassava variety 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).

Several breeding strategies have been proposed since 1985. Tan (1987) suggested that the goal of cassava yield improvement was to improve HI while maintaining the same canopy strength of traditional cultivars. In addition, Kawano (1988) showed that a simultaneous improvement in HI and total biological yield (TBY) in these genotypes would result in higher yield than those of presently available cultivars, both in high and low-yielding environments. Later, Kawano *et al.* (1990) showed that further improvement in HI and TBY were possible. Rojanaridpiched *et al.* (1995) tested the new cultivars, Rayong 3, Rayong 60, Rayong 90, Rayong 5 and Kasetsart 50 in comparison with Rayong 1 in 53 locations during 1991 and 1992. Rayong 3, which had higher HI but lower 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 Rayong 5, which had higher HIs and TBYs yielded higher than Rayong 1 in all environments.

Kasetsart 50 and Rayong 5 are popular cultivars because of their higher fresh root yields and higher root starch contents than Rayong 1, while their plant types are as vigorous as that of Rayong 1. Since the release of Kasetsart 50 in 1992 and Rayong 5 in 1994, the breeding objective at KU has been to breed for new clones with higher yield than Kasetsart 50 and Rayong 5, while maintaining the root starch content and other agronomic triats equivalent to, or better than, these two cultivars.

Since the KU breeding program is not so large, that breeding effort has been concentrated on the cross between Rayong 5 and Kasetsart 50. The two cultivars were derived from different parents; therefore, in-breeding effect should not occur. The pedigree of Kasetsart 50 and Rayong 5 are as follows:

cultivars	pedigrees
Kasetsart 50	Rayong 1 x Rayong 90
Rayong 5	27-77-10 x Rayong 3
Rayong 90	CMC76 x V43
27-77-10	CM321-170 x MCol 1684
Rayong 3	MMex 55 x MVen 307

The cross between Rayong 5 and Kasetsart 50 was made in 1991/92. The first year selection from 963 seedling plants (seedling selection) was based on plant type, root yield, root starch content and HI. Consequently, 204 plants were selected in 1992/93 at Sriracha Research Station. For the second year selection, each selected plant or clone was planted in a Single-row Trial at Sriracha Research Station in 1993/94. Selection was based on the same criteria as the seedling selection with additional consideration on root shape (compact roots) as a criterion for ease of harvest. A total of 108 clones were selected. These 108 clones were preliminarily tested at Huay Bong Station of TTDI in Nakhon Ratchasima. This preliminary yield test of 108 clones was split up into several sets. Each individual set consisted of ten clones with three additional check cultivars, i.e. Rayong 1, Rayong 5 and Kasetsart 50, and was replicated twice. Several clones had higher root yield and total plant weight than Rayong 1, Rayong 5 and Kasetsart 50, while maintaining as high a root starch content and HI as Rayong 5 and Kasetsart 50 (**Table 1**). A total of 28 clones were selected.

These 28 selected clones were grouped and tested in farmers' fields during

1995/96. Yield data are shown in **Tables 2** to **4**. Even though each promising clone was tested in only one location, the performances of several clones were very encouraging. When compared with the traditional cultivar Rayong 1, dry root yields of several promising clones were 39-113% higher than that of Rayong 1. In the last decade, it has been difficult to find any clones that yielded higher than Rayong 1. All of these promising clones were the F_1 from the cross between Rayong 5 and Kasetsart 50. These two parents have several good chareteristics, such as high root yield, starch content, HI and TBY. The dry root yield of MKUC34-114-206 was 38% higher than that of Kasetsart 50 (**Table 2**), while that of MKUC34-114-54 was 25% higher than that of Kasetsart 50 (**Table 3**), and that of MKUC34-114-85 was 12% higher than that of Rayong 5 (**Table 4**).

Table 1. Yield data of some selected clones harvested at 12 months after planting from a Preliminary Yield Trial at Huay Bong, Nakhon Ratchasima in 1994/95.

Clones	Fresh root yield (t/ha)	Root starch content (%)	HI	Total plant weight (t/ha)
		Set I		
MKUC34-114-187	50.4	24.7	0.53	95.2
MKUC34-114-206	34.2	24.5	0.50	68.6
Rayong 5	33.5	23.2	0.49	68.9
Kasetsart 50	21.1	21.6	0.41	51.7
Rayong 1	16.0	10.0	0.28	56.5
		Set II		
MKUC34-114-200	39.2	26.8	0.54	72.7
MKUC34-114-175	39.6	21.5	0.57	69.6
Rayong 5	37.0	23.7	0.53	69.6
Kasetsart 50	30.6	23.8	0.53	57.3
Rayong 1	21.7	18.6	0.36	60.5
		Set III		
MKUC34-114-54	33.1	23.3	0.43	76.4
Rayong 5	39.2	24.5	0.57	68.6
Kasetsart 50	30.0	24.4	0.31	66.6
Rayong 1	23.3	16.7	0.38	74.2

Table 1. (continued)

Clones	Fresh root yield (t/ha)	Root starch content (%)	HI	Total plant weight (t/ha)
		Set 6		
MKUC34-114-17	41.2	24.9		0.4787.5
Rayong 5	26.7	27.0		0.5449.0
Kasetsart 50	29.8	26.1		0.5554.0
Rayong 1	26.5	15.9		0.3674.0
		Set 7		
MKUC34-114-84	52.8	22.5		0.6877.8
MKUC34-114-85	41.5	20.5		0.5575.4
MKUC34-114-64	38.1	22.0		0.5175.2
Rayong 5	32.5	25.6		0.5163.7
Kasetsart 50	38.1	23.2		0.5766.7
Rayong 1	32.5	15.9		0.4277.2

Table 2. Yield data of some promising clones planted at Sriracha Research Station in 1995 and harvested at 10 months after planting.

Clones	Root yield (t/ha)			Root starch content	HI	Total plant weight	
	fresh	dry	(% of R_1[1])	(%)		(t/ha)	(% of R_1[1])
MKUC34-114-206	23.31	8.13	187	22.6	0.69	34.12	144
MKUC34-114-200	21.85	7.25	167	20.4	0.66	33.10	140
MKUC34-114-175	19.02	6.30	145	20.3	0.65	29.29	124
MKUC34-114-187	19.20	6.04	139	18.0	0.59	32.05	136
Kasetsart 50	17.36	5.89	135	21.3	0.63	27.58	117
Rayong 5	14.77	4.80	110	19.5	0.68	21.58	91
Rayong 1	15.76	4.34	100	12.8	0.67	23.54	100
LSD($P<0.05$)	5.89	1.85	-	1.13	0.06	8.06	-
CV(%)	18.09	17.61	-	3.37	5.61	16.15	-

[1] R_1 = Rayong 1

Table 3. Yield data of some promising clones planted at Huay Bong, Nakhon Ratchasima in 1995 and harvested at 9 months after planting.

Clones	Root yield (t/ha)			Root starch content	HI	Total plant weight	
	fresh	dry	(% of R_1[1)])	(%)		(t/ha)	(% of R_1[1)])
MKUC34-114-54	23.86	8.53	213	23.7	0.59	40.75	149
MKUC34-114-64	23.58	8.35	208	23.1	0.62	36.85	135
MKUC34-114-84	22.40	8.11	202	24.3	0.64	34.35	126
MKUC34-114-206	21.16	7.50	187	23.2	0.59	35.33	129
Kasetsart 50	19.16	6.80	170	23.0	0.54	35.05	128
Rayong 5	17.06	6.00	150	22.8	0.56	30.60	112
Rayong 1	12.66	4.00	100	18.1	0.47	27.21	100
LSD ($P<0.05$)	6.34	2.42	-	3.14	-	8.58	-
CV(%)	24.66	26.61	-	9.58	-	18.40	-

[1)] R_1=Rayong 1

Table 4. Yield data of some promising clones planted at Khonburi, Nakhon Ratchasima, in 1995 and harvested at 8 months after planting.

Clones	Root yield (t/ha)			Root starch content	HI	Total plant weight	
	fresh	dry	(% of R_1[1])	(%)		(t/ha)	(% of R_1[1])
MKUC34-114-85	28.23	9.78	197	22.2	0.64	43.89	160
MKUC34-114-17	25.64	9.21	185	23.9	0.55	46.48	169
Rayong 5	24.86	8.71	175	22.4	0.61	41.01	149
Kasetsart 50	21.25	7.71	155	24.5	0.58	36.71	134
Rayong 1	14.89	4.96	100	20.5	0.54	27.38	100
LSD ($P<0.05$)	6.01	2.26	-	1.55	0.05	9.75	-
CV(%)	19.66	20.85	-	4.63	4.74	17.79	-

[1] R_1=Rayong 1

This promising F_1 from the cross of Rayong 5 x Kasetsart 50 also possessed the same high root starch content and HI as the parents, but some clones had higher TBY. This result was simply the segregation from the cross between two good parents, which resulted in some better F_1.

Results from KU's cassava breeding program indicated that it is possible to get a high yielding clone of cassava by a few selected crosses between two good parents. Further progress in the Thai cassava breeding program will depend on the flow of new selected genetic materials into hybridizing schemes.

Future Breeding Direction

Recently, Thailand is facing a severe farm labor shortage. Thus, further improvements in cassava production depend more on mechanization. A compact root shape to enhance the ease of machine harvesting must be considered in the future. Also, very little attention has been paid to root HCN. Some complaints about the high HCN content of the roots of new cassava cultivars have been received from the starch industry. In a modern starch factory, 300-600 metric tons of fresh cassava root are crushed daily. Consequently, vaporized HCN released in small closed-in areas may be harzardous to workers in the factory.

VARIETAL MULTIPLICATION AND DISSEMINATION

Before the official release of Kasetsart 50 in 1992 and Rayong 5 in 1994, most cassava planting stakes were exchanged freely among farmers. New improved varieties have a high root starch content (23-24% for Kasetsart 50 and Rayong 5, as compared to 18% for Rayong 1) and a high root yield. The price of fresh roots from these two new varieties was about 0.10 baht per kilogram higher than from Rayong 1. Hence, with these two new varieties, farmers will get both a better yield and a higher price. Some progressive farmers and factory owners multiplied and sold planting stakes of these new varieties themselves. At the early stage of varietal release, one long stem of Kasetsart 50 might cost about 2-5 Baht. As a consequence, farmers in several locations shifted their activities from cassava root production to cassava stake production. Several systems of multiplication were used, such as the planting of two-node cuttings or very thin stakes, or leaving plants in the field to cut stems twice a year instead of harvesting roots annually. Several farmers earned large amounts of money from selling Kasetsart 50 stakes. Unfortunately, the actual amount of stakes multiplied by farmers could not be verified.

There are two new major programs of cassava varietal multiplications. Firstly, under the project entitled "Increase the Potential of Cassava Production," the DOAE, mandated by MOAC, has been in charge of multiplication plots totaling 6,400 ha annually for new varieties over a three year period (1994-1996). Participating farmers are responsible for the multiplication of cassava stems. Stakes from these multiplication plots have been disseminated to other farmers to set up distribution plots totaling 19,200 ha annually for three years, from 1995 to 1997. At the end of the project (1998) it is expected that 364,800 ha of Rayong 1 will be replaced by new higher yielding cultivars.

Secondly, The Thai Tapioca Development Institute (TTDI), which is a nonprofit foundation, was established in Sept 1993, with an initial trust fund of US$24 million from the government. The main objectives of TTDI are: 1. to develop high quality cassava roots at low cost for industrial usage; 2. to develop new technology for the manufacture of new products from cassava; and 3. to develop markets for cassava products. Under the program of "Cost Reduction in Cassava Production", a large-scale multiplication and distribution of new cassava cultivars has been conducted since 1995. Details of the program of DOAE and TTDI will be discussed in the following sections.

"Increase the Potential of Cassava Production" by DOAE

According to the plan, a total of 6,400 ha of multiplication plots are planted annually in farmers' fields by farmers under the supervision of DOAE's extension agronomist for three years (1994-1996), resulting in planting material for a total area of 19,200 ha. New cassava cultivars are Rayong 3, Rayong 5, Rayong 60, Rayong 90 and Kasetsart 50. RFCRC, under DOA, produces basic planting material of Rayong cultivars, while KU produces Kasetsart 50 for DOAE to plant in the farmers' fields.

Participating farmers receive free planting material of the new cassava cultivars and free 15-15-15 fertilizer at the the rate of 625 kg/ha. After harvest, it is expected that five times the original amount of cassava stakes can be obtained. Of each five stems, farmers keep two for their own production, while the remaining three stems must be returned to DOAE for further distribution to neighboring farmers. The distribution of new cassava cultivars has been organized and controlled by village commitees.

In 1994, the actual multiplication area was 5,440 ha, involving 2,458 farmers from 402 subdistricts in 134 districts in 25 provinces. Later, in 1995, the actual multiplication area was 6,274 ha, involving 3,899 farmers from 377 subdistricts, 125 districts in 22 provinces. The total area of multiplication of each cultivar in 1994 and 1995 are shown in **Table 5**. For this project, KU produced for the DOAE 750,000 long stems of Kasetsart 50 in 1994 and 1.5 million long stems in 1995.

"Cost Reduction in Cassava Production" by TTDI

In the middle of 1993 TTDI bought 260 ha of land at Huay Bong in Nakhon Ratchasima province. This land was used to establish the "Center for Cost Reduction in Cassava Production". At this Center, Rayong 60, Rayong 90, Sriracha 1, Kasetsart 50 and Rayong 1 were planted for yield comparisons in large plots. In late 1994, it was found that Kasetsart 50 had a high root yield, high root starch content, and vigorous stems, suitable for efficient multiplication. Therefore, the TTDI committee decided to multiply Kasetsart 50 for distribution to farmers.

Table 5. Area planted for the multiplication of new varieties by farmers under contract with the Department of Agricultural Extension in 1994 and 1995.

Cultivars multiplied	Multiplication areas (ha)	
	1994	1995
Sriracha 1	-	17
Rayong 3	599	-
Rayong 5	-	1,620
Rayong 60	2,315	690
Rayong 90	2,146	2,591
Kasetsart 50	420	1,356
Total	**5,440**	**6,274**

In late 1994, about 1301 farmers from 11 provinces of the Northeast received training at the TTDI's Center on how to increase the productivity of cassava production. Researchers from KU and RFCRC functioned as trainers. Farmers who attended the training were eligible to receive 1,500 long stems of Kasetsart 50. This amount of planting material is enough to plant about 0.8 ha. Farmers who received the planting material of Kasetsart 50 must, after harvest, distribute 4,500 long stems of Kasetsart 50 to neighboring farmers. TTDI produced its own planting material of Kasetsart 50 and bought some directly from KU. Distribution of stems of Kasetsart 50 to farmers who attended the training in 1994 was done in the early rainy season of 1995. A total of 1,797,000 long stems of Kasetsart 50 were distributed to 1,198 farmers from 11 provinces as summarized in **Table 6.**

Table 6. Summary of farmers trained and new cassava cultivars distributed to farmers by TTDI in 1995 and 1996.

	1995	1996
No. of farmers trained at TTDI (persons)	1,301	7,089
No. of farmers having received stakes from TTDI	1,198	4,243
No. of farmers having obtained stakes from neighbors	-	1,431
Area planted with Kasetsart 50 by TTDI-trained farmers (ha)	958	4,398
Area planted with Rayong 5 by TTDI-trained farmers (ha)	-	140

In 1995/96, 7,089 farmers from 23 provinces attended the cassava training courses. This year, the project's operational procedure is similar to that in 1994/95 with some modification. In 1994/95, each farmer who obtained 1,500 stems of Kasetsart 50 had to distribute about 4,500 stems to neighboring farmers. The target number of distributed stems was 5.3 million, but the actual number of stems distributed was only about 3.0 million (56.7% of target) because of the high demand for Kasetsart 50 stakes, and the reluctance of farmers to give the stakes to neighboring farmers. Both Kasetsart 50 and Rayong 5 are favored by farmers. Therefore, in 1995/96 TTDI required the farmers to return stems on a 1: 1 basis. A total of 5.9 million stems of Kasetsart 50 and

0.484 million stems of Rayong 5 were distributed to 4,243 farmers. Another 1,431 farmers obtained Kasetsart 50 from their neighbors who in turn had received stems from TTDI in 1995. This resulted in a total of 8.5 million stems. The area planted to Kasetsart 50 and Rayong 5 distributed by the TTDI project is shown in **Table 6**.

Varietal Adoption

Since the release of Rayong 3 in 1983, considerable efforts were made to multiply and promote this cultivar. Klakhaeng *et al*. (1995) estimated that the area planted to Rayong 3 in 1992 was 108,000 ha or about 7.3% of the total cassava growing area. However, the yield potential of Rayong 3 is lower than that of Rayong 5, Rayong 60, Rayong 90 and Kasetsart 50. Rayong 3 is characterized by a very small plant type compared with Rayong 1, which makes it unsuitable for growing in poor soil.

Currently, the surveyed data by DOAE revealed that in 1994 and 1995 the total area under new cultivars was 296,254 and 387,861 ha, respectively (**Table 7**). In 1995, the area under new cultivars was about 29% of the the total planting area. It was found that the area under Rayong 3 had decreased from 135,421 ha in 1994 to only 14,953 ha in 1995. Among the new cultivars, the area under Rayong 60 was larger than that of Rayong 90, which was followed by that of Rayong 5 and Kasetsart 50 (**Table 7**). Details of cultivar distribution among various provinces are shown in **Table 8**. The area planted to new cultivars in 1995 was concentrated in some provinces, such as Nakhon Ratchasima, Prachin Buri and Chachoengsao. Areas planted to new cultivars of some provinces, such as Chaiyaphum, Udon Thani, Nong Khai, which are leading production areas as well, were not as large as those of Nakhon Ratchasima, due in part to the long distance from research stations.

It is surprising that the area under new cultivars in 1995 was already 29% of the total cassava area, even though, the target acreage of DOAE was only 20%. The cultivation area of the newest cultivars, Rayong 5 and Kasetsart 50, is likely to increase dramatically in the near future, because of their high yield potential and root starch content. Rayong 60 has also high yield potential, but the root starch content is equivalent to that of Rayong 1, which results in a lower root price in the rainy season. Rayong 90 has high yield potential and high root starch content, but its germination rate is reduced dramatically if stakes are stored longer than 3-4 weeks.

The area planted to new cultivars will increase rapidly if the distribution effort is concentrated in areas where the new cultivars are presently not yet widely grown. The rapid expansion of cultivated area of new cultivars in 1994 and 1995 may partly be due to the farmers' own efforts. The positive impact of DOAE's and TTDI's programs on expansion of cultivated area is likely to be materialized in the next couple of years.

Table 7. Areas planted to new cassava cultivars in Thailand in 1994 and 1995.

Cultivars	Planted area (ha)	
	1994	1995
Rayong 3	135,421	14,953
Rayong 60	125,049	207,589
Rayong 90	35,461	81,049
Kasetsart 50	322	17,846
Rayong 5	NA[1]	66,424
Total	**296,254**	**387,861**

[1]NA = Not available

Table 8. Total planted area of cassava and area planted to new cultivars in some leading cassava growing provinces of Thailand in 1995.

	Planted area (ha)				
	Total area	R5	R60	R90	KU 50
Nakhon Ratchasima	297,679	5,467	71,095	18,777	5,640
Chaiyaphum	83,980	54	460	884	377
Chachoengsao	70,334	4,640	6,080	7,587	3,200
Prachin Buri[1]	67,580	7,979	16,353	5,302	4,059
Udon Thani	66,097	1,752	6,781	710	322
Nong Khai	61,369	40	174	10	16
Kamphaeng Phet	59,175	30,757	18,454	12,303	-
Kalasin	58,019	3,225	2,726	2,530	168
Khon Kaen	57,319	92	724	476	249
Chon Buri	42,439	269	838	2,908	274
Rayong	39,843	1,520	939	1,463	422
Phitsanulok	39,520	117	2,080	152	-
Total (41 provinces)[2]	**1,322,859**	**66,423**	**207,588**	**81,049**	**17,846**

[1]including Srakaew province.
[2]in each column the figure reflects the total cassava cultivation area of 41 provinces.

An evaluation of the root yield of Kasetsart 50 was conducted by TTDI. A survey of yield performance from 26 farmers in 8 provinces who had received Kasetsart 50 from TTDI in 1995 was conducted during April 1996. An average yield of 26.4 t/ha with 27% root starch content was obtained from Kasetsart 50, as shown in **Table 9**. The result is very satisfactory in comparison to the nation average yield of around 14 t/ha. With this result, the TTDI committee approved further multiplication of new cultivars in 1997 for the third year.

Table 9. Yield of Kasetsart 50 in farmers' fields, as indicated by a survey of 26 TTDI-trained farmers in 1996.

Provinces	No. of farms surveyed	Germination (%)	Root yield (t/ha)	Root starch content (%)
Chaiyaphum	2	87	23.6	23
Nakhon Ratchasima	6	70	25.5	25
Buri Ram	4	78	32.9	28
Khon Kaen	5	78	29.2	28
Kalasin	2	70	21.3	27
Sakon Nakhon	4	83	29.3	27
Nongbua Lampoo	2	87	24.8	27
Udon Thani	1	81	18.5	28
Average		77	26.4	27

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CASSAVA VARIETAL IMPROVEMENT IN VIETNAM

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ABSTRACT

In recent years (1990-1995) the cassava area in Vietnam has remained stable, or has increased slightly in the south due to the new demand for cassava roots used for starch processing. Therefore, our cassava breeding program, in collaboration with CIAT, has put a high priority on developing new varieties with high yield potential and high dry matter and starch content in the roots.

Due to the particular agro-climatic conditions in Vietnam the country can be divided into two large regions. The south is characterized by a tropical climate, while the north has a sub-tropical climate. So, new varieties adapted to these specific environments are also needed.

Out of the 29 promising clones introduced from the Thai-CIAT program in 1989 and 1990, two best selections, KM60 and KM94, have been giving 17 to 112% higher dry root yields and 10 to 103% higher fresh root yields compared to the local cultivars at research stations, and 30 to 47% higher fresh root yields in cassava production zones. Both KM60 and KM94 were officially released early in 1995. They were grown over 7000 ha in 1995 and are expected to be planted in about 30,000 ha in the 1996/97 crop year. The additional economic benefit resulting from adoption of the new cultivars was estimated to have reached 0.95 million US dollars in 1995 and is expected to reach 5 million US dollars in 1996.

Some promising clones may be adapted to specific locations. Clone SM937-26 gave very good yields at Lam Dong and Khanh Hoa provinces, CMR29-60-15 and SM1157-3 in Ha Tay province, while SM1157-3 and SM981-3 were best in Bac Thai province. These clones are now included in Regional Trials and in the On-farm Evaluation Network in 1996.

Follow-up selection of genotypes adapted to our cassava production conditions started in 1990. Some promising clones, like OMR33-17-15 in the south and CM4955-7 in the north, are being evaluated on farmer's fields this year. They are both the result of intensive selection by HARC and the Agro-forestry College in Bac Thai from hybrid seeds provided by CIAT/Colombia and the Thai-CIAT program. Although the rate of selection with CIAT/Colombia materials is not quite as high as those from the Thai-CIAT program, the greater genetic diversity of this material is playing an important role in cassava breeding and genetic improvement in Vietnam. Results from our current selection will identify new high-yielding cultivars and bring economic benefits for growers and processors; they may also open up new export opportunities by greater product competitiveness in international markets.

INTRODUCTION

During recent years (1990-1995) the cassava area in Vietnam has been stable or has slightly increased in the south by the setting up of new starch and monosodium glutamate factories. The demand for cassava fresh roots as raw material for these factories ranges from 270,000 to 600,000 t/year. Traditional rural processing of cassava

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fresh roots into starch and maltose around Ho Chi Minh city and Hanoi consumed about 395,077 ton fresh roots in 1992, and this is expected to reach 898,740 ton fresh roots by the year 2000. Cassava is thus becoming an industrial crop in some parts of the country.

Therefore, the cassava breeding program in Vietnam, in cooperation with CIAT, has put high priority in developing new varieties that have high yield potential and high root dry matter content, which is suitable as raw material for the processing industry. Breeding materials, both in the form of stem cuttings from the Thai-CIAT program and hybrid seeds from CIAT/Colombia and the Thai-CIAT program have been introduced and evaluated in order to select the most suitable genotypes under our cassava production conditions.

Soils and Agro-Climate

Vietnam is located between latitudes 8.5 and 23.5° N and longitudes 102 and 110° E. The country has been divided into seven Agro-ecological zones. In general, the northern part is characterized by a subtropical climate with low winter (15°C) and high summer (29°C) temperatures. Most rain falls during the summer months of May to Sept. In the south, the climate is tropical with relatively little fluctuation in monthly temperatures, which vary from 25 to 29°C. The rainy season is about one month delayed compared with the north, but total rainfall is similar (Nguyen Huu Hy *et al.*, 1995).

The soils of Vietnam are closely associated with its topography. It was estimated that in Vietnam about 66% of cassava is grown on Ultisols, 17% on Inceptisols, 7% on Oxisols, 4% on Alfisols, 2% on Entisols and 3% on Vertisols (Howeler, 1992). The soil pH generally varies from 4.5 to 6.0. Therefore, one important breeding objective is to develop new varieties adapted to specific environments.

Breeding Objectives and Materials

Cassava breeding in Vietnam is mainly conducted by three institutions under the coordination of the National Root Crops Program, i.e. Hung Loc Agricultural Research Center in the south, the Agro-Forestry College of Thai Nguyen Univ. in Bac Thai and the Potato and Vegetable Research Center in Hanoi.

Breeding materials have been introduced from CIAT since 1989 and upto 1995 these consist of:

-29 promising clones from the Thai-CIAT program
-Hybrid seeds from CIAT/Colombia
-Hybrid seeds from the Thai-CIAT program

The general cassava breeding objective in Vietnam is to develop promising clones with the following characteristics:

-High yield potential and high dry matter and starch contents in the roots
-Sweet varieties for specific end-uses

-High harvest index (HI)
-Early harvestability (8-10 months)
-Adaptation to acid infertile soils and to low levels of inputs
-Good plant type for association with other crops
-Specific adaptation to a given region

Research methodologies as well as on-farm evaluations have followed the CIAT breeding scheme.

ACHIEVEMENTS

Evaluation of Promising Clones Introduced from the Thai-CIAT Program in 1989

Success of Two New Recommended Varieties, KM60 and KM94

After the introduction in 1989 of 29 promising clones from the Thai-CIAT program in the form of stem cuttings, a series of intensive evaluations have been conducted by the cassava breeding network throughout the country. From this, two varieties, Rayong 60 and Kasetsart 50, were selected and renamed as KM60 and KM94, respectively. These have been released as new varieties and have been widely adopted by farmers. In the south, these varieties have been giving from 66 to 103% higher yields than the improved local cultivar, HL23, in terms of fresh roots, and from 75 to 112% in terms of dry root yield at research stations; and from 30 to 38% higher fresh root yields in on-farm production trials (**Tables 1 and 2**). In the north, the yields of KM60 and KM94 at research station trials were only 10-13% higher than those of the local cultivar, Vinh Phu, but in on-farm production their fresh root yields were 30-47% higher than those of Vinh Phu (**Tables 1 and 2**). The dry matter contents of these varieties are also 4-8% higher than those of the local cultivars.

Table 1. Comparison of average yield parameters of KM60 and KM94 with those of local varieties at Research Stations in North and South Vietnam from 1990 to 1995.

Clones	Fresh root yield (t/ha)	% of control	Dry matter content (%)	% of control	Dry root yield (t/ha)	% of control
				NORTH		
KM94	24.9	110	40.0	108	9.85	117
KM60	25.6	113	38.5	104	9.96	119
Vinh Phu	22.6	100	37.0	100	8.36	100
				SOUTH		
KM94	36.60	203	38.3	104	14.0	212
KM60	29.95	166	38.7	106	11.6	175
HL23	18.00	100	36.5	100	6.6	100

Table 2. Comparison of average fresh root yields of KM60 and KM94 with those of local varieties in On-Farm Production in North and South Vietnam from 1992 to 1995.

Clones	South		North	
	t/ha	% of control	t/ha	% of control
KM94[1)]	35.0	138	25.6	147
KM60	33.0	130	22.6	130
Local cultivars	25.2	100	-	-
Vinh Phu	-	-	17.3	100

[1)]Data for 1995 only

Both KM60 and KM94 were officially released early in 1995 and were quickly disseminated in cassava production areas by the cassava technology transfer network. It was estimated that about 7,000 ha were grown with these two varieties in 1995 and that the area planted exceeded 30,000 ha in 1996.

The adoption of KM60 and KM94 as new high-yielding cultivars partly satistifies the increasing demand for good raw materials for the starch processing industry. It is also bringing additional economic benefits to farmers, which was estimated to have reached 0.95 million US dollars in 1995 (Kawano, 1995).

Varietal Selection for Adaptation to Specific Regions

One of the most important characteristics of KM60 and KM94 is that they are adapted to a wide range of agro-ecological conditions as well as to variable farmer's practices; hence, in this case there is little interaction between genotype and environment. But for future genotypes it may be necessary to exploit more fully the potential of certain clones for specific regions.

Results of yield trials conducted at Hung Loc Research Center in south Vietnam have shown that SM937-26 gave very good yields at Lam Dong and Khanh Hoa provinces (**Table 3**), while CMR29-60-15 and SM1157-3 were good in Ha Tay (**Table 4**), and SM981-3 and SM1157-3 were the highest yielders in Bac Thai province (**Table 5**). These clones are now included in the Regional Trials and On-farm Evaluation Network in 1996.

Table 3. Results of Regional Yield Trials conducted by Hung Loc Agric. Research Center in Central and South Vietnam in 1994.

Clones	Fresh root yield at various locations (t/ha)							Average yield (t/ha)
	Thua Thien	Quang Nam	Quang Ngai	Khanh Hoa	Binh Thuan	Dac Lac	Lam Dong	
KM94	42.1	34.5	38.8	52.5	21.5	27.3	26.5	34.7
SM937-26	33.8	27.7	26.2	56.4	18.8	19.6	25.0	29.6
CMR937-14	-	-	-	42.6	15.5	-	22.2	26.7
KM60	40.4	26.8	34.8	64.4	19.5	25.2	24.9	33.7
Local check[1)]	37.5	21.5	16.9	57.6	19.3	13.5	19.9	26.6

[1)]Local checks: H34, Nam Thuc and Gon

First Promising Clones Selected from Hybrid Seeds

The introduction of hybrid seeds of selected crosses from CIAT started in 1990. Recurrent evaluation from this seed is an opportunity to select those genotypes most adapted to our specific cassava production conditions. During five years of intensive selection from the seeds introduced in 1990 and 1991, OMR33-17-15 gave very promising results in the south (**Table 6**) and CM4955-7 in the north (**Table 7**).

Table 4. Results of an Advanced Yield Trial conducted at the Potato and Vegetable Research Center in Hanoi in 1995.

Clones	Fresh root yield (t/ha)	Root dry matter content (%)	Dry root yield (t/ha)	Harvest index
KM94	26.83	40.1	10.76	0.64
KM60	22.67	38.4	8.71	0.60
CMR29-60-15	24.83	39.1	9.71	0.61
SM1157-3*	23.00	37.4	8.60	0.59
CMR25-33-105	21.33	37.7	8.04	0.66
SM981-3*	18.50	38.8	7.18	0.55
Vinh Phu (Local)	19.50	38.6	7.53	0.58

Table 5. Results of an Advanced Yield Trial conducted at Agro-forestry College in Bac Thai in 1995.

Clones	Fresh root yield (t/ha)	Total biomass yield (t/ha)	Harvest index	Root dry matter content (%)	Dry root yield (t/ha)
Vinh Phu	17.1	26.5	0.64	38.4	6.5
KM60	20.5	30.5	0.67	41.4	8.5
SM1157-3[1)]	28.0	45.3	0.62	41.6	11.6
SM981-3[1)]	24.0	36.0	0.66	41.6	10.0
OMR25-33-105	19.8	27.0	0.73	41.6	8.2
CMR29-60-15	20.0	32.0	0.62	43.2	8.6
SM937-8[1)]	22.6	35.9	0.63	40.0	8.9

[1)]Clones have been selected from hybrid seeds at Hung Loc Agric. Research Center

Table 6. Fresh root yield of OMR33-17-15 in comparison with those of KM94, KM60 and local cultivars at some locations in South Vietnam in 1994.

Clones	Fresh root yield at various locations (t/ha)					Average yield (t/ha)
	Xuan Thanh	Tra Co	Long Thanh	Tay Ninh	Ho Chi Minh	
OMR33-17-15	27.1	35.7	41,0	29.3	49.5	40.5
KM94	27.8	42.5	46,0	41.7	50.4	41.7
KM60	23.1	37.1	-	30.6	-	30.3
Local cultivars	12.7	-	-	26.1	21.1	19.9

Source: Tran Ngoc Quyen, 1994

Observation of Yield Potential of Materials Introduced from CIAT/Colombia and the Thai-CIAT Program

It is obvious that cross parents have not been selected only for our ecosystem. Some progenies may show good performance, while others may not be quite so good in the new environment. Therefore, it is also important to estimate the yield potential of different materials under our own conditions to get feedback for future selections. From hybrid seeds introduced in 1993, we have seen that the selection rate in F_1 seedlings derived from hybrid seeds from CIAT/Colombia was lower than from the Thai-CIAT materials, i.e 18.5 and 21.0%, respectively. Especially in Single Row Trials, the selection rate of CIAT/Colombia materials was much lower than that of Thai-CIAT materials (14 and 40%, respectively) (**Table 8**). This observation was confirmed in the Preliminary Yield Trial conducted at the Agro-forestry College in Bac Thai in 1995 (**Table 9**). The best clones that have been selected for the Replicated Yield Trial in 1996 indicate that Thai-CIAT materials seem to be better than CIAT/Colombia materials for direct selection of promising clones that can be recommended for cassava production. It is too early to draw any conclusion, because the success of a breeding program depends not only on the skill of the breeders but also on the breeding materials. So, having good parental materials with wide genetic variability will give us a good chance to select the most suitable genotypes for both direct-use and for the future breeding program.

Table 7. Results of an Advanced Yield Trial conducted at Agro-forestry College in Bac Thai in 1994.

Clones[1)]	Fresh root yield (t/ha)	Total biomass yield (t/ha)	Harvest index	Root dry matter content (%)	Dry root yield (t/ha)
Vinh Phu(check)	15.6	25.8	0.60	38.4	6.0
KM60(check)	24.5	40.0	0.61	41.5	10.1
CM4955-7	30.0	48.5	0.62	41.5	12.4
SM1035-1	21.0	37.6	0.55	39.8	8.3
CM7889-10	18.7	29.7	0.63	38.9	7.2
CM7909-2	18.5	33.7	0.55	36.3	6.7
CM7889-2	15.8	28.3	0.56	41.5	6.5
SM1200-6	16.2	24.7	0.65	38.3	6.2
SM1079-1	14.7	30.3	0.48	40.4	5.9

[1)]Clones had been selected from hybrid seeds introduced in 1991

Table 8. Results of an evaluation of the selection rate of materials introduced from CIAT/Colombia and the Thai-CIAT program in F1 Seedling and Single Row Trials conducted at Agro-forestry College in Bac Thai in 1993 and 1994.

Stage of evaluation	CIAT/ Colombia	Thai-CIAT	Vinh Phu (check)	KM60 (check)
F1 Seedling Trial 5				
-Total seeds	3000	1004	-	-
-No of clones harvested	384	262	-	-
-No of clones selected for next step	71	55	-	-
-Selection rate(%)	18.5	21.0	-	-
Single Row Trials				
-Mean fresh root weight(t/ha)	16.3	22.8	17.6	23.5
-Mean total plant weight(t/ha)	32.6	39.0	31.7	37.5
-Mean harvest index	0.50	0.58	0.55	0.62
-Mean RDMC[1)]	37.3	41.6	39.4	42.3
-No of clones selected for next step	10.0	21.0	-	-
-Selection rate(%)	14.0	40.0	-	-

1)RDMC=Root dry matter content

Table 9. Average yield parameters of clones selected from seeds introduced from CIAT/Colombia and the Thai-CIAT program in a Preliminary Yield Trial conducted at Agro-forestry College in Bac Thai in 1995.

Mean traits	CIAT/ Colombia	Thai-CIAT	Vinh Phu (check)	KM60 (check)
All entries mean				
-Fresh root yield(t/ha)	23.9	25.3	26.4	30.0
-Biomass yield(t/ha)	45.6	45.6	45.2	46.2
-Harvest index	0.52	0.55	0.58	0.64
-RDMC[1)](%)	38.5	38.8	38.8	39.2
-Starch content(%)	27.3	27.6	27.4	28.1
Clones selected for RYT[1)]				
-Fresh root yield(t/ha)	27.3	32.0	-	-
-Biomass yield(t/ha)	47.1	52.2	-	-
-Harvest index	0.58	0.61	-	-
-RDMC(%)	37.2	39.6	-	-
-Starch content(%)	25.6	28.3	-	-

[1)]RDMC = Root dry matter content; RYT = Replicated Yield Trial

CONCLUSIONS

During the past five years much progress has been made in cassava varietal improvement in Vietnam. **Figure 1, 2** and **3** show that in all three institutions involved in cassava breeding in Vietnam, the fresh yield of the breeding population increased markedly compared to that of the control varieties, while the root dry matter content also increased to 5-10% above that of the control varieties. Two high-yielding varieties, KM60 and KM94, that are well adapted to our conditions have been officially released and have brought additional economic benifits for farmers.

Breeding materials introduced both from CIAT/Colombia and from the Thai-CIAT program have played a significant role in cassava varietal improvement in Vietnam. At present, several promising clones selected from these materials, which have some outstanding characteristics, may in the future supply the raw material for processing factories, for animal feed and for other specific end-uses through further breeding and the strengthening of the technology transfer network.

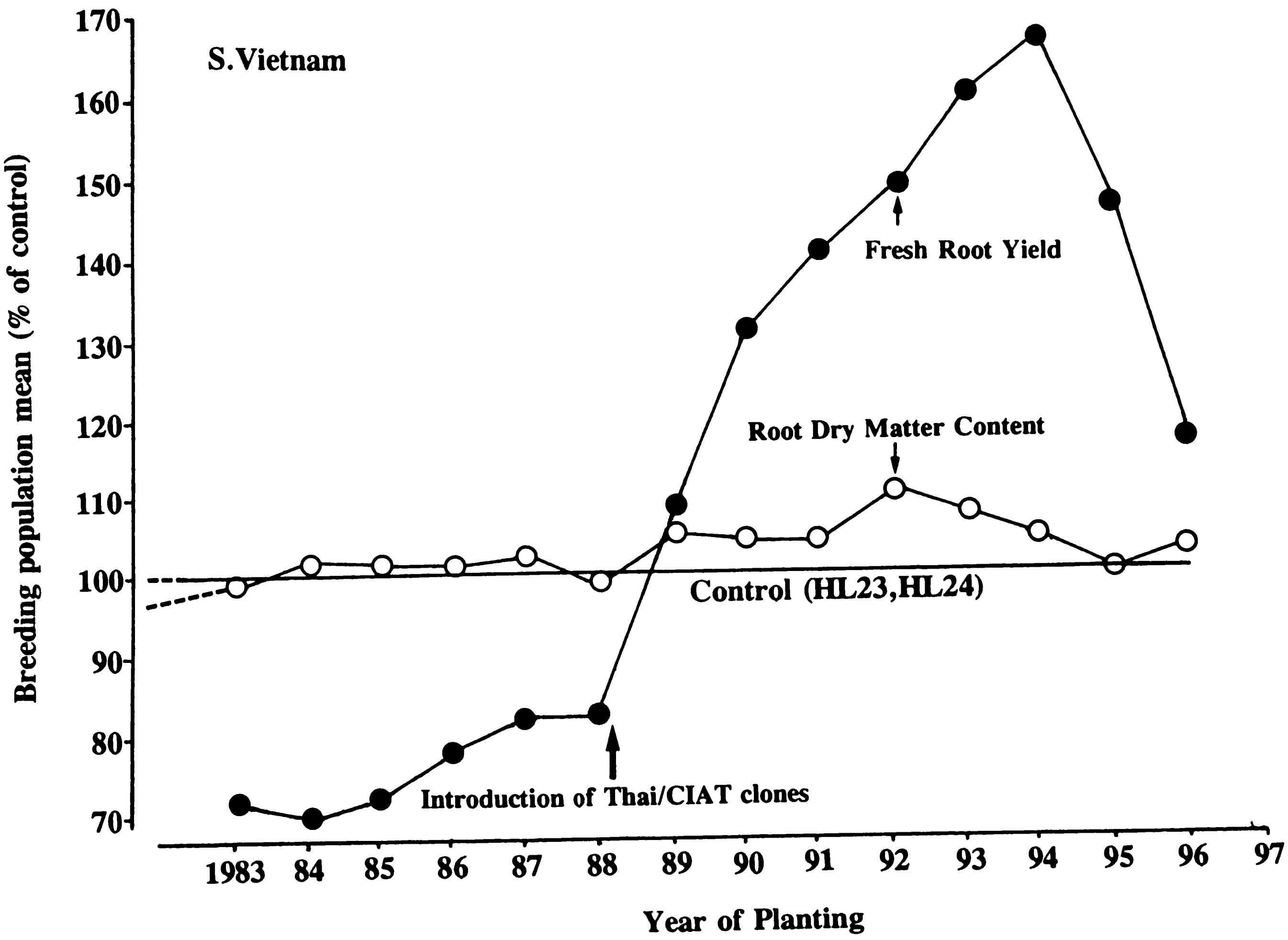

Figure 1. Change in the mean of breeding population (all entry mean in yield trials) in fresh root yield and root dry matter content at Hung Loc Agric. Research Center, South Vietnam.

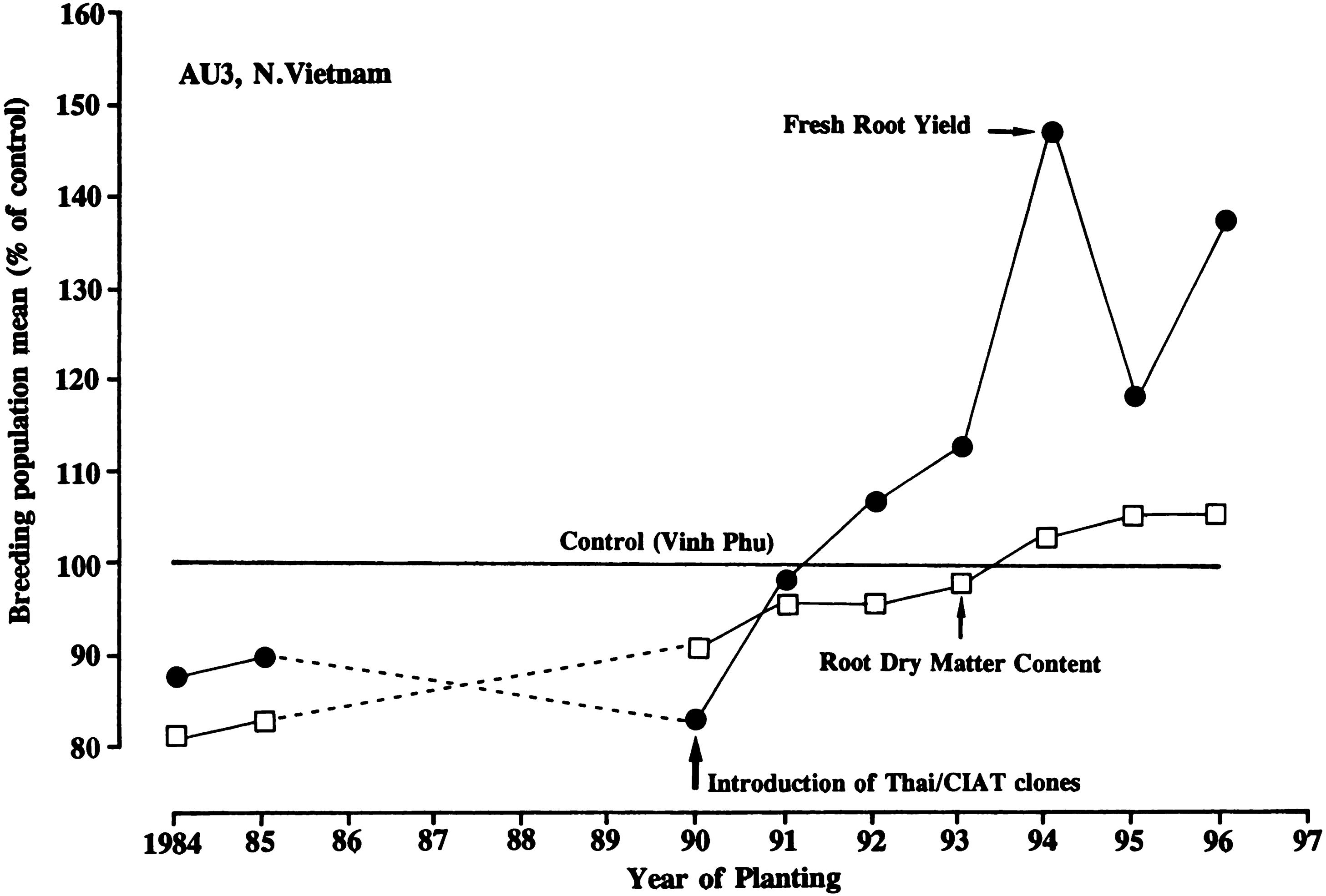

Figure 2. Change in the mean of advanced cassava clonal population (all entry mean in Advanced Yield Trials) in fresh root yield and root dry matter content at Bac Thai Agro-forestry College, North Vietnam.

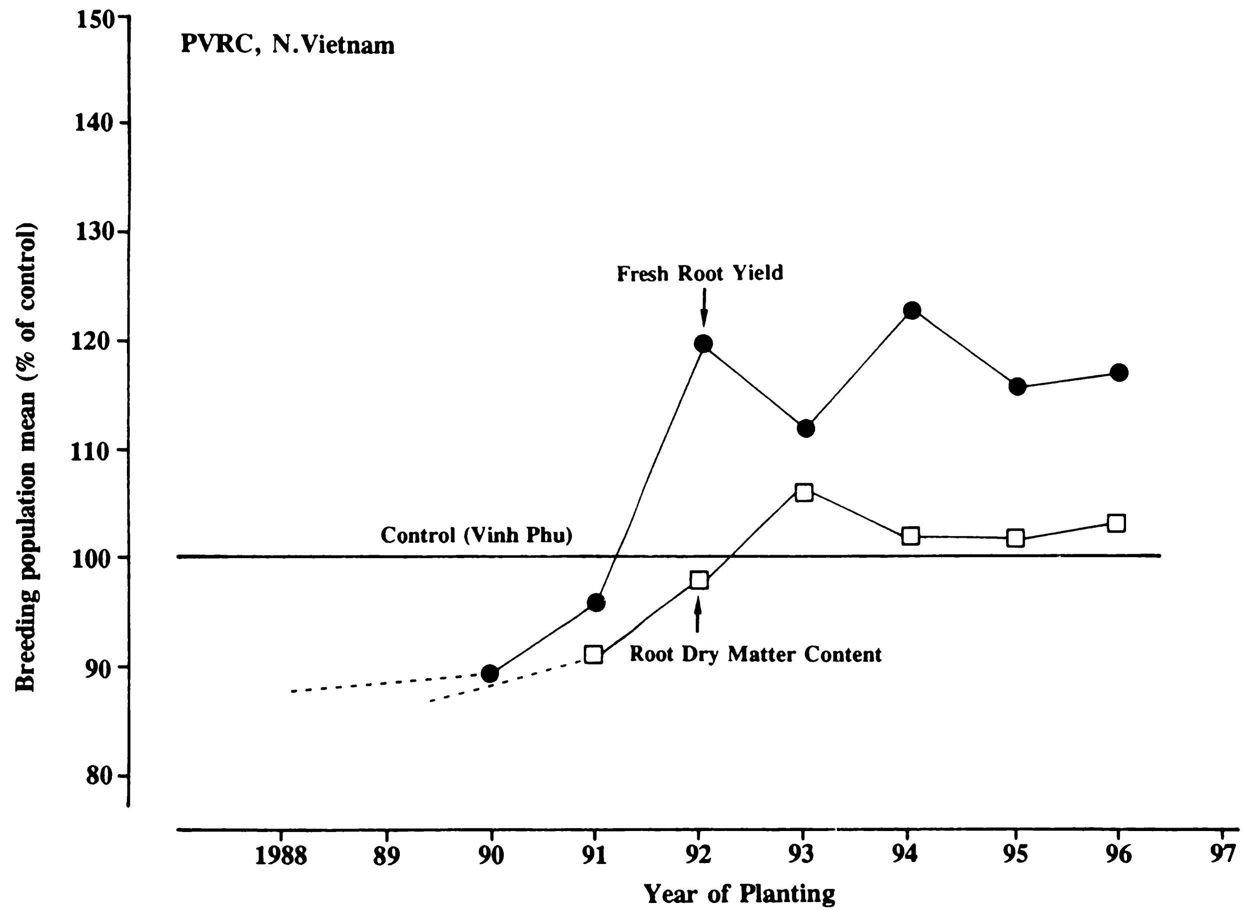

Figure 3. Change in the mean of advanced cassava clonal population (all entry mean in Advanced Yield Trials) in fresh root yield and root dry matter content at Potato and Vegetable Research Center, North Vietnam.

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CASSAVA VARIETAL DISSEMINATION IN VIETNAM

Hoang Kim[1], *Tran Ngoc Quyen*[1], *Pham Van Bien*[2] *and Kazuo Kawano*[3]

ABSTRACT

Before 1985, Gon, H34 and Xanh Vinh Phu were the most popular cassava varieties in Vietnam. From 1986 to 1993, HL20, HL23 and HL24 were selected from the local variety collection by Hung Loc Agricultural Research Center (HARC) and were grown extensively in South Vietnam with annual areas of about 70,000 to 80,000 ha planted to these varieties.

More recently (1993-1996) the Vietnam Root Crops Program in cooperation with CIAT, selected and recommended two new cassava varieties, KM60 (Rayong 60) and KM94 (MKUC 28-77-3); these were recognized and released for production by the Ministry of Agriculture and Rural Development (MARD). The two varieties are now widely grown in an area of about 15,000 ha in 1996.

The report presents the linkage between cassava research and extension activities in Vietnam. Experiences and methods of cassava varietal dissemination include ten mutual link-up activities (ten Ts). The most important one was the establishment of the Vietnam Cassava Research and Extension Network (including advanced cassava farmers, researchers, extensionists, managers of cassava research and development projects, cassava trade and processing companies), and the establishment of on-farm research and demonstration fields (Farmer Participatory Research - FPR).

The Vietnam Cassava Research and Extension Network obtained good results during the period of 1993-1995. Advanced farmers who obtained high yields and high profits due to the growing of improved cassava varieties, became attractive models for other cassava growers, resulting in the expansion of new varieties. In Tay Ninh province, for example, in 1990 the cassava growing area was 3,350 ha, with an average yield of 10.8 t/ha and a total production of 36,200 tons. With the planting of new high-yielding varieties and new cultivation techniques, in 1995 the cassava growing areas had increased to 18,870 ha with an averaged yield of 20.5 t/ha and a total production of 386,900 tons.

Six essential conditions for the successful cassava varietal dissemination in Vietnam include: Materials, Markets, Management, Method, Manpower and Money (six Ms). However, other problems should be taken into account: Crop competition (especially between cassava and sugarcane); soil fertility degradation and erosion; and decreasing varietal diversity.

INTRODUCTION

Cassava in one of the main crops in Vietnam (**Table 1**). It plays an important role in the strategy of national food security. It is also a main source of raw material for starch and animal feed factories. In 1995, the total cassava area reached 277,500 ha with an average yield of 8.0 t/ha and a total production of 2,211,700 tons (General Statistical Office, 1996).

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Table 1. Area, yield and production of principle crops in Vietnam in 1995.

Crop	Area ('000ha)	Yield (t/ha)	Production ('000t)
Food crops			
Rice	6,765.6	3.69	24,962.8
Maize	556.8	2.13	1,484.2
Sweet potato	304.6	5.53	1,685.8
Cassava	277.5	7.97	2,221.7
Vegetables	328.2	12.62	4,145.6
Beans	187.5	0.68	126.7
Annual industrial crops			
Groundnuts	259.9	1.28	334.4
Soybean	121.1	1.03	125.5
Sugarcane	224.8	47.60	10,711.2
Tobacco (leaves)	27.0	1.00	27.0
Mulberry	21.8	6.84	148.9
Cotton	14.6	0.71	10.0
Rushes	9.0	6.49	5.9
Jute	4.2	2.27	9.5
Perennial industrial crops			
Rubber	278.4	0.84[1)]	122.7
Coffee (beans)	186.4	2.18[1)]	218.1
Tea (dry)	66.7	3.41[1)]	180.9
Cashew nut[1)]	250.0	0.83[1)]	100.0
Fruits[2)]	310.0	-	-
Pepper[2)]	7.0	1.28	9.0

[1)] The harvested areas of rubber, coffee, tea and cashew nut in 1995 are: 146,900, 99,900, 53,000 and 120,000 ha, respectively.

Source: *General Statistical Office, 1996*

Cassava areas and production in Vietnam have flucated markedly during the period from 1976 to 1995 (**Figure 1**). The biggest cassava area was 461,400 ha with a total production of 3,422,000 tons in 1979. Cassava root yield increased from 7.5 t/ha in 1980 to 8.0 t/ha in 1995 (Nguyen Van Thang, 1996).

Before 1985, the most popular cassava varieties grown in Vietnam were Gon, H34 and Xanh Vinh Phu. During the period of 1986-1993 (**Table 2**), three cassava varieties, HL20, HL23 and HL24, were selected from local cassava collections and released by the Hung Loc Agricultural Research Center (HARC). They were grown annually on about 70,000 ha in South Vietnam (Tran Ngoc Ngoan *et al.*, 1995).

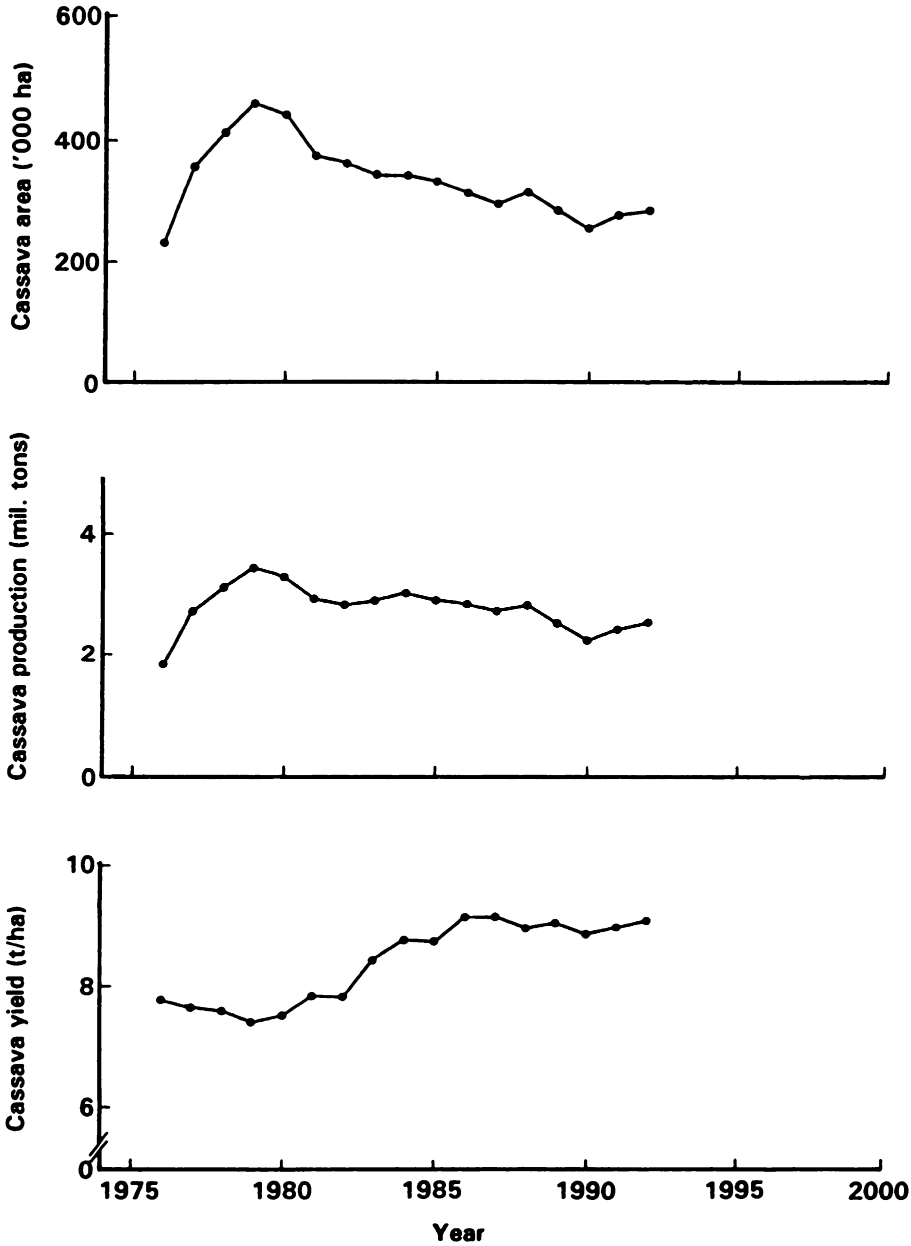

Figure 1. Cassava area, production and yield in Vietnam from 1976 to 1992.

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 Highlands	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
Man	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
H34	0	0	9.6	28.2	77.0	6.8
HL20	0	0	0	0	0	33.6
HL23	0	0	0	36.3	0	8.2
HL24	0	0	0	0.7	21.0	30.9
Others	9.8	0	30.0	28.2	0	8.1

Source: Tran Ngoc Ngoan el al.,1995

The Vietnam Root Crops Program, with strong supports from CIAT, has made considerable progress since 1988. During the period of 1993-1995, two new cassava varieties, KM60 (Rayong 60) and KM94 (MKUC28-77-3), were recommended and allowed to be released for production by the Ministry of Agriculture and Rural Development (MARD). The two varieties are now widely grown in an area of about 15,000 ha in 1996.

Advanced farmers who obtained good yields and high profits from growing improved cassava varieties became attractive models for other cassava growers, resulting in the expansion of new varieties. In Tay Ninh province, for examples, the total cassava area in 1990 was 3,350 ha with an average yield of 10.8 t/ha and total production of 36,200 tons. However, with the planting of new high-yielding varieties and applying new cultivation techniques, the cassava area increased to 18,870 ha with an average yield of 20.5 t/ha and a total production of 386,900 tons in 1995 (General Statistical Office, 1996).

This report presents methods and experiences in cassava varietal dissemination in Vietnam. The report also introduces the initial results and discusses the essential conditions required for success in cassava varietal dissemination, and outlines new problems and challenges in cassava production in Vietnam.

METHODS OF CASSAVA VARIETAL DISSEMINATION IN VIETNAM: A CASE STUDY OF HARC.

1. Establishment of National Cassava Research and Extension Network

The chart shown in **Figure 2**, indicates the coordination between cassava research and extension activities. It was considered essential to build up a National Cassava Research and Extension Network, which includes advanced cassava farmers, researchers, extensionists, managers of cassava research and development projects, as well as cassava trade and processing companies. The network was established in 1991 and workshops have been organized annually at HARC. The objectives, responsibilities, subjects and methods of operation were further developed and adapted to Vietnamese production conditions in the course of the years (Hoang Kim *et al.*, 1995).

2. Establishment of Demonstration Fields and On-farm Research (OFR)

On-farm research and the transfer of technologies were particularly emphasized: HARC focussed mainly on three related research areas, i.e. breeding, cultivation techniques and the transfer of technologies (Hoang Kim *et al.*, 1995). Methodologies to study cropping systems, developed by IRRI, (Zandstra *et al.*, 1981; Carangal, 1990) and agricultural ecology systems analysis (Conway, 1986) were used in cassava research and development programs.

Cassava breeding lines were evaluated first in Preliminary Yield Trials (PYT), which are non-replicated with a plot area of 12-36 m^2. The selected accessions then were evaluated in Standard Yield Trials (SYT) and Regional Yield Trials (RYT) using a completely randomized block design (CRBD) with a plot area of 30-50 m^2 and 3-4 replications.

The most promising clones were demonstrated on farmers' fields with 4-5 varieties (including two local popular varieties) per household. Each variety was grown in 10-30 m^2 without replication. Two to four promising varieties (including one local variety) were then selected and evaluated in pre-production plots of 1000 m^2 per variety. A field day was organized at harvesting time.

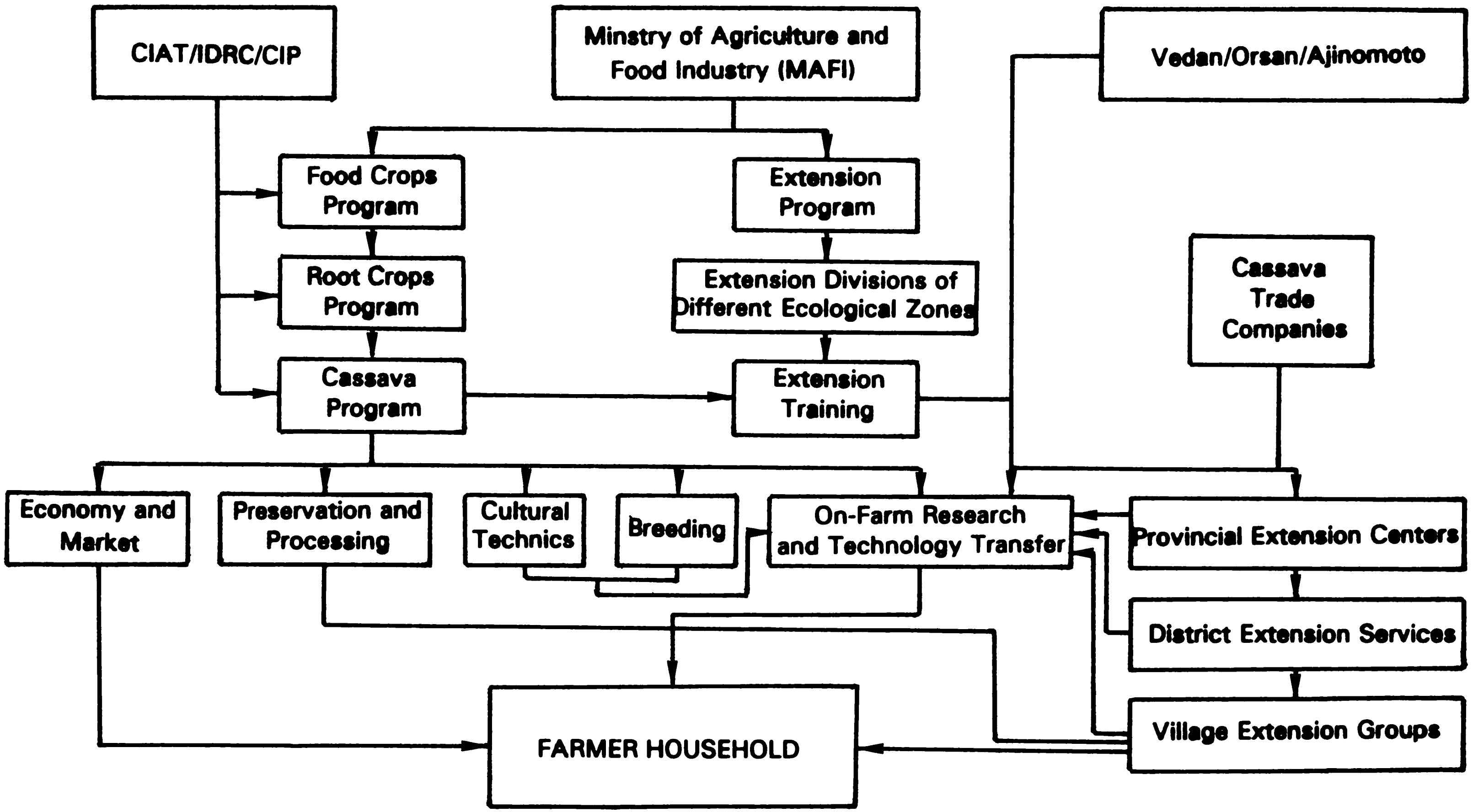

Figure 2. Coordination of cassava research and extension organizations in Vietnam.

3. Ten Mutual Link-up Extension Activities (ten Ts)

The extension methodology used by the Institute of Agricultural Science of South Vietnam (IAS) can be summarized by the following ten words starting with the letter 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 day
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

RESULTS AND DISCUSSION

a. Results

HARC's cassava germplasm includes 71 local cultivars and 26 cultivars and promising clones introduced from CIAT, as well as 26,652 hybrid seeds introduced from CIAT/Colombia and from the Thai-CIAT program. KM60 was the highest yielding variety in all RYT and On-farm Trials from 1990 to 1992 (**Table 3**). This variety is preferred because of its higher starch yield as compared to the local ones. It is also tolerant to drought and has a straight stem and little branching.

KM94 has been the best variety in all SYT at HARC from 1991 to 1993 (**Table 4**). KM94 was also evaluated in RYT in 25 locations in several provinces in 1994. It was selected for production because of its consistent high yield (**Table 5** and **6**). KM60 and KM94 are now expanding rapidly in production. In the latter part of 1996 the two varieties are being planted in about 15,000 ha (**Table 7**), mainly concentrated in Dong Nai, Tay Ninh, Song Be, An Giang, Quang Ngai, Gia Lai, Lam Dong, Ba Ria-Vung Tau, Dac Lac, Binh Thuan and Binh Dinh provinces.

A comparision in terms of economic returns between KM60 and HL20 in Dong Nai (**Table 8**) shows that KM60 produced a profit of 7.71 million dong/ha, while HL20 only gave 4.19 million dong/ha (Ao Van Thinh, 1996).

Table 3. Cassava yields in Regional and On-farm Trials coordinated by Hung Loc Agricultural Research Center, 1991/92.

Varieties	Regional Yield Trials (t/ha)							On-farm Trials (t/ha)			
	Ho Chi Minh		Khanh Hoa	Song Be	Tay Ninh		Average	Grey soil[1]		Red soil[1]	
	RYT1	RYT2	RYT3	RYT4	RYT5	RYT6		No. of trials	Root yield (t/ha)	No. of trials	Root yield (t/ha)
KM60	17.2	31.6	18.7	29.5	37.4	34.5	28.1	21	24.4	15	22.5
CM6125-125								8	25.2	10	21.4
CM6125-129								13	23.2	7	14.1
Rayong 1	15.0	26.4	18.6	19.0	36.5	20.5	22.7				
HL20								19	17.1		
HL23	18.0	26.0	15.3	17.7		16.3	19.2	2	23.0	15	16.5
HL24	13.8	27.6	12.2	21.2	28.1	14.2	16.8			5	12.4
Gon	8.0	13.2		14.3	31.3		16.9			5	10.2
H34			13.9				13.9				

[1] Grey soils: 21 households x 4-5 varieties x 30m²/variety at Ho Nai 4 village, Thong Nhat district, Dong Nai province.
Red soils: 15 households x 3-5 varieties x 1000m²/variety at Xuan Thanh village, Long Khanh district, Dong Nai province.

Table 4. Results of three Advanced Yield Trials at Hung Loc Center, based on selections from hybrid seeds introduced from the Thai-CIAT program in 1991-1994.

Clones	Parents	Fresh root yield (t/ha)				Dry root yield (t/ha)	Root dry matter (%)	Root starch content (%)
		91/92	92/93	93/94	Aver.			
KM94	R1xR90	29.5	42.4	44.1	38.6	15.0	39.0	28.6
SM937-26	MCol72	44.6	41.8	35.6	40.6	15.4	37.9	27.1
CMR29-60-15	R60xR90	29.5	34.0	27.9	30.5	12.1	39.9	28.7
SM937-8	MCol72	30.6	33.0	29.2	30.9	12.1	39.0	29.0
SM937-14	MCol72	30.4	37.9	34.4	34.2	12.9	37.9	27.0
CMR29-56-101	CMR149-128xR1	27.4	40.1	32.7	33.4	12.8	38.4	27.4
CMR26-14-9	MCol72	20.8	34.1	-	27.4	10.2	37.2	24.8
KM60	MCol1684xR1	-	-	32.5	32.5	12.6	38.7	28.3
HL24	Local check	18.0	22.9	19.7	20.2	7.4	36.7	25.8
CV(%)		12.5	11.2	18.2				
LSD(0.05)		3.8	8.4	4.2				

Table 5. Cassava fresh root yields (t/ha) in Regional Trials coordinated by Hung Loc Agricultural Research Center, 1994/95.

Varieties	Hue-Thua Thien	Quang Nam	Quang Ngai	Khanh Hoa	Binh Thuan	Dac Lac	Lam Dong	Average
KM94	42.1	34.5	38.8	52.5	21.5	27.3	26.5	34.7
SM937-16	33.8	27.7	26.2	56.4	18.8	19.6	26.0	29.6
KM95	34.2	26.4	32.6	45.4	18.1	24.2	20.2	28.7
CMR937-14	-	-	-	42.6	15.5	-	22.1	26.7
CMR33-38-5	-	28.2	-	-	20.9	26.5	-	25.2
CMR33-38-24	42.8	-	34.7	41.7	19.6	-	-	34.3
OMR29-56-101	-	25.2	-	-	16.8	19.2	26.6	21.9
CMR25-105-112	-	24.2	-	44.6	-	-	-	34.4
SM1045-11	-	-	-	-	19.3	-	-	19.3
KM60	40.4	26.8	34.8	44.0	19.5	25.2	24.9	30.8
Batrang	21.7	-	-	-	-	-	-	21.7
Gon	-	-	26.5	-	9.7	13.5	-	16.5
HL34	37.5	21.5	16.9	-	19.3	-	19.9	23.0
CV(%)		12.5	9.1			13.5	12.9	
LSD(0.05)		5.7	4.8			8.8	2.8	

Table 6. Cassava fresh root yields (t/ha) in Regional Trials coordinated by Hung Loc Agricultural Research Center, 1994/95.

Varieties	Dong Nai						
	Xuan Thanh	Tra Co	Vinh An	Long Thanh	Tay Ninh	Ho Chi Minh	Average
KM94	27.8e	42.5f	54.0c	46.0	41.7	50.4	44.9
SM937-26	23.9cd	38.9ef	40.4b	-	31.4	35.9	33.9
OMR33-17-15	27.1e	35.7de	-	41.0	29.3	49.5	37.8
CMR937-14	16.6b	31.7bcd	-	-	-	47.6	35.8
CMR33-38-5	16.9b	34.1cde	-	23.8	20.5	47.6	31.0
CMR33-38-8	18.7b	-	42.8b	54.0	23.9	43.5	35.3
CMR33-38-24	13.5a	26.0a	-	44.0	21.4	32.7	27.3
CMR25-105-112	-	29.8abc	38.1b	19.6	33.0	-	30.0
OMR33-16-2	26.3de	27.2ab	-	-	23.1	42.0	23.6
SM1045-11	-	-	-	22.8	19.5	-	21.1
KM60	23.1c	37.1e	41.2b	-	30.6	-	32.2
H34	-	-	-	-	-	21.1	21.1
HL20	-	-	-	-	26.1	-	26.1
HL23	12.7a	-	23.6a	-	-	-	18.1
CV (%)	7.8	8.4	6.5				
LSD(0.05)	5.3	2.4	2.4				

Table 7. Cassava varietal dissemination scheme in Vietnam, 1990-1996.

Year	KM60					KM94				
	PYT[1)]	SYT[1)]	RYT[1)]	OYT[1)]	Area (ha)	PYT	SYT	RYT	OYT	Area (ha)
1989/90	1				0.01					
1990/91	1	1			0.1					
1991/92	1	2			1.2	1				0.01
1992/93	2	3	6	31	8.1	1	1			0.15
1993/94	2	3	9	*[2)]	72	2	2	6		2.2
1994/95	2	3	20	**	660	2	3	20	15*	24
1995/96	3	3	24	***	6,300	3	3	24	***	360
		3	25	***	> 10,000		3	25	***	>5,000

[1)] PYT = Preliminary Yield Trial.
SYT = Standard Yield Trial.
RYT = Regional Yield Trial.
OYT = On-farm Yield Trial.

[2)] * = some farmer participation
** = more farmer participation
*** = a lot of farmer participation

Table 8. Production costs and returns per hectare when planting old and new cassava cultivars in Dong Nai province in 1995/96.

Economic item or indicator	Unit	HL20 (old cultivar)			KM60 (new cultivar)		
		Amount	Unit price ('000 d)	Total price ('000 d)	Amount	Unit price ('000 d)	Total price ('000 d)
Land tax	ha	1	250	250	1	250	250
Land preparation	ha	1	500	500	1	500	500
Planting material	long stake	1,500	0.15	225	1,500	0.5	750
Labor for planting	man-day	7	15	105	7	15	105
Weeding	man-day	20	15	300	20	15	300
Fertilizer -Urea	kg	100	2.8	280	160	2.8	448
-Single Superphos.	kg	200	0.8	160	200	0.8	160
-Potassium Chlor.	kg	100	1.7	170	160	1.7	272
Harvesting man-day	kg	30	19	570	40	19	760
Total production cost				2,560			3,545
Gross income (sale)	t	15	450	6,750	25	450	11,250
Net income ha			4,190			7,705	

1 US$ = 11,000 dong

***Source:** Ao Van Thinh, 1996, obtained from Provincial Agric. Office.*

An outstanding example is Tay Ninh, where the new high-yielding cassava varieties are rapidly replacing the local low-yielding clones. Before 1990, Gon, H34 and Binh Duong varieties comprised 100% of production. In 1995, however, the new varieties covered 80-90%, while the newest clones, i.e. KM60, KM94, SM937-26, and KM95, covered about 20% of the total cassava area of Tay Ninh. According to **Table 9**, the averaged yield in 1995 was 20.5 t/ha in 18,850 ha, resulting in a total production of 386,900 tons, as compared to an average yield in 1990 of 10.8 t/ha, a planting area of 3,350 ha and production of 36,200 tons (Tran Vien Thong, 1996).

An economic analysis shows that in Tay Ninh the planting of KM60 could give a net income of 4.46 million dong/ha with an average yield of 20 t/ha in 1995 (**Table 10**).

Table 11 shows the inputs and economic benefits obtained by three advanced cassava farmers who planted the new variety KM60. Private companies that participated in the cassava R&D system also promoted greatly the varietal dissemination and the change in cropping systems. In 1995, KM60 and KM94 were released as national varieties.

Table 9. Cassava growing area, yield and production in Tay Ninh province from 1990 to 1995.

Year	Area(ha)	Yield (t/ha)	Production (t)
1990	3,355	10.8	36,210
1991	7,366	11.5	85,142
1992	7,173	11.7	83,652
1993	9,337	13.7	129,624
1994	15,846	18.7	196,598
1995	18,849	20.5	386,904

Source: *General Statistical Office, 1996.*
Tran Vien Thong, 1996.

Table 10. Cost and return analysis per hectare for a new cassava production scheme using cultivar KM60 in Tay Ninh province in 1995, assuming a yield of 20 t/ha fresh roots.

	Unit	Amount	Unit price ('000d)	Total price ('000d)
1.Total cost:				**3,937**
Plowing	buffalo-day	3	140	420
Other land preparation	buffalo-day	1	150	150
Planting	man-day	12	12	144
Weeding	man-day	10	12	120
Harvesting	man-day	30	12	360
Transportation	pick-up	4	200	800
Planting stakes	bundle	50	10	500
Chemical				72
Herbicide	liter	2	170	340
Urea	bag of 50 kg	1	148	148
Ammounium sulfate	bag of 50 kg	3	75	225
Single superphosphate	bag of 50 kg	6	48	288
Potassium chloride	bag of 50 kg	3	90	270
Farm yard manure	t	2	50	100
2.Gross income:				**8,400**
Root harvest	t	20	300	6,000
Planting stakes	bundle	400	6	2,400
3.Net income:				**4,463**

1US$ = 11,000 dong

***Source:** Agriculture and Forestry Service of Tay Ninh province.*

Table 11: Cost of production, gross and net income of three advanced cassava farmers in South Vietnam in 1995/96.

Item	Name of farmer: N.H. Cuong (Dong Nai)	Ho Sau (Ding Nai)	T.Q. Thanh (Tay Ninh)
Variety planted	KM 60	KM 60	KM 60
Farm size (ha)	small	medium	large
Yield (t/ha)	25	30	25
Price fresh roots (d/kg)	500	350	570
Total production costs('000d/ha)	6,440	4,210	3,930
Gross income('000d/ha)	12,500	10,500	14,250
Net income('000d/ha)	6,060	6,290	10,220

Source: *Nguyen Hung Cuong, 1997*
Ho Sau, 1997
Tong Quoc Thanh, 1997

b. Six essential conditions for the successful cassava varietal dissemination

To ensure that the cassava varietal dissemination is successful, the following factors should be of mayor concern: Materials, Markets, Management, Method, Manpower and Money.

Materials: The Vietnam Root Crops Program maintains a collection of promising cassava germplasm, consisting of both local varieties and clones introduced from CIAT; this constitutes a very important genetic resource for the country and guarantees future progress in cassava varietal improvement (**Figure 4**).

Markets: Cassava utilization for human consumption decreased. However, cassava demand for industrial and animal feed processing increased greatly in Vietnam. From 1990 up to 1996, the cassava market has been expanding. Many cassava processing factories were established and are now operating, thus greatly stimulating cassava production and development (**Figure 5**).

Management: Changes in goverment policy and economic reform created favorable conditions for agricultural development and stimulated the use of new varieties and the application of advanced cultivation techniques in cassava production. The Cassava R&D Network also plays an essential role in the evaluation and dissemination of new varieties (Huang Kim *et al.*, 1995).

Method: It is essential to plant demonstration fields and on-farm trials and to conduct Farmer Participatory Research (FPR) to enhance varietal dissemination. Varietal improvement should be combined with studies of cultivation techniques in certain cropping systems.

Manpower: Vietnamese farmers, especially advanced farmers, are quick and active in the testing and planting of new varieties. Cassava researchers, extensionists, processors and trades must also be firmly linked and work together through the cassava R&D network.

Money: Funding for cassava R&D activities have come from the goverment, agricultural products trade companies, the agricultural extension budget, international cooperation programs, various countries and from non-governmental organizations (NGOs). Presently, funding for cassava R&D in Vietnam is very limited. However, it has increased in recent years.

c. Constraints to cassava production

1. Crop competition: Sugarcane, rubber, coffee, fruit trees and cashew nuts are competing with cassava, especially sugarcane. By the year 2000, Vietnam will try to produce one million tons of sugar, 220-240 thousand tons of coffee, 180-200 thousand tons of rubber and 120 thousand tons of cashew nuts. A total of 29 sugar factories are operating to implement the planned objective. Rubber, coffee and fruit trees are receiving big investments from the goverment. Competition from other, more valuable crops may become a big problem for cassava production. The development of cassava varieties suitable for each agro-ecological region and more productive cropping systems are important to be able to make cassava an economically attractive crop.

2. Soil fertility degradation and erosion: In Vietnam, cassava is mainly grown on grey Podzolic soils of low fertility and with slopes of 0-15%. In the past, fertilizer application was very limitted. Growing cassava continuously in a certain area usually leads to yield reductions. Studies on fertilizer application, legume intercropping and suitable cultivation techniques for sloping soils are therefore required.

3. Genetic erosion: Cassava varietal improvement has greatly increased production. However, the planting of new cassava varieties has created pressure to eliminate old varieties and has narrowed the cassava germplasm base. Although no serious outbreaks of pests or diseases have occured, genetic diversity should be maintained in the cassava R&D program.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. Cassava varietal dissemination in Vietnam has made quick and reliable progress. The

Vietnam Root Crops Program in cooperation with CIAT, recently (1993-1996) selected and recommended two new cassava varieties: KM60 (Rayong 60) and KM94 (MKUC 28-77-3). These were released for production by the Ministry of Agriculture and Rural Development (MARD). The two varieties are now widely grown in an area of about 15,000 ha in 1996. Advanced farmers, who obtained high yields and high profits due to the growing of improved cassava varieties, have become good models for other cassava growers to follow, resulting in the expansion of new varieties.

2. Experience in the linking of cassava R&D activities in Vietnam included the establishment of the Vietnam Cassava Research and Extension Network and the establishment of on-farm research and demonstration fields and Farmer Participatory Research (FPR); these involve ten mutual link-up activities, called the "ten Ts" (in Vietnamese).
3. Six essential conditions for successful cassava varietal dissemination in Vietnam include: Materials, Markets, Management, Method, Manpower and Money ("six Ms") Vietnam now has favorable conditions for cassava production. However, other problems should be taken into account, such as crop competition (especially from sugarcane); soil fertility degradation and erosion; and decreasing varietal diversity.

Recommendations

1. Further strengthening of cooperation between the Vietnam Root Crops Program and CIAT, not only in varietal improvement but also in the area of on-farm research and transfer of technologies.
2. Use of biotechnology in cassava breeding and the multiplication of planting materials.
3. Studies on intercrop competition, soil fertility maintenance and erosion control, and ways to enhance varietal diversity.
4. Trying to win financial support from cassava processing and trade companies (Vedan, Ajinomoto, etc) and International Agricultural Research Organizations (CIAT, IDRC, ACIAR) as well as from countries and non-governmental organizations.

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BREEDING AND VARIETAL IMPROVEMENT OF CASSAVA IN INDIA

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ABSTRACT

An analysis of the recent trend in cassava area, production and yield during 1993-96 revealed an impressive increase in Tamil Nadu, which is the predominant state where cassava is grown as an industrial crop. Its present yield of 29 t/ha is the highest in the world. Even though the overall national trend in cassava area and production is declining, India's current average yield of 21 t/ha is also the world's highest.

In India, cassava breeding is mainly carried out at CTCRI in Thiruvananthapuram and at its regional centre at Bhubaneswar. The All India Co-ordinated Research Project on Tuber Crops, with eleven centres in the country, is also engaged in cassava improvement in a limited way. The Tamil Nadu centre has recently identified a high yielding short duration variety, H-119, while the Assam centre has identified two varieties, i.e. H-165 and Sree Prakash, suitable for the region. The co-ordinating centres in Madhya Pradesh and Andhra Pradesh, along with the CTCRI regional centre at Bhubaneswar, have been evaluating the promising exotic germplasm received from the Thai-CIAT program. High root yields of more than 35 t/ha were recorded for some of the CIAT selections, i.e. CMR33-67, CMR36-32, SM2077 and SM2090.

Attention is currently being given to the development of early maturing, good cooking quality varieties, which can be harvested at sixth months, so that they can effectively be utilized in cassava-rice double cropping systems as practised in Kerala. Three short-duration indigenous clones, i.e. CI-649, CI-731 and CI-732, were identified, which are now in the pre-release stage. These varieties are also included in the initial evaluation trial of the All India Co-ordinated Research Project on Tuber Crops.

Breeding efforts are also focused on developing high yielding, high starch varieties for areas like Tamil Nadu, Andhra Pradesh and Madhya Pradesh. A unique approach in this direction is the production of "triploids". The triploids, possessing high yield combined with high starch recovery, hold much promise to become popular in regions like Salem district of Tamil Nadu, where the crop is grown for the starch industry. A triploid, 2/14, has already been proposed for release under the name 'Sree Harsha' by the State Varietal Release Committee.

Studies are also in progress on the possibility of using sexual seed for the rapid propagation and spread of cassava. Results indicate that even unselected first clonal progenies of promising parents have a comparable root yield and dry matter production capacity as those of the high yielding released varieties of cassava.

Cassava mosaic disease is still posing great problems in germplasm conservation. Use of a nursery technique with three noded cuttings coupled with thorough screening and roguing of CMD affected plants in the nursery and field was effective in the recovery and quicker multiplication of symptom-free plants.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz), popularly known in India as tapioca, is reported to have been introduced into India sometime in the seventeenth century by Portuguese traders who visited South India. Many of the "types" under cultivation today have originated either by selection from the lines introduced in the early days from exotic

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sources through chance seedling progenies or through natural mutations. The crop is now grown in an area of 235 thousand hectares with an annual production of 5.34 million tonnes (FAO, 1994). In India the cultivation of this crop is mainly concentrated in the southern states, i.e., Kerala, Tamil Nadu and Andhra Pradesh, and to some extent in the northeastern mountainous region. The three southern states together account for about 96% of the cassava area and 98% of production in India.

Area, Production and Yield

An analysis of cassava planted area and production shows an enormous increase up to 1974/75 (0.39 million ha), after which it started declining fast until 1985/86 (0.27 million ha), followed by a slower decrease thereafter. The production area in Kerala during the last three years (1991-94) is showing a slight decreasing trend (**Table 1**). The major factor accounting for this decline in area is the shift in cropping pattern in Kerala State, where plantation crops are starting to dominate the agricultural economy. However, cassava production statistics for 1992-95 reveal that in Tamil Nadu, the predominant state where cassava is grown as an industrial crop, the area, production and yield have all increased impressively. The area under cassava in Tamil Nadu has increased from 76,431 ha in 1990 to 85,543 ha in 1994 with a production of 2.856 million tonnes. The hybrids H-165 and H-226 occupy more than two thirds of the cassava area in Tamil Nadu. Similarly, in Andhra Pradesh the same two varieties are gaining popularity and are currently grown in an area of about 16,300 ha. In Assam, H-165 and Sree Prakash have been found to be promising and have been recommended for cultivation in the state in 1995. Tamil Nadu's present cassava yield of 29 t/ha is the highest in the world. Even though the overall national trend in area and production is declining, India's current cassava yield of 22 t/ha is the world's highest and more than double that of the world average of 10 t/ha.

Table 1. Area, production and yield of cassava in Kerala.

	Year		
	1991/92	1992/93	1993/94
Area ('000ha)	141.88	135.03	130.99
Production ('000t)	2670.55	2629.13	2602.20
Yield (t/ha)	18.82	19.47	19.87

***Source:** Farm guide 1997, Govt. of Kerala.*

Cropping Systems

The cropping system of cassava in Kerala has undergone a tremendous change, from mainly upland monocropping to multiple cropping. The suitation is entirely different in Tamil Nadu and Andhra Pradesh, where cassava is cultivated as an upland monocrop. In Tamil Nadu, cassava is grown mainly as an irrigated crop under full-sun conditions, except in Kanyakumari district, where it is grown as a rainfed crop under both upland and lowland conditions (Ramanathan *et al.*, 1990). In the irrigated area, more than 75% of the area is planted with the high-yielding hybrid varieties H-165 and H-226, whereas local varieties are grown in about 80% of the rainfed area. In the irrigated and rainfed areas, Jan/Feb and April are the main months of cassava planting, respectively. Similarly, there is a striking difference in terms of varietal dissemination in Kerala *vis-a-vis* neighboring states of Tamil Nadu and Andhra Pradesh. While the local varieties dominate (75% of the area) the cassava area in Kerala, in the other two states mainly hybrids are grown. It was also observed that while there is great genetic diversity in Kerala state, only a few varieties prevail in the other states.

Cassava Utilization and Varietal Distribution

Change in the utilization pattern of cassava roots have contributed to a great extent to the spread of hybrid varieties and improved production technologies. In Kerala, the major portion (>70%) of cassava is used for direct human consumption, whereas in Tamil Nadu and Andhra Pradesh 70% of production is utilized as industrial raw material for the manufacture of starch and sago. There are about 1000 small-scale starch factories in Tamil Nadu and about 45 in Andhra Pradesh, but in Kerala there are only 20 units. With the wide-spread availability of cereals like rice and wheat resulting in a reduced consumption of cassava as a cereal substitute, the crop's diversification to industrial processing is the only alternative to sustain and increase the current level of production. With the cassava-based industries picking up in Tamil Nadu and Andhra Pradesh, it is no surprise that cassava hybrids have become popular in those states. Even in Kerala, which has low industrial utilization of cassava, the yield of cassava has remarkably increased from 7-8 t/ha in the 1950s to 18-19 t/ha in the 90s. This was achieved mostly by low external-input improved production practices, along with a limited coverage of high-yielding varieties.

There is a distinct variation in the preference for cassava varieties in different regions of Kerala. A survey conducted by CTCRI revealed that the local varieties are still very popular in Kerala state (68%) and their concentration is highest in central and northern regions with a coverage of 80-90% of the area in Kottayam and Malappuram districts (**Table 2**). In Trivandrum district, local varieties occupied about 53% of the area and in Quilon around 36% (Ramanathan *et al.*, 1989). The improved variety M-4 is very popular throughout the state and its dominance is especially noticeable in the southern region.

Table 2. Varietal coverage of cassava in various districts of Kerala.

Varieties	Varietal coverage in each district (% of area planted)					
	Trivan drum	Quilon	Pathanama	Kottayam thitta	Malap puram	Overall
Local varieties	52.76	35.55	12.65	81.65	90.51	68.78
Improved variety M-4	40.63	49.26	53.94	18.35	9.21	25.13
High-yielding varieties						
H-165	4.68	2.25	5.45		-	1.65
H-226	0.15	10.80	22.02	-	0.15	3.27
Sree Visakham	1.22	1.07	-	-	0.13	0.44
Sree Sahya	0.56	1.07	5.94	-	-	0.73

Source:* *Ramanathan et al., 1989

The utilization pattern of cassava in various districts of Tamil Nadu was observed to have an influence on the varieties preferred for cultivation by the farmers. As most of the production is used for direct human consumption in Kanyakumari district, good tasting local varieties are preferred and are presently grown in about 80% of the area (**Table 3**). The improved cassava variety M-4 had a coverage of only 6% of the area. The high-yielding varieties H-165 and Sree Visakham (H-1687) were also rather popular in this district and they accounted for about 13% of the area. With the concentration of cassava-based starch and sago factories in and around Salem, there was a preference for growing high-yielding varieties in the districts of Salem, South Arcot and Dharmapuri. About 75% of the cassava area in each of these districts was found to be planted with the hybrids H-165 and H-226. The remaining 25% of the area in Salem and Dharmapuri was planted to the popular local variety "Burma" (Ramanathan *et al.*, 1990).

Table 3. Varietal coverage of cassava in various districts of Tamil Nadu.

Varieties	Varietal coverage in each district (% of area planted)				
	Kanyakumari	Salem	South Arcot	Dharmapuri	Overall
Local varieties	80.21	27.83	7.65	27.58	23.10
Improved varities M-4	6.40	-	11.33	-	4.41
High-yielding variteties					
H-165	4.76	5.15	57.03	-	22.33
H-226	-	67.02	23.99	72.42	49.73
Sree Visakham	8.63	-	-	-	0.43

Source:* *Ramanathan et al., 1990.

VARIETAL IMPROVEMENT

Germplasm Collection and Breeding

In India breeding research in cassava is mainly centered at the Central Tuber Crops Research Institute (CTCRI), in Thiruvananthapuram, Kerala and at its regional Centre in Bhubaneswar. The All India Co-ordinated Research Project on Tuber Crops, whose headquarters is located at CTCRI, is also engaged in a limited way in cassava improvement. Out of the eleven centers located at different Agricultural Universities and at the ICAR Research Complex for the Northeastern Hill Region in Shillong, eight centers are conducting cassava research.

Genetic variability is the essence of any plant breeding program. An assembly of diverse genetic stocks of any crop is the raw material from which a new variety can be moulded to suit the requirement of the farmers. A germplasm bank, including wild relatives from within and outside the country, has been built up. The CTCRI germplasm bank presently maintains 781 exotic and 806 indigenous acessions of cassava, as well as eight wild species. The All India Co-ordinated Research centres maintain 765 indigenous accessions. Many of the local varieties of cassava under cultivation in Kerala are either chance seedlings or are bud mutations selected for desirable characteristics and maintained by farmers through vegetative propagation. Varieties best suited to the requirements imposed by the local conditions are generally adopted and popularized in various cassava growing areas. Moreover, the tendency of farmers to clonally multiply the self-sown seedlings, if these are bestowed with any desirable attributes, particularly better root characteristics, led to the addition of numerous varieties (Nair and Pillai, 1995). The majority of these types have local names, which generally indicate one of the striking features of the plant.

A systematic evaluation of the genetic stocks has resulted in the identification of several promising clones, which were later utilized either as parents in the intervarietal hybridization or were released as varieties. As such, six varieties, i.e. H-165, H-226, H-97, Sree Visakham, Sree Sahya and Sree Prakash, have been released from the Central Tuber Crops Research Institute (Magoon *et al.*, 1970; Jos *et al.*, 1981). The Kerala Agricultural University released a short duration cultivar called "Nidhi". Attention is currently given for the development of early-maturing, good cooking quality varieties, which can be harvested at six months, so that they can effectively be utilized in the rice-cassava crop rotation program now in vogue in Kerala state. Research in this direction has resulted in the identification from the germplasm bank of three short-duration indigenous clones, i.e. CI-649, CI-731 and CI-732, which are now in the pre-release stage in Kerala. These varieties are presently under initial evaluation in Andhra Pradesh, Tamil Nadu and Madhya Pradesh under the All India Co-ordinated Research Project on Tuber Crops.

Evaluation of CIAT Germplasm

Cassava seeds received from CIAT were initially screened at the Regional Centre in Bhubaneswar. During the period from 1989-96, five sets of cassava botanical seeds comprising 119 accessions were introduced from CIAT. Out of five sets, four sets of seeds were evaluated preliminarily for yield characters and their reaction to diseases. Germination percentage of seeds ranged from 0-100%. The highest average germination was observed in the third batch (63.2%). Seedlings were evaluated in the field. Harvesting was done at 7-10 months. The fresh root yield, along with the number of selections made in each batch, are presented in **Table 4**.

Table 4. Fresh root yield obtained and the number of selections made in four batches of cassava seeds received from CIAT.

Batches	Range in fresh root yield (t/ha)	Average root yield (t/ha)	No.of selections
1st batch	0.00-24.69	5.43	1
2nd batch	4.94-43.02	8.11	1
3rd batch	8.64-43.20	19.45	9
4th batch	0.00-37.65	12.86	3

The root yield ranged from zero to 43.2 t/ha. The highest average yield of 19.45 t/ha was recorded in the third batch. A total of 14 high-yielding lines were selected (**Table 5**).

The highest fresh root yield (43.2 t/ha) was obtained with CMR36-32, which was not significantly different from that of CMR33-67 (43.02 t/ha). SM2077 and SM2090 were the next highest yielders, which recorded 37.65 and 35.18 t/ha, respectively. Cassava Mosaic Disease (CMD) was not noticed at the Regional Center in Bhubaneswar, but when these promising selections were transferred to the germplasm bank at CTCRI, clear CMD symptoms were noticed in all the clones. The most important disease noticed at the regional center was witches broom, which infected six accessions, i.e. CMR38-58, CMR36-12, CMR36-38, CMR36-116, CMR36-71 and CMR36-73. Angular spot disease and leaf spot disease were also noticed. The fifth set of seeds received from CIAT was distributed to the Regional Center in Bhubaneswar as well as to the Co-ordinating Centers in Madhya Pradesh and Andhra Pradesh for further evaluation and selection.

Table 5. Performance of 14 selections from cassava botanical seeds received from CIAT.

Selections	Fresh root yield (t/ha)	Root color[1)]	Root taste[2)]
OMR32-02	24.69	W	NB
CMR33-67	43.02	W	S
CMR36-32	43.20	W	S
CMR36-34	22.21	W	NB
CMR36-38	22.21	W	NB
CMR36-116	25.91	W	S
CMR36-123	28.50	W	B
CMR36-159	22.21	W	S
OMR36-28	23.44	W	S
OMR36-31	28.38	W	B
OMR36-73	23.45	W	B
CM8619	25.43	W	S
SM2077	37.65	W	S
SM2090	35.18	W	NB

[1)]W = white
[2)]NB = not bitter; B = bitter; S = sweet

Production of Chromosomal Lines

Polyploidy breeding has great potential in crops where the economic produce is a vegetative part, especially when it can be clonally multiplied. The somatic chromosome number in cassava is relatively low (2n = 36), and hence the plant can tolerate higher ploidy. So the production of induced tetraploids (4n = 72) and triploids (3n = 54) constitute yet another basic approach to cassava improvement. Autotetraploidy is being induced with colchicine in a wide range of genotypes, so as to provide considerable variability at the polyploid level and allow a large-scale hybridization program, followed by selection among polyploid types (Magoon *et al.*, 1969). The induced tetraploids so far produced have also been successfully utilized for the production of triploids. Triploids are obtained by crossing induced tetraploids with some of the cultivated cassava types; they were found to be superior to colchicine-induced tetraploids in yield and sometimes outyielded diploids (Jos *et al.*, 1987). The triploid plants consistently showed higher root dry matter (DM) contents. The triploid 2/14 produced a higher root yield, dry matter (>45%) and recoverable starch content (>35%) under multi-locational trials than the standard cassava check varieties. This promising triploid was proposed for release to the State Variety Release Committee under the name "Sree Harsha".

Enhancement of Carotene in Cassava

In most cassava clones, the flesh or the edible portion of the root is white and devoid of any carotene. Yellow pigmented cassava varieties are cultivated in a limited way in Colombia, the Philippines, Jamaica and in some south African countries (Oduro, 1981). Among a total of 654 accessions screened for carotene, 21 clones had yellow flesh (Moorthy *et al.*, 1990). The frequency of high-carotene clones were found to be higher among the exotic collections. The carotene content ranged from 65 IU/100 g to 670 IU/100 g. An attempt was made to elevate the carotene levels through genepool development from the existing genetic resources (Jos *et al.*, 1990). By simple recurrent selection the carotene content could be elevatd to 1500 IU in the first cycle, to 2200 IU in the second, to 3217 IU in the third, and to 3985 IU/100 g in the fourth cycle (**Table 6**).

Table 6. Carotene content of cassava roots in the fourth cycle of recurrent selection.

Color of flesh	No. of clones	Carotene content (IU/100g)
Orange	12	2000-3985
Yellow	9	2880-3925
Yellow orange	12	2200-3400

Interspecific Hybridization

Interspecific hybridization and genome analyses carried out on different crops have opened up new avenues of improvement of crop plants and have successfully contributed to the development of radically new and better types (Magoon, 1967). By virtue of sharing a common genepool, cassava is easily crossable with a number of wild species, and the occurrence of desirable genes makes interspecific hybridization one of the most significant approaches in cassava germplasm development. However, the absence of any wild species in Asia makes it difficult to procure the materials and to maintain the species under our conditions; the lack of clonal propagation in some of them, as well as their poor flowering, make the interspecific hybridization also rather difficult. Though half a dozen species were used in the program, success could be achieved only in four combinations, i.e. cassava x *M. glaziovii*, cassava x *M. tristis*, cassava x *M. flabellifolia* and cassava x *M. caerulescence*. The hybrid, cassava x *M. caerulescence* was found to be completely free of CMD symptoms. However, the transfer of tolerance to the cultivated varieties was hindered by its erratic flowering and female sterility. Interspecific back-cross (BC1 and BC2) populations were grown for CMD screening and evaluation. Fifty seven per cent of the back cross population was completely free of CMD symptoms. Twenty eight hybrids recorded yields ranging from 2.0-3.5 kg per plant.

True Cassava Seed Program

In the traditional production system it is difficult to bring large new areas under cassava cultivation because of the low multiplication rate, bulkiness of planting material, difficulty in transportation, rapid loss of viability of the planting material and the high risk of introducing disease and pest problems (Rajendran and Ravindran, 1993). Studies using sexual seeds have revealed that in the true seed program the multiplication rate could be raised to above 1:150, as compared to 1:10 in the conventional method. Promising cultivars have been identified which can produce more than 200 kg of sexual seeds per hectare. At the time of transplantation of the seedlings in the field, the tap root is cut and removed, which contributes to a high clonal yield at the seedling stage.

The first clonal progeny lines of promising parents had comparable root yield potential and root dry matter production as those of the popular clonal varieties. These studies indicate that cassava propagation from true seed has considerable potential in some new industrial areas due to their high multiplication rate, ease in covering extensive areas with lesser expense and comparable root yield and dry matter content. The incidence of CMD is considerably reduced in these progeny lines.

Rapid Multiplication of CMD-free Plants

A quick method was developed at CTCRI for the multiplication of mosaic free planting material. Symptom-free plants are selected from the field and stems are collected. The stems are cut into small stakes having only 3 to 4 nodes. In the normal practice, the setts are planted directly in the field. But in this new system, a nursery stage is introduced before transplantation to field. The stakes are planted on nursery beds and left to sprout. Screening for CMD symptoms is done as soon as leaf emergence has started. Only symptom-free settlings are transplanted to the field at 25 days after nursery growth. Roguing is also continued in the main field. At harvest, symptom-free stems are again collected and setts are screened through this nursery technique before transplanting to the field.

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CASSAVA RESEARCH PROGRAM AT TAMIL NADU AGRICULTURAL UNIVERSITY (TNAU) IN INDIA

S. Thamburaj[1]

ABSTRACT

Cassava is cultivated in Tamil Nadu in an area of 85,983 ha with an annual production of about 2.5 million t of roots (1993-94). At the world level, Tamil Nadu ranks first in yield, with 28.7 t/ha, as compared to the Indian average of 22.8 and a world average of 9.6 t/ha. In Tamil Nadu cassava is grown mainly in Salem and Kanyakumari districts located in the dry western zone (60% irrigated and 40% rainfall) and the high rainfall southern zone (mostly rainfed), respectively. The area under cassava is increasing in other districts of Tamil Nadu as well.

With respect to varieties, about 50% of the total area is grown with high-yielding varieties, like H-226 and MVD-1 in most areas of Salem district, and with Co-1, Co-2, Co-3 in different parts of Tamil Nadu. Locally adapted and traditional varieties, like Burma and Malabar, are still under cultivation, but they are low yielding and susceptible to cassava mosaic disease.

The cassava germplasm collection has now increased to 480 accessions, including some CIAT clones. Two early maturing clones were identified, i.e., H-119 from CTCRI, Trivandrum, and Co-3 developed by Tamil Nadu Agr. Univ. in Coimbatore. The crop duration is 7 1/2 to 8 months with a high yield of 32 and 35 t/ha, respectively, and a starch content of about 30%. For the high rainfall zone of Kanyakumari district, the local clone Adukkumuttan performs well, giving a 15 to 28% increase in yield compared to the released varieties. For coastal areas of South Arcot district, two clones, i.e. ME-46 and ME-10, were shown to be better, with a yield of 44 t/ha; these are now under further evaluation. Under the Asian cassava breeding network a total number of 85 hybrid progenies were received from CIAT/Colombia and the Thai-CIAT program. Preliminary evaluation has indicated that a few clones have high root yields of more than 5 kg/plant, high starch content of over 35%, field tolerance to mosaic virus and a shorter crop duration of 7 to 8 months.

The optimum fertilizer rate for Co-3 cassava under irrigated conditions was found to be 60:60:120 kg N-P_2O_5-K_2O/ha, which increased the yields by 36% over the control. For the recently developed short-duration clones, like H-119, CI-590 and S-856, under irrigated conditions the optimum spacing and fertilizer requirements are 75 x 75 cm and 75:25:75kg N-P_2O_5-K_2O/ha, respectively. Application of *Azospirillum* inoculum at 2 kg/ha as basal dressing with recommended fertilizers, combined with three foliar sprays of zinc sulfate (0.5%) and iron sulfate (1.0%) at 60, 75 and 90 days after planting, increased the root yield and starch content of Co-1 and Co-2 varieties. Under abundant water supply, cassava intercropped with groundnut can be irrigated at 0.6 IW/CPE ratio with an interval of 12 days and the application at 10 t/ha of coconut husk waste. Under limited water supply, irrigation may be reduced to 0.45 IW/CPE ratio with an interval of 16 days.

INTRODUCTION

In India, the major cassava growing states are Kerala and Tamil Nadu. In Tamil Nadu cassava is an industrial crop grown in an area of about 86 thousand ha (1994/95) with a production of 3.24 million tonnes of roots per year **(Figure 1)**. Tamil Nadu

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accounts for 33% of the area and 46% of cassava production in India. The area has increased considerably during the last ten years because of the industrial exploitation of the crop. In 1986/87 there were only 48 thousand ha with a production of 1.8 million tonnes. The crop has now acquired a status of one of the important commercial crops in the state. Tamil Nadu is blessed with varied soil and climatic conditions that are well suited for cassava growing. Already Tamil Nadu has the highest cassava yield, with a range from 14.76 to 60.33 t/ha and a mean of 37.72 t/ha. This could be attributed to the growing of high-yielding varieties released by CTCRI in Trivandrum and by Tamil Nadu Agricultural University, and the adoption of recommended crop production technologies, both under irrigated and rainfed conditions. The Indian average cassava yield is 22.87 t/ha, while it ranges from 5.1* to 14.4 t/ha in most other cassava growing countries.

Tamil Nadu state is divided into seven agroclimatic zones and the major traditional cassava growing areas in the western part of the state are the districts of Salem, South Arcot Vallalar and Dharmapuri (60% irrigated and 40% rainfed) and the southern district of Kanyakumari (mostly rainfed) **(Figure 2)**. There are about 800 sago and starch factories in and around Salem, South Arcot Vallalar and Dharmapuri districts which depend on cassava roots. The number of factories in Salem district alone is 650. It is estimated that 60% of the cassava starch produced in India is from Salem district. This district accounts for 44% of area and 47% of production of cassava in Tamil Nadu. Because of ease in cultivation, few pests and diseases problems, drought tolerance and the increase in root prices, the area under cassava is also increasing in other districts of Tamil Nadu, i.e. in Periyar, Tiruchirapalli and Coimbatore districts.

Even though the area is increasing, the production is not sufficient to meet the demand of the factories, which operate only about six months of the year. The industries operate at only 50% of capacity. Hence, there is a need to increase the cassava area and production in Tamil Nadu.

There is also scope for further increases in yield through the development of new varieties with high yield and higher starch content and the recommendation of zone-specific packages of practices, especially suited for rainfed culture of cassava.

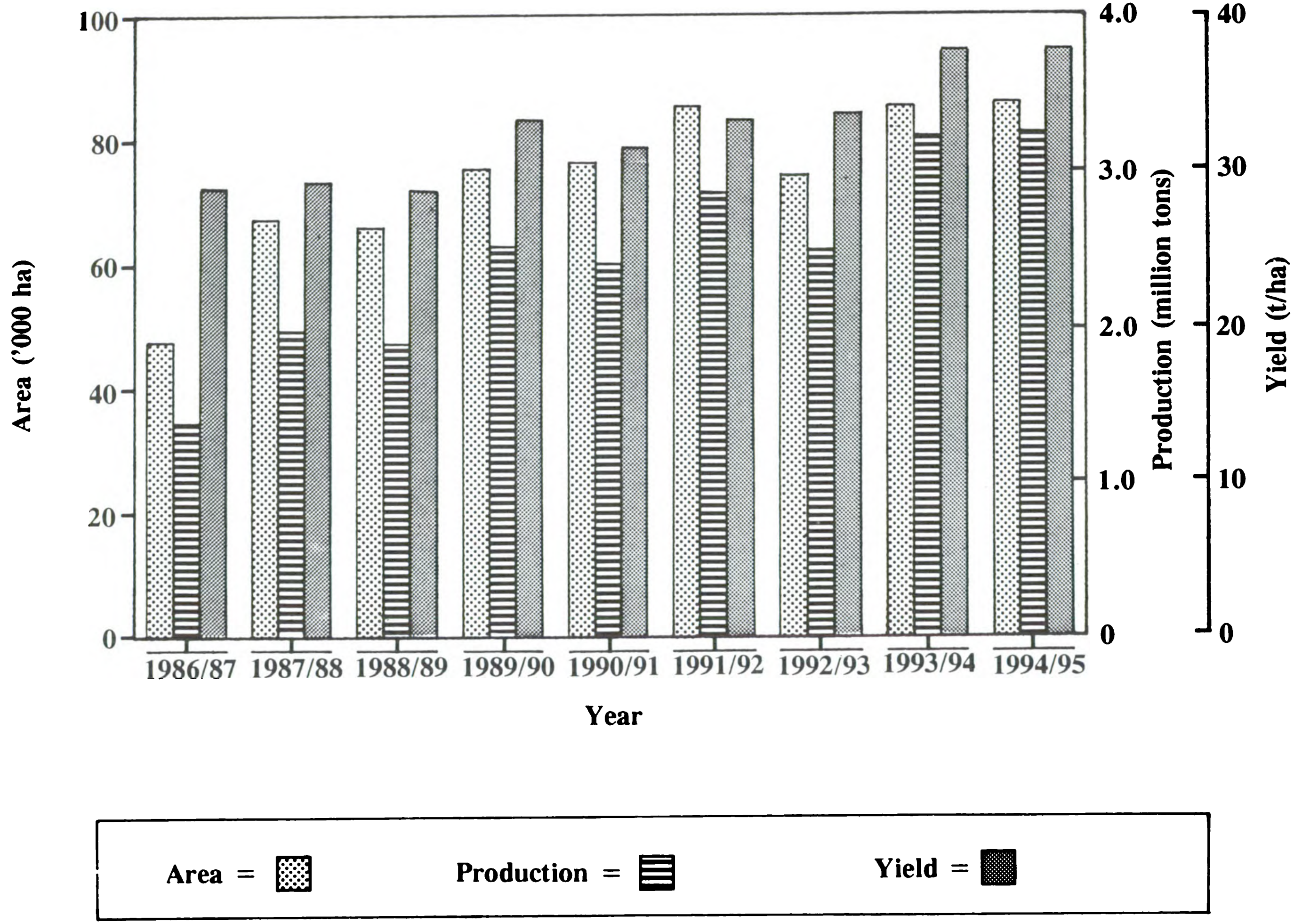

Figure 1. Area, production and yield of cassava in Tamil Nadu state, India, from 1986/87 to 1994/95.

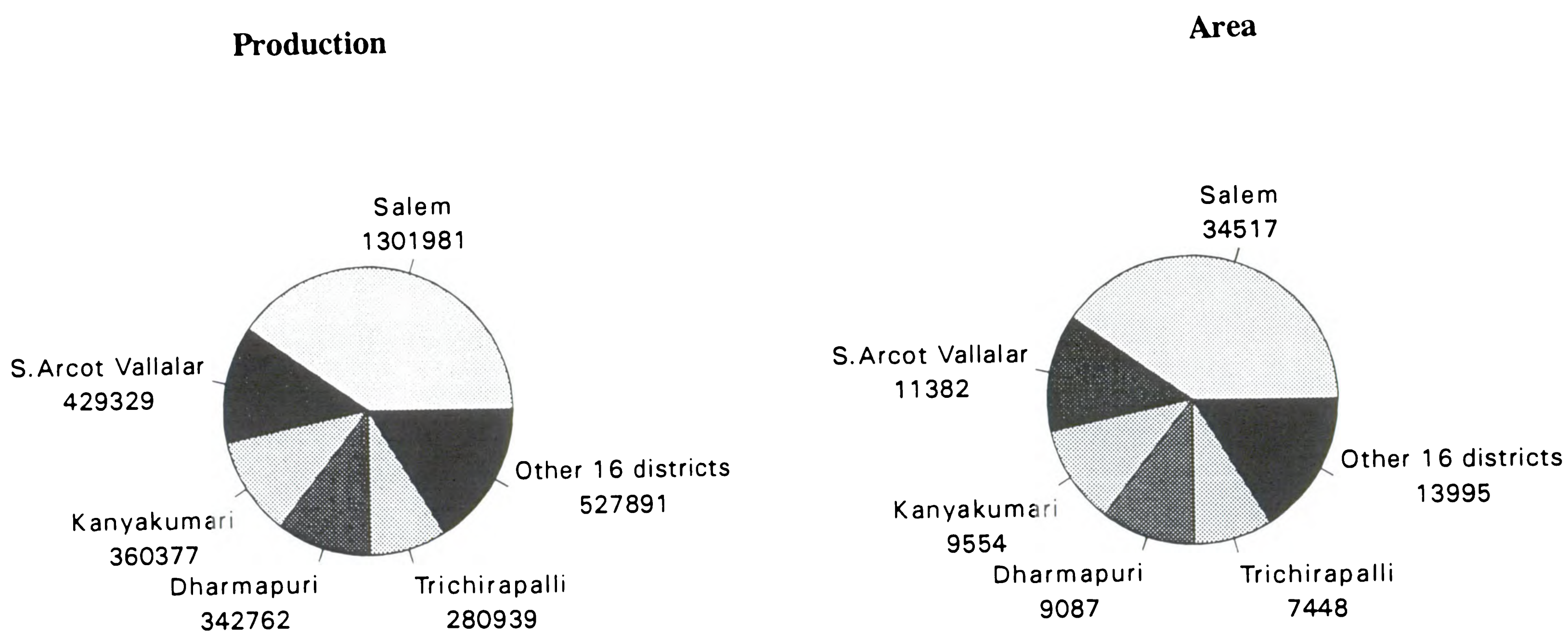

Figure 2. Major cassava growing districts in Tamil Nadu, India.

RESEARCH ACCOMPLISHMENTS

Earlier Research on Cassava

As far as the varietal situation is concerned, about 50% of the total area is grown with high-yielding varieties like H-226, MVD-1 (in most areas of Salem district), and Co-1 and Co-2 and Co-3 in different parts of Tamil Nadu. The salient features of these varieties are shown in **Table 1**.

Another improved variety MVD-1 (Mulluvadi 1) was released during 1983 by the State Department of Horticulture through clonal selection. It yields 34.5 t/ha in a duration of nine months. The roots contain 35% starch. It is a non-branching type and exhibits field tolerance to mosaic virus. Locally acclimatized and traditional varieties like "Burma" and "Malabar", are still under cultivation, but they are low-yielding and susceptible to CMD.

The recommendations on agronomic requirements and utilization of cassava, based on earlier field experiments at TNAU are: 1) use of single-bud setts for rapid multiplication, 2) dipping the setts in a superphosphate slurry, 3) use of ridges and furrows (75 x 90 cm) for irrigated crop; bed system for rainfed crop (60 x 60 cm); and mound system (90 x 90 cm) for high-rainfall zones, 4) application of 25 t/ha of FYM with 50:50:100 kg/ha of N-P_2O_5-K_2O for irrigated crop, 5) growing of intercrops like onion and blackgram, 6) use of growth hormones TIBA at 1000 ppm, Alar at 1000 ppm or bioregulator Ethrel at 500 ppm, 7) irrigating cassava at 60% moisture with a consumption of water of 1607 mm and witholding water one month before harvest, 8) allowing two shoots per sett, 9) adoption of no-tillage method with application of organic mulch of banana pseudostem or cumbu stalks, 10) pre-emergence herbicide application of pendemethalin at 1.0 kg a.i./ha, followed by two hand weedings, 11) utilizing cassava leaves for rearing silkworm, 12) using dry flour of cassava leaves in cattle or pig feed, 13) utilization of seed for extraction of edible oil, 14) use dry cassava chips or pellets as cattle feed, 15) development of recipes for Indian foods like *pergath, bonda*, stuffed *parota*, sweet balls, *susiam, munthirirotu, idly, halva, idiappam*, vermicelli, ready mixes of *soji* and bakery products, 16) protein enrichment of cassava vermicelli by the incorporation of green gram, bengal gram or soybean flour and 17) development of animal feed pelletization.

Earlier work on mutation breeding indicated the possibility of inducing variability for higher yield, compact growth habit, early maturity, higher starch content and lower HCN. A protocol for *in-vitro* propagation of cassava has been developed. Research on the use of true cassava seed indicated that soaking the seeds in potassium nitrate solution (0.5%) for 24 hours prior to planting enhanced the germination as well as the seedling vigor. The performance of plants raised from true cassava seeds is being studied.

Table 1. Salient features of cassava varieties developed by Tamil Nadu Agric. University.

Particulars	Co-1	Co-2	Co-3
Year of release	1974	1984	1993
Root yield (t/ha)	30.11	37.65	42.58
Crop duration (days)	255-270	255-270	240
Starch content (%)	35.00	34.35	35.60
Taste	Sweet	Sweet	Sweet
Color of skin	Brownish white	Brownish white	Dark brown
Color of flesh	White	White	White
Incidence of mosaic disease	Low	Very low	Very low
Branching habit	Non-branching	Branching at later stage	Branching

Current Research on Cassava

1. Crop Improvement

For any breeding program to succeed, the availability of diverse genetic material is important. With that in view, attempts were made to enrich the cassava collections. The germplasm bank at TNAU has presently the following number of accessions:

Indigenous	115
From CTCRI, Trivandrum	30
From CIAT/Colombia and the Thai-CIAT program	525
Total	670

Polyploidy breeding has been reported to have many advantages in cassava. The two promising triploids developed at CTCRI, Trivandrum, were tested for two years at Coimbatore. The results have indicated that the triploid variety 2/14 was similar to the check Co-2 with respect to root yield, DM and starch content. Results of the triploids being tested under Salem conditions are shown in **Table 2**.

Developing varieties with a shorter crop duration is another important objective in cassava breeding. Four short duration clones, i.e., H-119, CI-590, S-856 and H-5/78, were evaluated for three seasons. The results indicate that the clones H-119, CI-590, S-856 and H-5/78 have a shorter crop duration of 7 1/2 to 8 months. Among these four, H-119 recorded a significantly higher average root yield of 36.43 t/ha. It is a non-branching clone. However, the clone H-119 was found to be susceptible to CMD under Coimbatore conditions (Table 3). Good performance of H-119 has also been reported by Nanda *et al.* (1996) under Madhya Pradesh conditions, a non-traditional area of cassava cultivation in India.

Table 2. Performance of triploid cassava varieties in Salem, Tamil Nadu, India.

Clones	Root yield (t/ha) 1993	1994	Average	Root dry matter content (%)	Root starch content (%)
76/9 (CP.4(2x) x S-300 (4x)	19.5	18.3	18.9	45.8	34.2
2/14 (CP.2 (2x) x H-2304 (4x)	28.6	25.3	27.0	48.2	35.6
H-1687	30.0	23.8	26.9	39.1	30.2
H-2304	18.5	20.6	19.6	41.6	31.5
M-4	22.4	24.5	23.5	38.1	30.0
Co-2	28.4	27.1	27.8	48.6	35.0
SED	0.887	0.957	0.922		
CD (P=0.05)	2.14	2.310	2.230		

Table 3. Performance of short-duration cassava clones in Coimbatore, Tamil Nadu, India.

Clones	Root yield (t/ha) 1987/88	1988/89	1989/90	Average	Crop duration (days)	Root starch content (%)
H-119	34.3	38.3	36.7	36.43	230	32.0
CI-590	20.4	28.7	26.9	25.33	240	33.0
S-856	29.5	30.7	30.7	32.96	230	30.8
H-5/78	13.9	27.1	30.6	23.06	240	30.6
SED	1.43	2.27	1.80			
CD(P=0.05)	4.02	6.35	3.78			

Based on these results, the best two clones, H-119 and S-856, were tested in multi-locational trials in farmers' fields in Coimbatore using Co-2 as a check. Again, the clone H-119 had a significantly higher yield of 30.56 t/ha, a 13.0% increase over Co-2. The root yield of S-856 was 27.80 t/ha, which was not significantly different from that of Co-2. However, with regard to quality, Co-2 registered better consumers' preference (80.2%) than H-119 (78.5%) and S-856 (78.0%). The mosaic incidence was also higher in H-119 and S-856 (65.0 and 61.2%, respectively) as compared to that of Co-2 (5.2%).

For the high-rainfall zone of Kanyakumari district, the local clone, Adukkumuttan performs well with 20-28% higher yields than the released varieties.

For coastal areas of South Arcot Vallalar district, two clones, i.e., ME-46 and ME-10, were found to be the best with a mean root yield of 44 t/ha; they are now under further evaluation.

Cassava is grown on a large-scale in Salem district of Tamil Nadu. Sofar, varieties developed at CTCRI, Trivandrum, and at TNAU, Coimbatore, have been introduced. However, there is a need to develop or identify varieties more suited to the conditions that exists in this altogether different environment. With this objective, a total of 13 clones were tested during 1995 in a farmer's field in Salem. Among the clones, S-1315 performed best with a root yield of 4.5 kg per plant, followed by CE-22 (3.5 kg) and H-2304 (3.0 kg). There was no virus incidence in the clones H-97, CI-167, H-119, H-2304 and Co-2 under field conditions.

There exists a possibility of introducing true cassava seeds for commercial cultivation in Tamil Nadu where CMD is noticed on a large scale. To elucit basic information, research was conducted at the Department of Seed Technology of Tamil Nadu Agricultural University. The seed maturation studies conducted in true cassava seed have indicated that seeds attained physiological maturity 60 days after flowering under Coimbatore conditions. The physical index of maturity was the color change from green to yellow. Delayed harvest resulted in the shattering of the seeds (Nepolian, 1995). Germination studies on true cassava seeds have brought out that soaking of seeds in 0.5% KNO_3 solution for 24 hours prior to planting resulted in 94% germination. Storage studies revealed that cassava seeds can be stored at 6.26% moisture for ten months under ambient conditions without a decrease in germination. Rajendran *et al.* (1993) reported that the seeds could be stored for four to six months with good germination, while the seed viability reduced thereafter under Kerala conditions. Sowing at 2 cm depth in soil with 50% water holding capacity was observed to be optimum (Nepolian, 1995). Studies on the physiology of root development in plants raised from true cassava seed is in progress at the Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore.

2. Evaluation of CIAT Hybrid Clones

Under the International Evaluation Network Programme, seeds of 109 cassava hybrids were received from CIAT/Colombia and from the Thai-CIAT program during 1993. The seeds were sown in polybags in the nursery and the seedling progenies were transplanted. Among 109 hybrids only 91 established in the field. A total number of 525 clonal progenies were forwarded to further clonal generations. From the seedling progenies, stakes were prepared and clonal progenies were evaluated for two clonal generations during 1995 and 1996. The results on the variability of the progenies for morphological traits, root yield, harvest index, starch content and reaction to cassava mosaic disease are presented in **Tables 4** and **5**. Based on the performance of these clonal progenies, a total number of 20 and 38 clonal progenies were selected during 1995 and 1996, respectively. The data on root yield along with other traits are presented in **Tables 6** and **7**.

The following 21 CIAT hybrid clones were selected for non-branching habit, which will be tested later for high density planting. The figures in parenthesis indicate the number of clones in each hybrid exhibiting non-branching habit.

CM8487 (3), SM1450 (2), SM1454 (8), SM1520 (2), SM1542 (13), SM1557 (1), SM1636 (1), SM1673 (2), SM1679 (2), SM1784 (8), SM1789 (10), SM1791 (4), SM1858 (1), SM1864 (3), SM1969 (3), OMR36-05 (12), SM1780 (2), SM1883 (3), SM1890 (3), SM1891 (6) and SM 8208 (4).

Based on the performance of two seasons' clonal generations, the following 16 clones were selected for short-duration (early harvestability), ranging from 205 to 225 days. The figures in parenthesis indicate the clone number (ME) of each hybrid.

SM1475 (359), SM1858 (578), SM1470 (356), SM1544 (426), SM1665 (476), SM1475 (358), SM1454 (323), SM1774 (521), SM1432 (310), SM1454 (321), SM1447 (314), SM1460 (349), SM1523 (398), OMR36-4-1 (633), SM1787 (245), and SM1670 (200)

Since flowering is an important trait for breeding programs, the CIAT hybrid clones were also evaluated for their flowering habit. Among the clonal progenies, a total number of 33 and 48 clones flowered during 1995 and 1996, respectively. Out of these, the following 12 clones flowered uniformly during both years. The figures in parenthesis indicate the clone number (ME) of each hybrid.

SM1437 (175), SM1765 (208), SM1787 (242), SM1788 (249), SM1789 (250), SM1789 (255), SM1447 (312), SM1519 (375), SM1521 (383), SM1564 (445), SM1789 (566) and SM1858 (578)

The third clonal generation is in the field. Based on the performance of the clonal progenies, a few selected ones will be forwarded for regional evaluation trials in order to identify promising ones and to release as a new variety suited for cultivation in Tamil Nadu.

3. Crop Production Research

Nutrient management is an important aspect in cassava and studies on this aspect have provided useful results. Application of 10 tonnes of FYM + 60:75:100 kg/ha of N-P_2O_5-K_2O, 2 kg/ha of *Azospirillum*, combined with three foliar sprays of 0.5% zinc sulfate and 1% ferrous sulfate (60, 75 and 90 days after planting) resulted in root yields of Co-1 and Co-2 varieties of 34.57 and 35.43 t/ha, respectively (**Table 8**). The starch content was also the highest (39.98%) in Co-2 in this treatment. There was no significant difference in the HCN content of the root parenchyma. A quantity of 2 kg of *Azospirillum* inoculum is to be mixed with one liter of water, made into a slurry and the basal 1/3 of the stake is to be dipped for 20 min in the slurry before planting.

Table 4. Range in plant characteristics of hybrid clones received from CIAT

Characters	1995			1996		
	Range	Mean	CV (%)	Range	Mean	CV (%)
Plant height (cm)	121.3-291.6	210.75	13.1	118.8-296.2	205.86	9.1
Stem girth (cm)	2.0-11.6	7.21	15.2	2.1-17.2	8.06	14.8
Root length (cm)	6.8-45.2	18.18	14.0	6.1-61.0	23.06	16.2
Length of peduncle (cm)	0.0-4.6	1.20	8.5	0.0-5.9	1.36	9.6
Dry matter content (%)	18.2-37.5	26.52	16.2	17.5-40.2	29.22	17.2
Starch content (%)	21.0-36.8	31.20	10.6	22.0-37.2	30.51	11.2
HCN content (mg/kg)	12.2-40.3	22.56	11.2	14.5-41.6	23.19	10.4
Harvest index (%)	32.0-66.7	47.07	12.3	28.1-59.0	43.71	10.2
Fresh root yield (kg/plant)	1.3-3.5	2.41	19.9	1.2-4.9	2.27	28.5
Foliage weight (kg/plant)	1.3-5.1	2.63	26.2	1.6-5.2	2.77	26.7

From another study, the optimum fertilizer dose for the newly released cassava variety Co-3 under irrigated conditions was determined to be 60:60:120 kg/ha of N-P_2O_5-K_2O, which increased the root yield by 36% over the control.

A trial was conducted for three seasons to assess the fertilizer and spacing requirements for the short-duration clones H-119, CI-590 and S-856. The results indicate that all three short-duration clones produced higher yields at a closer spacing of 75 x 75 cm and a lower dose of fertilizers of 75:25:75 kg/ha of N-P_2O_5-K_2O. Besides the root yield, the dry matter and harvest index were also increased. The interaction effects were significant, and irrespective of the fertilizer dose, closer spacing resulted in higher root yields.

Nitrogen use efficiency by crops is of major interest in the tropics. Nitrogen is subject to leaching, denitrification and volatilization, which makes it unavailable to plants. Hence, studies were conducted under irrigated conditions on the use of nitrification inhibitors with nitrogenous fertilizers. The results of the trial on the use of slow-release fertilizers conducted for three seasons has indicated that the root yield in cassava was increased by all the four slow-release fertilizers (**Table 9**). However, a significantly higher average yield of 34.8 t/ha was obtained with the application of neem-coated urea; the next best treatment was sulfur-coated urea (32.3 t/ha).

Table 5. Evaluation during 1995 and 1996 of plant characteristics of cassava hybrid clones received from CIAT.

Character	Variations	1995 season (%)	1996 season (%)
Vigor	Very poor	2.80	2.50
	Poor	9.21	8.00
	Intermediate	50.50	55.80
	Good	26.20	27.20
	Very good	11.29	6.50
Flowering	Nil	85.21	89.87
	Few	2.50	2.12
	Intermediate	8.18	5.21
	Abundant	3.11	2.80
Plant height	Dwarf (<200 cm)	49.64	44.85
	Medium (200-300cm)	46.04	49.47
	Tall (>300cm)	4.32	5.68
Stem girth	Thin (<5cm)	5.60	55.47
	Medium (5-10cm)	84.20	85.05
	Thick (>10cm)	10.20	9.48
Branching habit	Non-branching	69.20	68.14
	Early-branching	18.50	20.04
	Late-branching	12.30	11.82
Lodging	None or light	40.80	42.55
	Intermediate	55.20	52.25
	Severe	4.00	5.20
Petiole color	Pink	58.00	58.65
	Green	37.50	36.71
	Pink+Green	4.50	4.64
Emerging leaf color	Green	61.20	61.18
	Pink	38.80	38.82
Root length	Short (<20cm)	36.20	39.08
	Intermediate (20-30cm)	45.10	42.36
	Long (>30cm)	18.70	18.76
Length of peduncle	Nil	85.20	66.65
	Short (<3cm)	5.60	25.25
	Intermediate (3-5cm)	5.26	5.04
	Long (>5cm)	3.94	3.06
Root color	White	10.00	10.08
	Light brown	24.60	23.84
	Dark brown	65.40	66.08
Flesh color	White	69.00	69.15
	Cream	28.90	28.66
	Yellow	2.10	2.19

Table 5. (continued)

Character	Variations	1995 season (%)	1996 season (%)
Root shape	Conical	2.50	2.41
	Conical cylindrical	38.00	38.51
	Cylindrical	56.00	55.14
	Irregular	3.50	3.94
Constrictions	None or few	80.00	82.05
	Intermediate	16.80	13.57
	Several	3.20	4.38
Foliage and root evaluation	Very good	45.00	42.80
	Good	25.00	20.60
	Regular	15.20	18.20
	Bad	7.58	8.00
	Very bad	7.22	10.40
Dry matter	High (>30%)	26.10	22.15
	Medium (20-30%)	40.80	42.63
	Low (<20%)	33.10	35.22
Starch content	High (>30%)	23.20	24.10
	Mekium (25-30%)	52.10	53.26
	Low (<25%)	24.70	22.64
HCN content	High (>30mg/kg)	30.00	31.65
	Medium (20-30mg/kg)	45.28	40.15
	Low (<20mg/kg)	24.72	28.20
Harvest index	Low (<0.40)	20.95	38.35
	Medium (0.40-0.50)	54.36	30.40
	High (>0.50)	24.69	31.25
Fresh root yield (kg/plant)	<2	55.67	62.88
	2-3	33.49	19.00
	3-4	8.13	9.17
	>4	2.71	8.95
Incidence of CMD (score)	0 (no CMD)	2.60	2.56
	1	0.50	0.24
	2	1.21	1.73
	3	7.90	8.64
	4	34.50	31.75
	5	53.29	55.08

Table 6. Yield data of selected CIAT hybrid cassava progenies[1] grown at TNAU in 1995.

CIAT hybrid No.	Clone No. (ME)	Plant height (cm)	Root yield (kg/plant)	Foliage weight (kg/plant)	Harvest index	Starch content (%)
OMR36-42	641	297	5.6	5.20	0.52	36.25
OMR36-05	671	288	4.4	8.30	0.35	35.20
OMR36-67	645	238	4.0	5.10	0.44	35.15
SM7564	656	304	4.9	4.00	0.55	36.00
CM8487	296	175	3.5	2.70	0.69	33.50
SM1432	306	127	3.0	1.90	0.68	33.10
SM1432	310	231	3.2	3.30	0.49	34.10
SM1456	332	205	3.0	3.25	0.48	33.90
SM1460	347	270	3.2	3.20	0.50	33.90
SM1470	356	270	3.1	3.20	0.49	33.20
SM1673	397	151	3.1	2.25	0.58	33.30
SM1789	564	185	3.7	3.20	0.53	35.30
SM1855	572	210	3.1	5.20	0.37	34.30
SM1858	578	245	4.0	3.00	0.57	36.80
OMR36-05	618	258	3.8	4.10	0.48	35.00
OMR36-05	625	259	3.9	2.60	0.60	35.12
OMR36-42	654	248	3.6	6.00	0.37	34.86
OMR36-42	637	266	3.5	4.20	0.45	34.90
OMR36-42	640	240	3.0	2.60	0.54	33.85
SM1564	657	240	3.2	4.10	0.44	33.90

[1]clonal progenies obtained from sexual seed received from CIAT in 1993.

Table 7. Yield data of selected CIAT hybrid cassava progenies[1)] grown at TNAU in 1996.

CIAT hybrid No.	Clone No. (ME)	Plant height (cm)	Root yield (kg/plant)	Foliage weight (kg/plant)	Harvest index	Starch content (%)
SM1444	183	270	6.0	3.65	0.62	35.00
SM1414	186	350	7.3	9.00	0.45	35.62
SM1432	302	217	4.1	4.60	0.47	34.80
SM1432	310	250	5.2	6.20	0.46	36.10
SM1447	314	267	5.1	7.50	0.40	35.50
SM1454	321	255	5.2	4.20	0.55	35.90
SM1454	343	205	5.5	3.40	0.55	35.96
SM1460	346	225	5.1	4.85	0.46	35.90
SM1460	344	256	5.1	2.70	0.57	30.90
SM1470	356	226	7.0	6.00	0.54	35.50
SM1475	358	266	5.6	7.50	0.57	36.20
SM1475	359	323	9.0	10.70	0.46	36.80
SM1521	384	185	4.3	5.70	0.43	34.80
SM1523	398	240	5.5	4.30	0.56	35.90
SM1544	426	195	5.8	1.80	0.76	35.30
SM1545	430	215	5.0	7.00	0.42	36.20
SM1573	464	110	4.0	2.50	0.62	34.80
SM1665	476	225	5.8	4.50	0.56	35.20
SM1670	200	168	4.9	3.40	0.59	35.60
SM1670	201	240	4.1	2.00	0.67	34.60
SM1718	218	260	4.3	5.60	0.43	35.00
SM1774	269	285	9.8	5.20	0.65	36.40
SM1774	521	204	5.5	4.80	0.53	35.00
SM1783	222	228	4.8	4.70	0.51	35.50
SM1784	539	295	4.5	4.00	0.53	34.90
SM1784	541	180	4.0	0.85	0.82	34.00
SM1784	551	220	4.6	4.70	0.50	35.00
SM1787	240	277	4.0	4.50	0.41	34.00
SM1787	243	200	4.2	3.70	0.53	34.25
SM1787	245	240	4.8	3.70	0.36	35.00
SM1787	256	295	4.1	5.00	0.45	34.60
SM1789	251	290	4.1	5.20	0.44	34.60
SM1855	573	220	4.6	2.20	0.68	34.80
SM1858	578	245	8.5	5.60	0.60	36.20
SM1883	265	267	8.0	6.00	0.57	36.00
SM1890	270	280	7.0	3.90	0.64	35.00
SM1891	278	268	4.1	4.90	0.46	34.82
OMR36-41	635	178	5.0	2.80	0.63	35.10

[1)]clonal progenies obtained from sexual seed received from CIAT in 1993.

Table 8. Effect of micronutrients (Zn and Fe) and biofertilizer (*Azospirillum*) on the yield and starch content of two cassava cultivars grown at TNAU.

Treatments	Fresh root yield (t/ha)		Starch content (%)	
	Co-1	Co-2	Co-1	Co-2
Control (fertilizers only)	16.50	22.40	32.60	34.14
Fertilizers+Zn+Fe+*Azospirillum*	34.57	35.43	35.16	39.98

Earlier studies on intercropping indicated that Bellary onion (*Allium cepa* var. cepa) and blackgram were suitable intercrops for cassava. In a separate study by Mohammed Yassin (1995) conducted for two years on the N management and intercropping in cassava, it was found that growing vegetable cowpea or sunhemp as intercrops and incorporating the haulms into the soil increased the root yield of cassava from 18.87 to 45.0 t/ha in the first experiment, and from 13.45 to 35.63 t/ha in the second experiment. The cost benefit ratio was higher, i.e. 1:3.8 and 1:2.8 during the first and second years, respectively, as compared to monocropped cassava. The starch and DM content of the root was also increased. The effect was more pronounced when neem-coated urea or prilled urea + *Azospirillum* at the rate 2 kg/ha were applied.

Ayyaswamy (1994) conducted experiments on irrigation scheduling and intercropping systems in cassava. The results have indicated that under abundant water supply, cassava grown as an intercrop in groundnut and irrigated at 0.6 IW/CPE ratio with an interval of 12 days and with coconut fibre waste (as soil amendment) applied at 10 t/ha increased the root yield and net returns per hectare. Under limited water supply, the same treatment with a change in irrigation scheduling at 0.45 IW/CPE ratio, applied at an interval of 16 days, was found optimum. There was improvement in both dry matter and starch content of the roots.

4. Post Harvest Technology

Research programs are in progress at Tamil Nadu Agricultural University on the processing of cassava roots. Susheela Thirumaran and Aruna Seralathan (1996) conducted experiments on the production of cassava-based defatted soyflour noodles. The results showed that the noodles had desirable properties, such as a more than six months shelf life and significantly high acceptability scores, while providing 340 kilo-calories of energy and having 16% protein. They have suggested that extrusion of nutritious noodles can be initiated as a commercial venture for school lunch programs.

Table 9. Effect of the application of slow-release nitrogen fertilizers on the yield of cassava grown in TNAU.

Treatments	Root yield (t/ha)			
	1992/93	1993/94	1994/95	Average
Prilled urea	30.3	31.4	33.1	31.6
Urea super-granule	29.6	30.8	31.2	30.5
Neem-coated urea	33.5	34.2	36.7	34.8
Sulfur-coated urea	30.5	32.7	33.6	32.3
Tar-coated urea	28.8	27.6	30.8	29.1
Control	24.7	26.1	27.9	26.2
SED	0.688	0.456	0.513	
CD(P=0.05)	1.480	0.970	1.262	

At Tamil Nadu Agricultural University, the College of Agricultural Engineering is involved in the development of machinery for cassava harvesting and processing. A root puller (harvester), chipper, peeler, mechanical stirrer for starch settling tanks, sago roaster and pelletizer are some of the pieces of equipment developed for use in small-scale industries.

THRUST AREAS AND SUGGESTIONS

1. Cassava in Tamil Nadu is affected by mosaic virus disease as a result of which the yield is considerably reduced. The incidence is greater in Salem, South Arcot Vallalar and Dharmapuri districts. Resistant varieties are to be developed. It is observed that there are variations in the susceptibility of clones to cassava mosaic disease in different agro-climatic zones. Some of the clones susceptible at Coimbatore are free from CMD at Salem or Kanyakumari in Tamil Nadu. It is suspected that there may be strains or races of the virus which needs to be investigated.
2. In Salem district, there are location-specific problems in cassava fields, like twisting, knotting and splitting of roots, which affect the root yield and industrial quality. The reasons are to be investigated and suitable remedial measures suggested.
3. Occurrence of root rot caused by *Sclerotium rolfsii* has recently been noticed in some locations of Salem district and resistant varieties and suitable management practices are to be developed.
4. In most of the locations cassava is grown as a rainfed crop. Unlike Kerala, the annual amount of rainfall is only 800-900 mm. There is a need to develop varieties adapted to rainfed cultivation and a package of cultural practices are to be developed.
5. In some parts of Salem and South Arcot Vallalar districts, cassava is grown in hilly areas at an altitude of 500 masl. There is a need to develop varieties for these zones along with agronomic practices.
6. Much emphasis is now given for production of organic foods. There is a need to

intensify research on organic gardening with special reference to the use of organic 8-manure, biofertilizers and biocontrol of pests and diseases.

7. Crop improvement programs are therefore to be planned with the objective of developing varieties with shorter crop duration (<7 months), high root yield (>35 t/ha), high starch content in roots (>35%) and resistance to biotic (mosaic virus, root rot, tip drying, leafspot and mites), and abiotic (drought and salt) stresses. Due emphasis is to be given to developing crop production technologies suited to varied agroclimatic zones of Tamil Nadu. It is also necessary to develop technologies for the manufacture of value-added products utilizing cassava as the raw material.

8. The major reason for slow adoption rate of improved varieties is the lack of planting material. There is a need for the development of large-scale rapid multiplication of elite clones including *in-vitro* propagation.

9. It is estimated that 60% of the starch produced in India is from cassava roots and the entire quantity is used for domestic consumption. At present the machinery used in the sago and starch factories is old, which results in lower productivity and it takes a longer time for extraction; these need to be modernized. Further, starch produced in these factories do not reach the standards for export. The starch recovery is only 60% and 40% of the starch left in the fibrous waste material is used in cattle feed.

10. There exists the possibility of manufacturing starch and animal feed pellets for export purpose. In Dharmapuri district, one fully-automated factory is being established for the manufacture of starch, exclusively for export. A few factories have been set up for manufacture of other value-added products, like industrial alcohol, sorbitol, liquid glucose, dextrin, high-frutose syrup, glue, cattle feed etc. This is a good beginning. There is need to develop varieties suitable for these various end-products and optimum growing and processing technologies.

11. The major constraint in the cassava industry is the high degree of price fluctuation, both for fresh roots and for products like starch and sago **(Figures 3 and 4)**. There is a need to stabilize the market prices of roots and cassava-based products.

12. The starch and sago factories require a large quantity of water for starch extraction and the effluent discharge pose a health hazard to the people and animals, as well as for the environment. Hence there is a need to modernize factories and to develop new low-cost effluent treatment technologies.

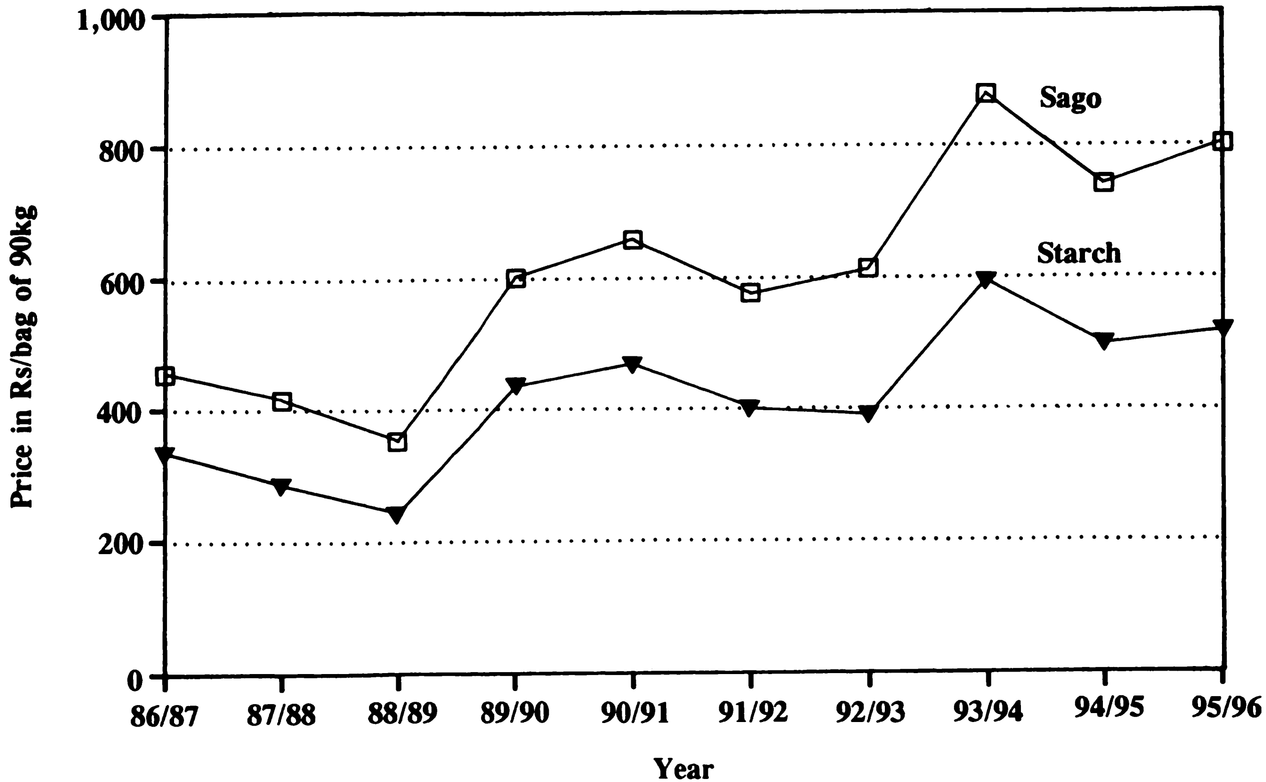

Figure 3. Average market price of fresh cassava roots in Salem, Tamil Nadu from 1986/87 to 1995/96.

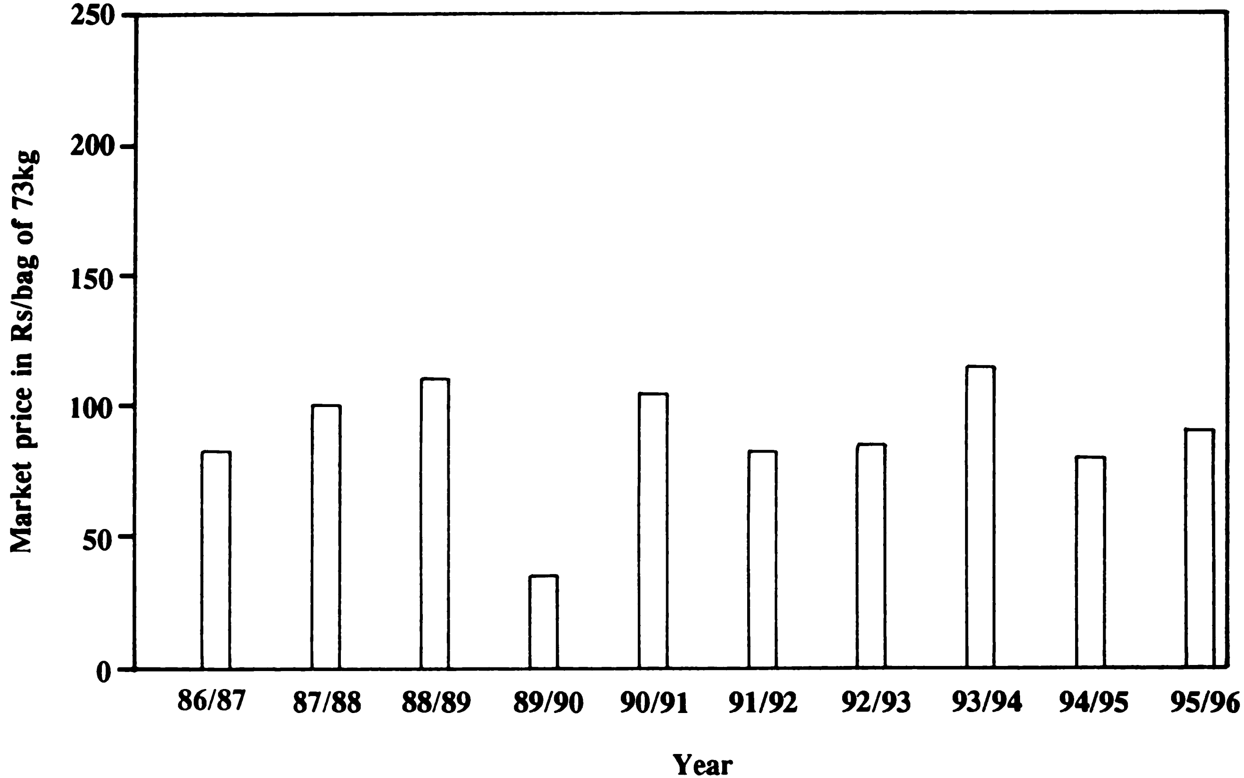

Figure 4. Price fluctuation of starch and sago in Salem, Tamil Nadu from 1986/87 to 1995/96.

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RECENT PROGRESS IN CASSAVA VARIETAL IMPROVEMENT IN THE PHILIPPINES

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ABSTRACT

In recent years cassava has become an important raw material for various domestic needs (food, feed, alcohol and high fructose sugar). To cope with high demand for cassava roots the breeding and selection program has been intensified to identify varieties that are high yielding and having high starch and dry matter contents. The continuous introduction of improved cassava populations from the Thai-CIAT program and from CIAT/Colombia contributed to the identification of good varieties, and consequently, the establishment of cassava genepools having a wide genetic base. This has led to the establishment of a breeding program using the best parents of local and foreign sources.

Progress in selection for the last three years was observed but was not phenomenal. In fact, from the regional trials jointly conducted by PRCRTC and its cooperating stations, two new varieties of cassava from CIAT/Colombia selected by the University of the Philippines at Los Banos, were released by the National Seed Industry Council. These are CM3419-2A as PSB CV-11 and SM972-20 as PSB CV-12. Both are intended for food and feed because of their low levels of HCN.

Using the popular variety Lakan as check for the selection and evaluation among introduced materials from CIAT/Colombia and Thailand, gradual progress is made in yield and dry matter content. Superior varieties have been identified but are still in the pipeline for further testing.

Varietal dissemination of new varieties has been intensified through on-farm trials and demonstration farms in strategic areas where farmers have the opportunity to observe and select.

The involvement of the private sector, specifically the San Miguel Corporation, in the creation of high demand for cassava has paved the way for the rapid increase of production in terms of area and varietal dissemination.

For the last two years the Agribusiness Division of San Miguel Corporation has supported 3,000 ha of cassava in Mindanao. Support given is in terms of planting material, land preparation and fertilizer input. All produce will go to San Miguel with a price profitable to the farmers. The projected cassava area needed to meet the needs of San Miguel Corporation is 55,000 ha. To this effect, variety trials are conducted in farmers' fields using recommended varieties (Rayong 60, Rayong 90, Rayong 5, KU-50 and the VC series) in Mindanao. Furthermore, rapid propagation is planned to back-up the need for more planting material.

Aside from the San Miguel Corporation, starch millers throughout the country continue to expand their production area due to the high demand for starch. High HCN varieties are preferable. VC-5, which is high in HCN, is now planted in more than 3,000 ha in Lanao, while more than 1,000 ha of Lakan are planted in Negros Occidental to support Unistarch.

Further selection will focus on identification of superior varieties with high starch content and high yield while having low to high levels of HCN.

INTRODUCTION

In recent years, domestic utilization of cassava in the Philippines has markedly increased. This is basically because cassava is recognized as a cheap raw material for

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production of food, feed and other industrial products. This recent development has finally realized the projection of the 1984 Asian Cassava Workshop in Thailand about the future potential of cassava in Asia. In fact, Walters (1983), Lynam (1986) and Singh (1986), emphasized that cassava will play a major role in satisfying the domestic needs of the country and that any future increase in the output used by the cassava producing countries in Asia should be aimed primarily at their domestic markets, such as for 1. animal feed; 2. starch production (food processing, textiles, paper and board, modified sugar); and 3. manufacture of ethanol.

True to the projection 12 years ago, cassava became an important raw material for production of animal feeds, starch and its derivatives, as well as alcohol. The demand for cassava roots is hastened by the involvement of the giant business conglomerate San Miguel Corporation, which needs around 55,000 ha of cassava to supply their various needs for feed, modified starch and alcohol (Bacusmo, personal communication). The overall effect is the massive expansion of cassava production in terms of area and yield. Superior varieties are, therefore, needed to satisfy the existing demand.

In support of this development, the cassava varietal improvement program of the Philippine Root Crops Research and Training Center (PRCRTC), and that at the Institute of Plant Breeding (IPB) of the Univ. of the Philippines at Los Baños, will continue to keep pace with the needs of the cassava industry. The introduction of elite materials from the Thai-CIAT program and CIAT/Colombia has greatly improved the selection and identification of best varieties for outright release and for utilization as cross parents in the breeding program.

VARIETAL IMPROVEMENT

Breeding Objectives

The breeding objectives for cassava in the Philippines have not changed since 1987 (Mariscal and Bacusmo, 1995). Generally, the breeding activities aim to satisfy the needs of the cassava farmers and processors who grow cassava in diverse agro-climatic conditions and utilize the storage roots in a variety of ways. Specifically, 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)
7. Level of HCN (low for staple food, high for starch millers)

Recent Developments (1993-1996)

1. Germplasm collection

To back up the cassava improvement activities at PRCRTC, a germplasm collection with wide genetic base is needed. Thus, PRCRTC maintained and upgraded the genetic stocks of cassava. To date PRCRTC maintains in the field 300 cassava accessions. These include 53 elite materials selected from Advanced Yield Trials as well as from tissue culture materials introduced from Thailand (**Table 1**). With support from the Cassava Biotechnology Network (CBN) of CIAT, germplasm materials from PRCRTC will be sent to CIAT Headquarters in Colombia for global maintenance.

2. Advances in selection

Since the later part of 1993, 14,962 cassava hybrid seeds coming from 246 crosses were introduced to PRCRTC (**Table 2**). A total of 4,405 hybrid seedlings have been evaluated. Most of these hybrid seedlings came from the seed introduction from CIAT/Colombia and the Thai-CIAT program at Rayong. Summaries of the number of genotypes at different testing stages are shown in **Table 3**. Since 1993, all trials conducted included materials from both Thailand and Colombia, with Lakan, a variety with a very stable yield and adaptability, used as check variety. From the replicated trials of all entries from the Thai-CIAT program, specifically the MT series, there was no progress in terms of yield and harvest index. However, it seems that there is positive improvement in terms of dry matter content (**Figure 1**). This shows that the check variety Lakan is actually quite good.

Table 1. Cassava germplasm collection at PRCRTC, ViSCA, Baybay, Leyte, Philippines, 1993-1996.

	No. of Accesions		
Source	1993/94	1994/95	1995/96
Local	86	86	86
Foreign	131	131	131
Tissue culture (Thailand)	30	30	30
Elite clones	26	41	53
Total	**273**	**288**	**300**

Table 2. CIAT cassava hybrid seeds supplied to PRCRTC, ViSCA, Baybay, Leyte. 1993-1996.

Date	Number of seeds	Number of crosses	Sources
March 1993	2,361	35	CIAT/Colombia
June 1993	1,050	29	Thai-CIAT program
July 1994	1,250	26	Thai-CIAT program
July 1994	2,038	35	CIAT/Colombia
March 1995	2,043	35	CIAT/Colombia
May 1995	1,190	17	Thai-CIAT program
January 1996	2,230	31	CIAT/Colombia
April 1996	1,350	19	Thai-CIAT program
July 1996	1,450	19	Thai-CIAT program
Total	**14,962**	**246**	

Table 3. Number of entries in different stages of cassava selection by PRCRTC, ViSCA, Baybay, Leyte, Philippines. 1993-1996.

Selection stage	Year			
	1993/94	1994/95	1995/96	Total
Observational Trial (F1 seedlings)	1,193	1,850	1,362	4,405
Single-row Trial	392	695	410	1,497
Preliminary Yield Trial	72	136	53	261
General Yield Trial	25	73	22	120
Advanced Yield Trial	19	20	23	62
Regional Trial	10	10	10	10
Varietal Release	2	1	1	4
Promotional Trial	-	-	2	2
On-farm Trial/Verification	4	5	5	14
Total	**1,717**	**2,789**	**1,886**	**6,375**

Considering the OMR series from Thailand, a similar trend as that of the MT series was observed. Not much improvement was observed, except for dry matter content, which was similar to that of the check (**Figure 2**). These results are also shown in **Tables 7** and **8**. From the MT series, no entry was able to surpass the check variety in terms of yield. Lakan had a yield of 38.0 t/ha, while the highest yield among entries was only 34.5 t/ha (MT4-111). However, with respect to dry matter, several entries surpassed the check. Some of these entries are MT4-52 and MT4-251 with dry matter contents of 37.4 and 37.0%, respectively (**Table 4**). The check variety had only 34.0% dry matter.

From the OMR series (**Table 5**) only one entry, CMR33-13-14, produced a high yield of 60.4 t/ha, which surpassed the check. Nevertheless, many of the entries had high dry matter contents that are comparable to, or far better, than that of the check variety. These are CMR33-13-14, OMR33-12-3, OMR33-12-7 and OMR33-15-3 with dry matter contents of 34.9, 35.8, 36.2 and 35.2%, respectively. Lakan had 34.9% dry matter.

Table 4. Yield parameters of six cassava hybrids from the Thai-CIAT program evaluated in the Advanced Yield Trial conducted at PRCRTC in 1994/95.

Entry	Fresh root yield (t/ha)[1]	Dry matter content (%)	Starch content (%)	Harvest index
MT12-44	19.0	34.6	22.5	0.46
MT4-111	34.5	32.9	20.2	0.56
MT4-52	23.7	37.4	26.4	0.46
MT9-21	26.5	33.2	20.6	0.62
MT4-251	14.6	37.0	25.8	0.59
MT15-32	26.5	35.9	24.4	0.50
Lakan(check)	38.0	34.0	21.7	0.55
VC-4(check)	25.2	31.1	17.6	0.60
Average	24.1	35.2	23.3	0.52

[1] Average over 4 replications
Source: PRCRTC, 1995

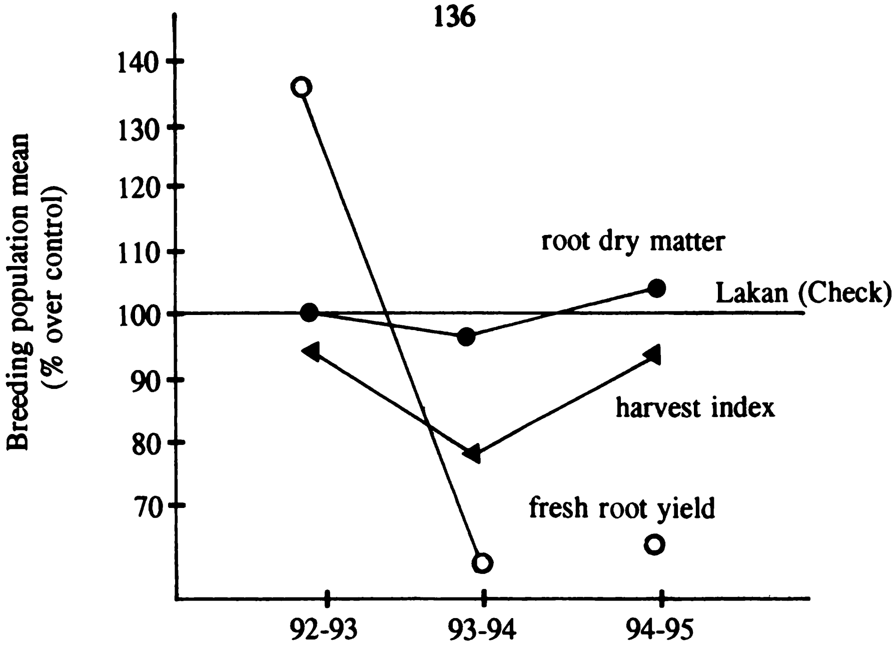

Figure 1. Change of mean frequency of all entries in Replicated Yield trials in terms of fresh root yield, dry matter content and harvest index of materials (MT series) from the Thai-CIAT program.

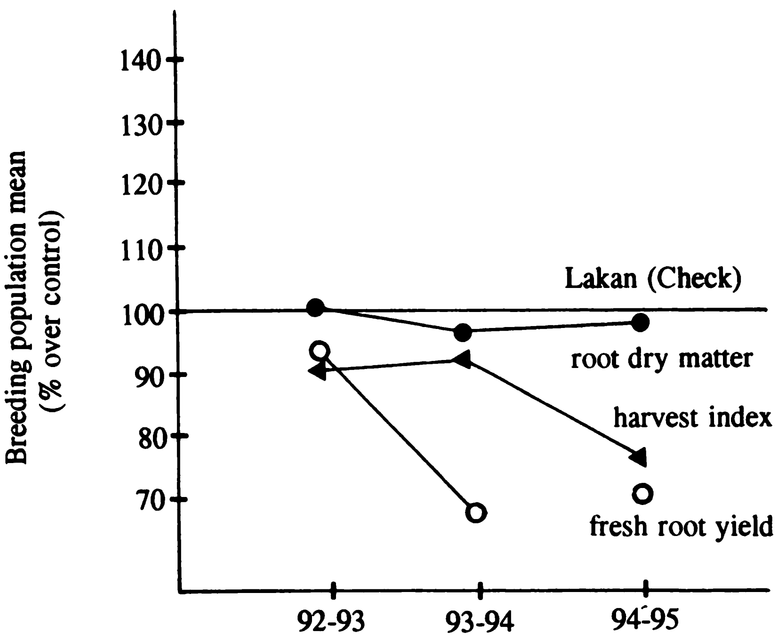

Figure 2. Change of mean frequency of all entries in Replicated Yield Trials in terms of fresh root yield, dry matter content and harvest index of materials (OMR series) from the Thai-CIAT program.

Table 5. Yield parameters of eight cassava hybrids from the Thai-CIAT program evaluated in the Advanced Yield Trial conducted at PRCRTC in 1994/95.

Entry	Fresh root yield (t/ha)[1]	Dry matter content (%)	Harvest index	HCN rating[2]
CMR33-13-14	60.4	34.9	0.58	5
OMR33-12-3	38.5	35.8	0.55	6
OMR33-12-7	38.9	36.2	0.57	6
OMR33-11-7	40.8	32.9	0.59	5
OMR33-05-1	34.6	33.4	0.58	7
OMR33-15-3	26.6	35.2	0.42	6
OMR33-15-5	38.2	32.7	0.62	5
Rayong 60	47.9	32.7	0.62	8
VC-4(check)	46.6	31.1	0.62	4
Lakan(check)	53.8	34.9	0.68	4
Average	40.7	34.2	0.57	

[1]Average over 4 replications
[2]Based on picrate test rating scale of 1 to 9:1=low, 9=high
Source: PRCRTC, 1996

From all entries in the Replicated Yield Trials with materials from CIAT/Colombia, no gain in selection was observed in terms of yield (**Figure 3**). The same pattern was also observed among entries of tissue-culture derived materials (**Figure 4**). **Table 6** clearly shows that only one entry, SM1558-2, produced a higher yield of 31.4 t/ha than the check, which produced 29.3 t/ha. However, several entries had high dry matter contents, which are comparable to, or even better than, that of the check. In **Table 7**, MMal 2 produced the highest yield of 50 t/ha, which surpassed that of the check cultivar. With respect to dry matter, no entry surpassed the check (Lakan).

These results clearly demonstrate that materials from the Thai-CIAT program and from CIAT/Colombia have high dry matter contents. Though there have been remarkable yield increases observed, superior clones/lines that could become candidates for varietal release and subsequent use in production areas in the Philippines have still to be identified.

Table 6. Yield parameters of 12 cassava hybrids from CIAT/Colombia evaluated in the General Yield Trial at PRCRT in 1994/95.

Entry	Fresh root yield (t/ha)[1]	Dry matter content (%)	Harvest index	HCN rating[2]
CM6149-3	20.3	34.8	0.60	5
CM6149-5	15.0	33.9	0.52	5
SM1449-9	19.1	33.5	0.61	3
SM1451-3	22.4	33.7	0.55	4
SM1477-3	17.8	31.1	0.43	4
SM1477-5	23.6	35.2	0.48	5
SM1542-5	10.3	33.2	0.62	5
SM1544-1	15.6	33.7	0.46	3
SM1558-2	31.4	34.9	0.56	3
SM1558-9	20.3	31.2	0.58	5
SM1564-8	14.9	37.6	0.44	3
SM1565-1	17.3	39.7	0.45	4
Lakan(check)	29.3	34.8	0.57	3
VC-1(check)	21.5	34.7	0.58	4
VC-3(check)	31.3	32.1	0.62	3
Average	16.4	34.4	0.52	

[1]Average of 3 replications
[2]Based on picrate test rating scale of 1 to 9: 1=low, 9=high
Source: PRCRTC, 1996.

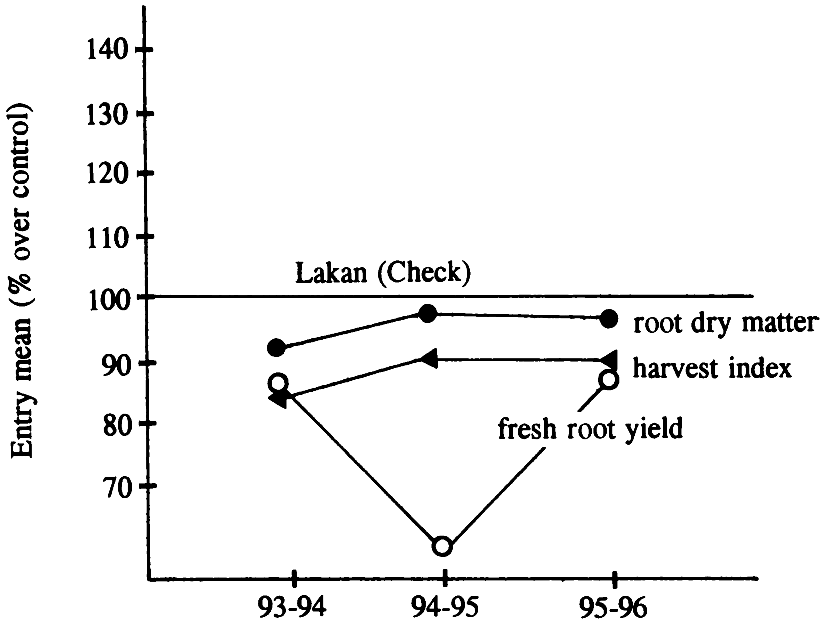

Figure 3. Change of mean frequency of all entries in Replicated Yield Trials in terms of fresh root yield, dry matter content and harvest index of materials from CIAT/Colombia.

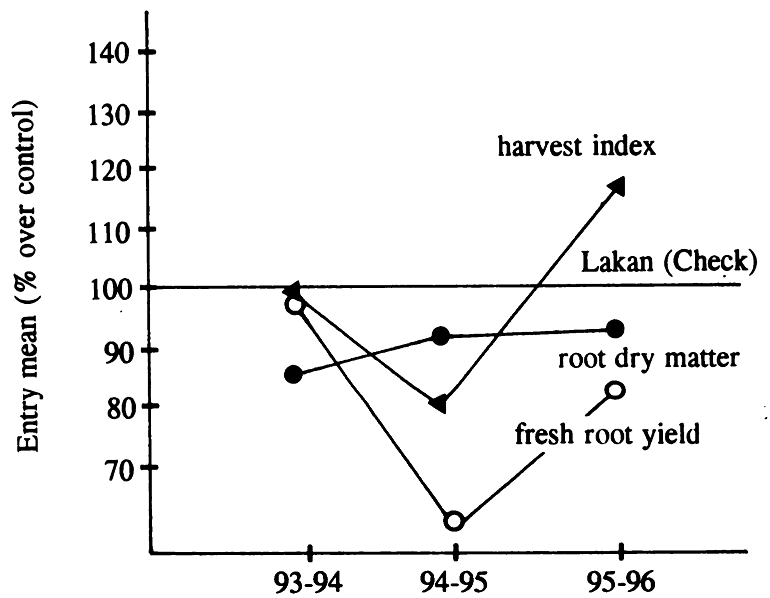

Figure 4. Change of mean frequency of all entries in Replicated Yield Trials in terms of fresh root yield, dry matter content and harvest index of tissue culture-derived materials from CIAT/Colombia.

Table 7. Yield parameters of ten cassava hybrids from the Thai-CIAT program introduced through tissue culture, and evaluated in the Advanced Yield Trial at PRCRTC in 1994/95.

Entry	Fresh root yield (t/ha)[1)]	Dry matter content (%)	Starch content (%)	Harvest index
CM3299-4	29.2	36.1	24.5	0.38
CM4054-40	24.7	36.5	25.1	0.60
MCol 2215	23.5	37.2	26.1	0.56
CM2772-3	27.3	37.4	26.4	0.52
Rayong 60	36.8	36.5	24.2	0.63
CM4231-32	28.3	32.9	20.1	0.58
CM3306-4	25.8	38.2	27.5	0.48
MCol 1505	33.8	36.5	25.2	0.48
MMal 2	50.0	35.5	23.7	0.46
CMR29-56-101	15.4	33.7	21.2	0.49
Lakan(check)	36.5	38.4	27.8	0.49
VC-4(check)	40.8	34.9	22.9	0.62
Average	29.5	36.0	24.5	0.56

[1)]Average over 4 replications
Source: *PRCRTC, 1995.*

3. Utilization of CIAT germplasm for local hybridization

Aside from screening and field evaluation of introduced hybrid seeds from CIAT, the PRCRTC utilized elite clones for its hybridization work to improve the local cultivars. A hybridization block was established and selected parents of local and foreign origin were planted for subsequent crossing. Open pollinated seeds in the germplasm collections were gathered for possible screening and evaluation. Controlled crossing work is still to be undertaken upon flowering of parental lines.

From the hybrid population previously developed, five promising local hybrids are included in the Regional Trial. Potential varieties for recommendation are the following: CMP62-15 and CMP21-15, each with average yields of 24.0 t/ha (**Table 8**). These two possible varieties outyielded the two check varieties.

Table 8. Average cassava root yields (t/ha) in Regional Trials conducted in eight locations in the Philippines from 1990 to 1995/96.

Entry	Year				General average
	1990-93	1993/94	1994/95	1995/96	
1. CMP21-6	-	17.5	25.3	-	21.4
2. CMP62-15	-	20.6	22.4	20.3	24.0
3. CMP32-10	-	14.9	31.2	19.2	21.8
4. CMP26-1	-	21.3	22.7	-	22.0
5. CMP21-15	-	24.9	26.1	21.0	24.0
6. VC-2(check)	26.4	17.7	26.1	17.8	22.0
7. CM3419-2A**	27.4	19.7	24.9	-	24.0
8. CM3283-4	24.8	14.5	21.8	-	20.4
9. CM3422-1	25.9	12.6	25.4	28.9	23.2
10. SM928-1	-	20.3	19.9	25.0	21.7
11. SM972-20**	-	13.6	39.1	24.1	25.6
12. UPLCa-5(check)	-	14.6	19.9	19.7	18.1
13. SM577-8*	-	-	-	16.2	16.2
14. SM466-6*	-	-	-	32.3	32.3
15. CG90-4-1*	-	-	-	32.4	32.4
16. CG87-3-11*	-	-	-	29.0	29.0

** Approved by the National Seed Industry Council for release
* New entry for Regional Trial

4. Evaluation for tolerance to shade and red spider mites

Considering that large areas intended for cassava in Mindanao and the Visayas are presently under coconut, selection of cassava genotypes grown under this condition was undertaken to identify cassava genotypes that will tolerate partial shading. Results of the General Yield Yrial involving the introduced materials from the Thai-CIAT program are very promising (**Table 9**). Several hybrids had a superior performance under coconut compared to the check variety Lakan. Some of the superior clones are CMR33-13-11, OMR33-12-3, OMR33-12-7 and OMR33-05-2 having average yields of 24.2, 20.1, 20.0 and 17.1 t/ha, respectively. Aside from yield, the CIAT materials have high dry matter contents that are comparable and even higher than that of the check variety. It is expected that from this population improved and superior genotypes suited for growing under coconut will be identified.

The screening for tolerance to red spider mites involving locally developed hybrids tested in the Advanced Yield Trial has resulted in the identification of two clones that outyielded the check variety (**Table 10**). These clones are MOP24-2-13 and MOP24-2-40 with average yields of 12.5 and 12.7 t/ha, respectively. Generally, all selections have shown field resistance to mites. However, the yields obtained were not high because the plants were affected by a strong typhoon during their critical growth period. Several trials, both for shade and mite tolerance, are still on-going.

5. Varietal release

Regional trials conducted during the period 1993-1996 have resulted in the release of two new cassava varieties by the National Seed Industry Council (NSIC), formerly known as the Philippine Seed Board (PSB). The two varieties of CIAT origin are CM3419-2A released as PSB CV-11, and SM972-20 released as PSB CV-12. These two new varieties were selected by the breeding program of the Institute of Plant Breeding at the University of the Philippines at Los Baños from the materials introduced from CIAT/Colombia. Both varieties have a low level of HCN and can be used both for human food and feed. **Tables 8, 11** and **12** show the performance of these cultivars in the Regional Trial.

It is interesting to note that some progress has been made in the selection for high yield among high HCN entries. However, the selection for high dry matter content among these high HCN varieties has not yet produced positive results (**Figure 5**). On the other hand, for low HCN entries (such as the two released varieties), remarkable results have been obtained in the selection for high yield, and some progress has been made in selecting for high dry matter content (**Figure 6**).

6. Varietal dissemination

Nowadays, the quest for planting materials of high-yielding cassava varieties continues to rise. Expansion of production areas in Mindanao, specifically in Lanao and Bukidnon provinces is the outcome of the San Miguel Corporation's Agribusiness Divisions' campaign for production of cassava to satisfy their current demand. No less than 55,000 ha are needed by San Miguel to supply their needs for production of animal feeds, modified starch and alcohol. For the last two years, this company has supported 3,000 ha of cassava. Support given was in terms of planting material, land preparation and fertilizer inputs. Farmers are made to sign a contract with San Miguel stipulating that all their produce will be absorbed by the company at an assured market price. Lately San Miguel is buying cassava dried chips at P2.50 per kilo. For initial expansion, the readily available Golden Yellow variety was used by the farmers.

The need for cassava raw materials was also felt by the starch processors and other feed millers in Mindanao. As such, cassava became a high demand commodity.

Table 9. Yield parameters of ten cassava hybrids from the Thai-CIAT program evaluated in a General Yield Trial under coconut at PRCRTC in 1994/95.

Entry	Fresh root yield (t/ha)[1)]	Dry matter content (%)	Harvest index	HCN rating[2)]
CMR33-13-8	9.3	34.3	0.48	6
CMR33-13-10	13.8	31.7	0.53	6
CMR33-13-11	24.2	35.8	0.54	7
CMR33-13-14	14.3	34.5	0.52	5
OMR33-12-3	20.1	36.6	0.61	7
OMR33-12-7	20.0	37.4	0.60	6
OMR33-11-7	15.3	34.8	0.66	6
OMR33-62-9	14.1	34.9	0.63	6
OMR33-05-1	16.2	36.2	0.62	6
OMR33-05-2	17.1	35.8	0.60	7
Lakan(check)	16.3	35.8	0.49	5
VC-3(check)	16.4	32.6	0.54	6
Average	16.4	35.2	0.58	

[1)]Average over 3 replications
[2)]Based on picrate test rating scale of 1 to 9: 1=low, 9=high
***Source:** PRCRTC, 1996.*

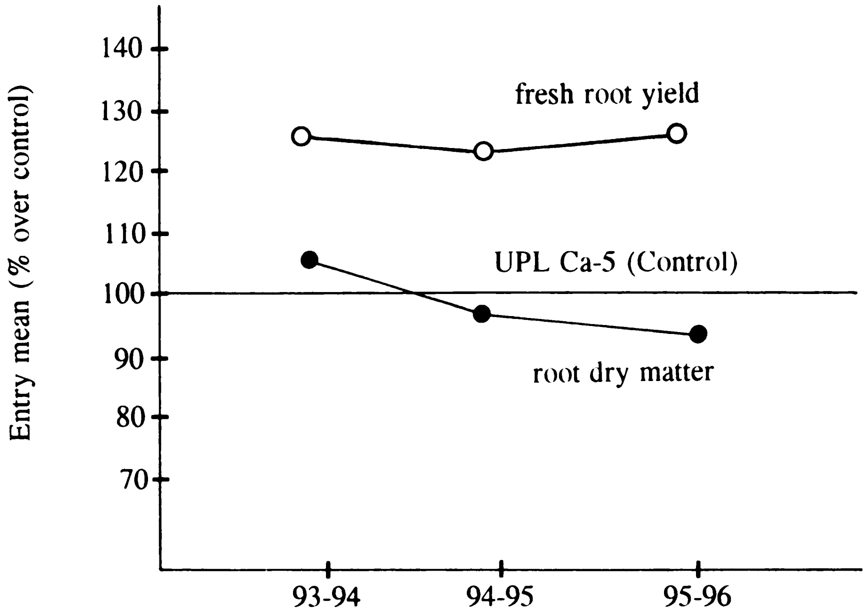

Figure 5. Change in mean frequency of all entries in Regional Yield Trials in terms of root yield and dry matter content of high-HCN cassava accessions.

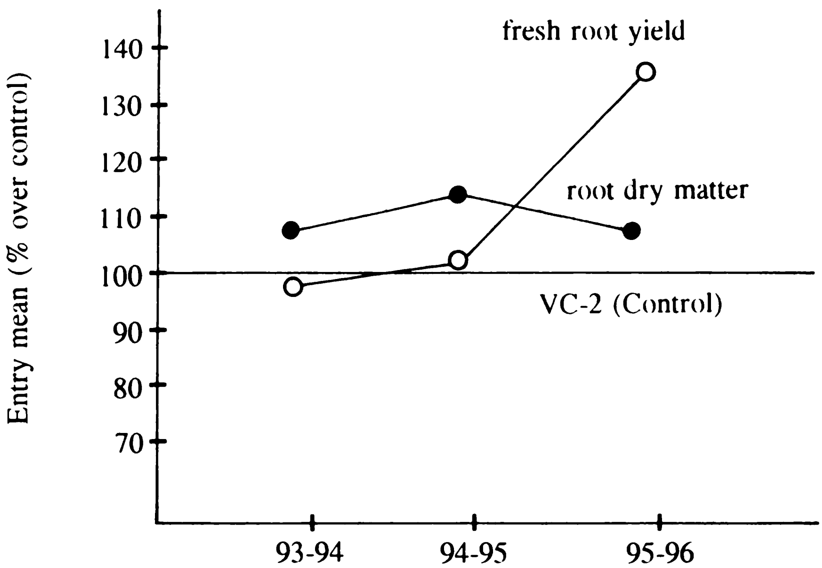

Figure 6. Change in mean frequency of all entries in Regional Yield Trials in terms of fresh root yield and dry matter content of low-HCN cassava accessions.

Table 10. Yield parameters of seven locally developed hybrids for mite resistance evaluated in the Advanced Yield Trial at PRCRTC in 1995/96.

Entry	Fresh root yield (t/ha)[1]	Dry matter content (%)	Harvest index	Mite reaction[2]
MOP24-2-34	9.3	36.2	0.42	R
MOP24-2-13	12.5	35.1	0.37	R
MOP24-2-19	9.0	35.1	0.42	R
MOP24-2-40	12.7	32.7	0.45	R
MOP24-2-8	7.4	39.4	0.48	R
MOP24-2-46	7.2	32.5	0.38	R
MOP24-2-4	8.4	38.1	0.49	R
Lakan(Check)	12.4	39.6	0.49	R
Avarage	9.8	35.6	0.38	

[1]/Average over 4 replications
[2]/R means resistant
Source: PRCRTC 1996

As far as varietal preference is concerned, feed millers prefer low-HCN varieties, while starch millers prefer high-HCN varieties. In effect, VC-5, which has high HCN is now planted in more than 3,000 ha in Lanao for starch production. Lakan, on the other hand, is now planted in more than 1,000 ha in Negros Occidental for starch production by Unistarch. Similarly, Lakan is also widely grown in Bohol to support Philstarch. With this development, farmers clamor for planting material of new high-yielding varieties. In their support, PRCRTC has undertaken several activities as follows:

Promotional trials

These trials are conducted in areas where cassava is a dominant crop. Farmers like to see for themselves the performance of new varieties before adopting them. Thus, promotional trials enable farmers to select which varieties they wish to plant.

A farmer in southern Leyte who supports a cooperative cassava-based feedmill-project participated in a promotional trial, which was established using four recommended varieties planted on big plots on sloping land. Vetiver grass was planted as contour hedgerows to reduce erosion. Results of the trial, which was jointly observed by farmers and researchers, were quite good (**Table 13**). VC-1 gave the highest yield of 34.0 t/ha. Farmers liked all of the varieties tested. In fact, all stakes were subsequently planted, resulting in a 40 ha expansion for the varieties tested. Presently, an On-farm Trial including several varieties is being conducted at Baloi, Lanao del Norte in cooperation with San Miguel Corporation. The varieties planted are: Rayong 60, Rayong 90, Rayong 5, KU-50, VC-1, VC-2, VC-3, VC-4, VC-5 and Lakan.

Establishment of Model Farms and Nurseries

To facilitate further distribution of new cassava varieties, PRCRTC initiated the establishment of one-hectare model farms in strategic locations in Mindanao where the bulk of cassava production is located. The model farms all intended to showcase the recommended varieties plus the necessary cultural management practices. These will also serve as the source of planting material for the farmers in the area. One model farm in Bukidnon, which was jointly supported by PRCRTC and San Miguel Corporation, produced yields of 40 t/ha.

Table 11. Summary data of the newly released cassava line CM 3419-2 and the check variety VC-2[1]

Parameters	CM3419-2 as PSB CV-11	Check VC-2
Average fresh root yield (t/ha)	25.5	25.0
Dry matter content(%)	30.2	32.1
Starch content(%)	16.4	19.0
HCN content	low	low
Reaction to pests and diseases:		
a. Red spider mite	HR	MR
b. CBB	HR	HR
c. Scale insects	HR	HR

[1]Average over 14 trials in 6 locations, 1991-1995.

Table 12. Summary data of the newly released cassava line SM 972-20 and the check variety VC-2[1)]

Parameters	SM972-20as PSB CV-12	Check VC-2
Average fresh root yield (t/ha)	23.0	21.4
Dry matter content(%)	33.9	32.1
Starch content(%)	21.5	19.6
HCN content	low	low
Reaction to pests and diseases:		
a. Red spider mite	HR	MR
b. CBB	HR	HR
c. Scale insects	MR	HR

[1)]Average over 11 trials in 6 locations, 1993-1996.

Table 13. Resuls[1)] of On-farm Trial of four cassava varieties planted on sloping land in Bontoc, southern Leyte, Philippines, in 1993/94.

Entry	Fresh root yield (t/ha)	Dry matter HCN content (%)rating[2)]
VC-1	34.0	33.26
VC-2	19.6	30.33
VC-3	25.6	27.03
Lakan	26.1	34.32
Average	26.3	31.2

[1)]Average over 4 replications, plot size 60 sq. meters
[2)]Based on picrate test rating scale of 1 to 9 : 1=low, 9=high
Source: PRCRTC, 1994.

Aside from the model farms, nurseries of the new cassava varieties are initiated under the management of farmers cooperatives. Planting material produced will be distributed to other farmers at cost.

Considering the urgency of the need for more planting material of improved varieties, the Agribusiness Division of San Miguel Corporation will adapt a rapid-propagation technique for multiplication of varieties supplied by PRCRTC. In this way a more rapid dissemination of new cassava varieties can be attained.

FUTURE PLANS

With the expansion of the area planted to cassava, PRCRTC will have to double its efforts to monitor the performance of cassava varieties planted in these plantations. The Center will also conduct intensive selection for superior varieties for the food, feed and alcohol industry.

The competitive advantage of cassava over other crops as raw material for domestic utilization is very high. Thus, in line with the Medium-Term Philippine Development Plan, priorities are geared toward domestic utilization of cassava. PRCRTC will cooperate in the effective transfer of mature technologies to cassava farmers and processors.

It is envisioned that in the next five years, average yields will increase and dissemination and adoption of new recommended varieties will have markedly increased.

Accordingly, the breeding objectives for cassava will remain the same, but more emphasis will be on the identification of superior varieties with high yield, high starch content and low to high HCN levels that will suit the various needs of the food, feed, flour and starch industries.

For effective technology transfer, closer cooperation among the government institutes, non-government organizations (NGOs) and the private sector will be sought.

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RECENT PROGRESS IN CASSAVA VARIETAL IMPROVEMENT IN INDONESIA

Soemarjo Poespodarsono[1]

ABSTRACT

In Indonesia, cassava is used mostly for human consumption, while a smaller part is used for animal feed and as raw material in industry. This crop is cultivated in almost all provinces of Indonesia. However, because the amount of rainfall among the regions varies and is not evenly distributed, some regions have a wet climate while others have a dry climate. The type of climate affects the suitability of a particular variety and its productivity.

The area planted to cassava in Indonesia is about 1.3 million ha producing approximately 16.3 million tons fresh cassava roots; this means that the average production per hectare is still low at about 12.2 t/ha. This low yield is due to the use of local varieties, traditional cropping patterns and simple cultural practices. According to the government, cassava production is projected to increase to about 16.5 million tons in the year 2000. This production can be achieved by intensifying the cultural practices as well as by the use of higher yielding cassava varieties, either sweet or bitter ones.

Up to now, a very limited number of high yielding varieties have been released, i.e. only ten new varieties from 1969 to 1990 for all cassava areas in Indonesia, compared to 74 rice, 28 maize, 25 soybean, and 5 sweet potato varieties. Some new cassava varieties were released, such as Adira 1 (sweet) and Adira 2 (bitter) in 1978, and Adira 4 (bitter) in 1986. In 1993 MARIF (Malang Research Institute for Food Crops) released two new varieties named Malang 1 (CM4049-2) and Malang 2 (CM4031-10).

Since 1984, Brawijaya University, in cooperation with CIAT, has been conducting cassava breeding. From F_1 cassava seed that had been provided, four promising clones were selected, i.e. UB 1/2 (CM3962-2), UB 15/10 (CM3380-10), UB 881-5 (SM881-5) and UB477-2 (SM477-2). Multi-location trials have been conducted several times with these clones, especially in East Java. Concerning governmental regulations about the realease of new varieties, one must conduct multi-locational trials of these promising lines or clones in at least five provinces. In 1995, those promising cassava clones were planted in East Java, Central Java, Lampung, North Sulawesi and Lombok. The result of these trials could suggest the release of these lines as new cassava varieties. From the results it was concluded that clones UB 1/2 and UB 15/10 (both bitter) are more suitable for regions with a wet climate, while clones UB 881-5 (bitter) and UB 477-2 (sweet) are more suitable for those with a dry climate.

INTRODUCTION

In Indonesia, cassava is cultivated in almost all provinces, particularly by small farmers but also by some large plantations. Recently, the cassava area has been approximately 1.33 million hectares, producing 16.3 million tons of fresh roots with an average yield of 12.2 t/ha (CBS, 1992). Most cassava produced by small farmers is used for food, either as occasional dishes or as a staple food; the rest is processed into dried root pieces (gaplek) or into starch. Cassava produced by big farmers or plantations is processed almost entirely into starch. Due to the usage of cassava roots mainly as human food, sweet varieties are needed for food or starch production, while bitter varieties can

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be used for production of dried roots, starch or animal feed. In general, cassava has a low social status, which is a factor that affects the price and government policy. According to government planning, the projected increase in cassava production during the next five years is only 0.17% per year, compared with 2.01% for rice, 3.77% for maize, 3.17% for soybean and 1.96 for sweet potato (NBP, 1993).

Cassava is planted in various types of soils and climates. Generally, the planting area of cassava consists of uplands, while a few areas are marginal land. As a result, cassava productivity and planting time depend on rainfall and its distribution. Based on Oldeman's climatic classification, climate types A up to type E are found in Indonesia. According to these climate types, Indonesia is generally divided into two main regions: one having a wet climate (A and B types) and another having a dry climate (C, D and E types). Roughly, the wet climate is found in the western and northern part and the dry climate in the southeastern part of Indonesia, including most of East Java. In the wet region cassava can be planted at any time of the year, but this is not the case in the drier regions, where cassava is planted at the beginning of the wet season. This affects the availability of cassava roots as raw material for the starch industry. Since cassava can be planted throughout the year in Sumatra most of the large cassava plantations are found there. Rainfall distribution also determines the yield of cassava (Wargiono, 1990).

Up to now farmers still plant many local varieties. These varieties are well adapted to the local environment, but they generally have a low starch content. On the other hand, a limited number of high-yielding varieties have been released, but not all of these were distributed to farmers. From 1969 to 1993 only ten new cassava varieties have been released, compared with 74 varieties of rice, 28 of maize, 21 of soybean and 5 of sweet potato (Baihaki, 1996). Two cassava varieties, i.e. Adira 1 (sweet) and Adira 2 (bitter), were released in 1978. Adira 4 (another bitter variety) was released in 1986 and is now widely grown. In 1993, MARIF (Malang Research Institute for Food Crops), now renamed as RILET (Research Institute for Legumes and Tuber Crops) released another two varieties, i.e. Malang 1 (CM4049-2) and Malang 2 (CM4031-10).

Considering that a wide range of ecological conditions exist in Indonesia, there is a need for many high-yielding varieties that are adapted to special local environments. That is why Indonesia needs more than one institution for handling the cassava breeding program.

CASSAVA BREEDING IN INDONESIA

Cassava breeding and the release of new varieties dates back to Dutch colonial times. During that era, some high-yielding varieties were probably released since many local varieties still have Dutch names, such as Faroka and Vandrum. These varieties, as well as others released at that time, are bitter varieties and were cultivated in areas surrounding starch factories. Sweet varieties were planted mainly near the farmers' homes.

Since 1984, Brawijaya University has been involved in cassava breeding, along with the Research Institutes for Food Crops in Bogor and Malang, and in close collaboration with CIAT. At the same time, CIAT also cooperated with private institutions such as the Umas Jaya Farm, which is located in Lampung province of Sumatra. Thus, cassava breeding is conducted in the two main regions, namely the wet region, represented by Bogor (West Java) and the Umas Jaya Farm, and the dry region, represented by Malang in East Java. It is expected that several high-yielding varieties will be released in the future, with each one adapted to a given environment.

The main objective of the cassava breeding program in Indonesia is to produce both sweet and bitter cassava varieties with the following characteristics:

1. High root yield
2. High harvest index
3. High root starch content
4. Tolerance to major pests and diseases
5. Non-branching growth habit
6. Good root shape

High root yield has the highest priority. Because many farmers are using high inputs, so they expect a variety to respond well to fertilizers and to good management. A high harvest index is needed in order to minimize total nutrient uptake and prevent nutrient exhaustion of poor upland soils. Varieties with high root starch content are preferred by farmers and cassava plantations, because the price of cassava is calculated from its starch content. Since most farmers do not control pests and diseases they need varieties that are tolerant to the major pests and diseases. A non-branching growth habit is preferred by farmers, because cassava is often intercropped with other annual crops; non-branching varieties cause less competition to those intercrops. The last characteristic, i.e. good root shape, is of particular interest to large cassava plantations, because it facilitates the harvest.

Besides the general objectives mentioned above, there are also more specific objectives which aim to solve various adverse conditions. The specific objectives are:

1. Tolerance to certain adverse soil and climatic conditions
2. Early harvestability

As mentioned before, cassava is mainly planted in uplands having different soil and climatic conditions, including some adverse conditions, such as long dry seasons or high levels of soil acidity; so, in order to obtain relatively high yields, varieties well adapted to those conditions are needed. A variety with early harvestability aims to spread the time of harvest, particularly to allow small farmers to increase their income.

Breeding Activities

Cassava breeding activities at Brawijaya University start with single plant selections from F_1 seeds. Initially these seeds were introduced only from CIAT/Colombia and about 2,000-3,000 seeds were sent each year. Since 1993/94, however, also F_1 seeds from the Thai-CIAT program, with clone codes of OMR or CMR, have been received.

At the start, each seed is germinated in polybags and after 2-3 months the seedling are transplanted to the experimental field. At harvest time about 10-20% of plants are selected, based on root size and shape as well as other morphological characteristics. The second generation is planted in a Single Row Trial with stakes from each selected clone, generally five stakes for one row of each line and with two rows of control varieties, i.e. Adira 4 (a national high-yielding variety) and Faroka (a local variety). These two control varieties are used for all stages of selection. The selection criterion for this second step is that selected clones must yield higher than or equal to the control varieties. This criterion is similar to that used in the third generation, i.e. the Unreplicated Yield Trial, in which each line is planted in a single plot. The next selection step is called the Advanced Yield Trial, which uses a randomized block design with three replications. In this generation, usually 15-20 clones are selected. Fresh root yield, root dry matter content (RDMC), biomass and harvest index are determined at harvest time. Usually, from these trials, sufficient planting material is obtained for planting in three sites of the Multi-location Trial.

In this paper, the results of these Multi-location Trials, conducted in Jatikerto (Central Malang), in Kalipare (South Malang) and in Tarokan (Kediri), are presented in **Tables 1, 2** and **3**, respectively. All these sites are located in East Java.

Table 1. Results of a Multi-location Trial conducted at Jatikerto Experiment Station in Malang, East Java, Indonesia in 1994/95.

Clones	Parents	Fresh root yield (t/ha)	RDMC (%)	Total biomass (t/ha)	Harvest index
OMR33-05-4	CMC76	37.2	33.1	46.7	0.80
OMR33-10-3	Rayong 5	30.0	34.8	50.7	0.54
OMR33-10-8	Rayong 5	33.0	34.8	57.7	0.57
CMR33-56-5	-	27.4	35.7	41.6	0.65
OMR33-10-11	Rayong 5	37.0	32.4	56.7	0.65
CMR33-12-14	CMR26-14-9xR90	30.3	34.0	46.3	0.65
CMR33-52-9	CMR26-14-9xR90	29.8	35.5	38.8	0.77
CMR33-56-8	CMR26-14-9xR90	25.7	34.4	34.3	0.75
CMR33-52-8	CMR26-11-9xR90	21.3	34.7	30.2	0.71
Adira 4(control)		25.4	34.0	38.6	0.66
Faroka (control)		34.6	33.6	49.1	0.70

Table 2. Results of a Multi-location Trial conducted in Kalipare in South Malang, East Java, Indonesia in 1994/95.

Clones	Parents	Fresh root yield (t/ha)	RDMC[1/] (%)	Total biomass (t/ha)	Harvest index
OMR33-05-4	CMC76	24.0	33.5	36.8	0.65
OMR33-10-3	Rayong 5	24.9	33.4	36.7	0.68
OMR33-10-8	Rayong 5	23.1	32.6	36.3	0.64
CMR33-56-5	-	21.5	35.6	32.8	0.66
OMR33-10-11	Rayong 5	25.5	32.1	36.6	0.64
CMR33-12-14	CMR26-14-9xR90	20.5	34.7	31.7	0.65
CMR33-52-9	CMR26-14-9xR90	20.1	34.9	30.9	0.65
CMR33-56-8	CMR26-14-9xR90	30.7	35.0	33.0	0.63
CMR33-52-8	CMR26-11-9xR90	19.2	34.5	29.0	0.66
Adira 4(control)		24.4	35.7	38.5	0.63

[1/] RDMC = root dry matter content

Table 3. Results of a Multi-location Trial conducted at Tarokan in Kedire, East Java, Indonesia in 1994/95.

Clones	Parents	Fresh root yield (t/ha)	RDMC[1/] (%)	Total biomass (t/ha)	Harvest index
OMR33-05-4	CMC76	23.5	32.6	34.1	0.69
OMR33-10-3	Rayong 5	24.1	31.3	33.9	0.71
OMR33-10-8	Rayong 5	24.1	31.2	37.4	0.64
CMR33-56-5	-	19.8	35.0	29.8	0.66
OMR33-10-11	Rayong 5	21.2	31.4	33.5	0.63
CMR33-12-14	CMR26-14-9xR90	18.9	34.5	28.1	0.67
CMR33-52-9	CMR26-14-9xR90	17.7	34.9	26.0	0.68
CMR33-56-8	CMR26-14-9xR90	15.1	35.2	22.0	0.69
CMR33-52-8	CMR26-11-9xR90	13.2	34.8	21.1	0.66
Adira 4(control)		25.3	34.8	37.7	0.67

[1/] RDMC = root dry matter content

Among these three locations, the soil and rainfall conditions of Jatikerto are better than those of Kalipare and Tarokan. This affects the performance of the selected clones. From these tables it is clear that OMR33-05-4 produced a high root yield and had a relatively high RDMC and harvest index. But OMR33-10-3 seems to be more suitable for poor conditions, such as in Kalipare and Tarokan.

Similar previous trials have produced several highly promising clones, such as UB 1/2 (CM3962-2, a selection from a cross of MCol 22 with CM849-1), UB 15/10 (CM3380-10, a selection from a cross of CM568-1 with CM523-7), UB 881-5 (SM881-5, selected from open-pollinated seeds of CM849-1) and UB 477-2 (SM479-2, selected from open-pollinated seeds of CM1022-4). According to government regulations, promising lines or clones can be released as new varieties only if they have been tested in at least five provinces (Multi-provincial Trials). Therefore, these highly promising clones have also been tested for this purpose in Lampung (Sumatra), Central Java, East Java, North Sulawesi, and Lombok. These trials have been harvested in early 1996, the result of which are presented in **Table 4**. It seems that UB 1/2 (CM3962-2) and UB 15/10 (CM3380-10) produced high fresh root yields in most sites. In Central Java all clones had relatively low yields, because cassava was intercropped with rice and maize, followed by mungbean. From these results, the two promising clones, UB 1/2 and UB 15/10, will be suggested to the Indonesian government for release as new cassava varieties.

Table 4. Results of Multi-provincial Trials conducted in Lampung, Central Java, East Java, Lombok and North Sulawesi in 1995/96.

	Fresh root yield (t/ha)					
Clones	Lampung	Central Java	East Java	Lombok	North Sulawesi	Average
UB 1/2	33.3	22.6	23.7	37.5	46.2	32.7
UB 15/10	32.9	25.5	31.8	34.0	25.5	29.9
Kasetsart 50	31.9	-	-	-	-	-
UB 477-2	20.9	22.8	27.6	33.6	34.0	27.8
UB 881-5	18.0	21.4	29.1	29.6	29.5	25.5
UB 1-2/15	-	23.3	-	20.5	20.9	21.6
UB 1-2/20	24.6	-	32.1	31.4	32.7	30.2
CMR33-10/3	28.3	-	-	-	-	-
OMR30-10-11	-	-	19.9	-	-	-
Adira 1	-	17.2	-	-	21.1	19.1
Adira 4	29.9	-	25.6	23.1	22.1	25.2
Malang 1	23.5	21.8	28.3	23.2	22.9	23.9
Malang 2	-	-	-	25.1	24.5	24.8

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CASSAVA VARIETAL IMPROVEMENT PROGRAM AT UMAS JAYA FARM AND ITS CONTRIBUTION TO SMALL FARMER COMMUNITIES IN SUMATRA, INDONESIA

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ABSTRACT

A three-way collaboration in cassava varietal improvement and dissemination was established in 1982, in which a development-oriented private corporation (Umas Jaya Farm in Lampung, Sumatra of Great Giant Pineapple Coy of Gunung Sewu Group) provided ample facilities for varietal selection, multiplication and dissemination to a resource-limited national cassava breeding program (CRIFC), while an international organization (CIAT) contributed the basic training of research personnel and additional breeding materials. The program continued even after the CRIFC breeder left for abroad in 1989. This program is now regarded to be the best functioning cassava varietal development program in Indonesia. We selected a clone with distinctly high yield and root starch content from the original CRIFC breeding stocks, multiplied it and released it. We donated the planting stakes of this cultivar to many small farmers' cooperatives and shipped out millions of stakes to large plantations in and outside Sumatra. This new clone is now widely known as M-31 in the production fields and Adira 4 in the official registration. The economic benefit generated by the new cultivar started with the additional root harvests and additional starch produced within UJF, but it soon spread into the production fields of thousands of small farmers. Hard data, and a few extrapolations from these, indicate that Adira 4 is now planted in more than 100,000 ha and the additional economic effects caused by its adoption is more than 194 million US dollars, of which at least one half has directly entered the household income of innumerable small farmers.

We continued selections based on CIAT materials and are identifying new clones that are better than Adira 4. From this work, two new cultivars, Malang 1 and Malang 2, were officially released recently and one clone, Kasetsart 50, is being pre-released. Our collaborative program offers an example that the private sector can efficiently and effectively handle cassava varietal development, especially the multiplication and dissemination, when government research and extension institutions cannot afford a functional research and dissemination program.

INTRODUCTION

Cassava has been a traditional food crop in the upland farming areas of Indonesia and its role, especially as a famine relief crop, should not be underestimated. Yet, with the continuous improvement of the diet of the rural population, especially through the increased availability of rice, the form of cassava utilization has been shifting steadily from fresh human consumption to processed foods, animal feed and industrial starch. While the importance of cassava for direct human consumption is gradually decreasing, its role as a major source of cash income for small farmers and as raw material for agro-industry is rapidly increasing. Several large-scale cassava starch processing plants have been established in southern Sumatra province of Lampung during the past fifteen years, in order to supply starch to the national food industry utilizing existing small farmers'

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production, as well as that of the large areas of previously under-utilized land now used for cassava plantations.

This is in accordance with the national policy of establishing agro-industries and creating employment using under-utilized lands on the outer islands. Umas Jaya Farm (UJF) was a pioneer of such enterprises, starting as a cassava production and starch processing plantation. We established a collaborative cassava varietal development program at UJF in 1982 and the initial development was highly successful. At the 3rd Asian Cassava Research Workshop in 1990, we reported this initial success and concluded the presentation by stating "How much of this success is going to be extended to the mass of small farm communities is yet to be seen" (Hardono *et al.*, 1992). Six years later, we therefore report how the initial technical success has been transferred and spread into the multitude of small farmers in Sumatra of Indonesia.

Umas Jaya Farm

A license to lease 13,000 ha of underutilized land located at Terbanggi Besar, Lampung, Sumatra, was conceded by the Indonesian government to the Gunung Sewu Group with the condition of developing the area for value-added agro-industrial production. Cassava roots produced in their plantation and the starch processed from these in their own factory were the major activities during the early years. The major operation has gradually shifted to the production and canning of pineapple, which proved to be more profitable for UJF. The pineapple operation, called Great Giant Pineapple Company, now employs more than 10,000 workers.

The UJF planted cassava annually at their own plantation in areas between 0 and 3,000 ha during the past 15 years; presently, it is no longer planting cassava within the UJF plantation, as the company has moved cassava production to their new satellite operations outside UJF. The starch processing plant of UJF, which was processing only the cassava roots produced in UJF in the early years, is now processing roots that are nearly 100% produced by small farmers outside UJF. The capacity of the starch factory is being upgraded to absorb more cassava produced by small farmers outside.

Thus, the production of fresh cassava roots has shifted to the hands of small farmers while UJF has shifted their emphasis of operation to factory processing during the past 15 years. This is a general pattern in all of Lampung where more than 20 large-scale cassava starch factories are in operation.

UJF has invested heavily, not only in the factories and production fields, but also to improve the local infrastructure like roads, housing for 8,000 laborers, electricity, water supply, schools, clinics, mosques, grocery shops, cafeterias, sport and entertainment facilities, and last but not least, research facilities. UJF now maintains one of the best managed field experimental plots in Indonesia, which are basically open to national research organizations. The University of Lampung, the Agricultural University of Bogor (IPB), the Technical University of Bandung (ITB), and Brawijaya University, among others, have been using the UJF field for their research. While establishing a commercially viable agro-industrial business is the principal goal of the UJF/GGPC operation, rural development and better social welfare are equally important long-term objectives.

Three Way Cooperation

During the 1970s, a modest root crop research program of the Bogor Research Institute for Food Crops (BORIF) under the Central Research Institute of Food Crops (CRIFC), was the only institution where research on cassava varietal improvement was conducted. Based on the national cassava germplasm collection, small-scale hybridization and selection at Bogor produced a series of improved hybrid clones. While there was a certain progress in their breeding work, their success was largely limited to the small scale dual purpose production of West Java. BORIF/CRIFC did not have sufficient resources to evaluate the advanced breeding materials for large-scale industrial production multi-locationally or to multiply planting stakes on a large scale.

We established a three-way collaboration in cassava varietal improvement and dissemination at UJF in 1982, in which UJF provided ample facilities for varietal selection, multiplication and dissemination to the BORIF/CRIFC cassava program, while CIAT contributed the basic training of research personnel and additional breeding materials. Both the breeder of the BORIF program (Roberto Soenarjo) and the UJF research and development manager (Hardono Nugroho) in the initial years of the collaborative program, had been participants in a CIAT Cassava Training Course in Cali, Colombia. From 1983, advanced breeding materials in the form of hybrid seeds have been introduced to BORIF from CIAT/Colombia and since 1985 from the Thai-CIAT program. These have been evaluated and selected jointly by the three parties at Umas Jaya Farm. Multi-location evaluations of the most advanced materials have also been conducted jointly. It was a new experience for the national program breeder to be able to evaluate his breeding materials without worrying about the size of experimental plots, availability of field labor or other expenses. The collaborative program continued even after the BORIF breeder left for abroad in 1989 and the program is now regarded as the best functioning cassava varietal development program in Indonesia.

Selection of M-31 (Adira 4)

A clone identified as M-31 was one of the breeding materials produced at BORIF that was taken to UJF for large-scale evaluations. At the second cycle of evaluation, it became clear that M-31 was outstanding, not only among the 40 clones brought from Bogor, but also in comparison with the then leading traditional cultivar of the plantation and the region, Kretek (**Table 1**). M-31 possessed high yielding capacity, high root dry matter content, and a good combination of vigorous vegetative growth with comparatively high harvest index; it also had a good plant type, and uniform and well-shaped roots with white root flesh color, an important trait for starch production.

By 1986, the official release of M-31 was recommended at BORIF and the name Adira 4 was given. Adira 4 showed its superior capacity for large-scale industrial starch production, giving a yield up to 80% higher than Kretek (**Table 2**); moreover, the adaptability of Adira 4 to drier climates of Central and East Java was also confirmed. By 1988, large quantities of planting stakes of Adira 4 were available for distribution outside the UJF plantation.

Varietal Dissemination

We started the distribution of Adira 4 planting stakes in 1987 by donating packages of long stakes (2500 long stakes each) to 40 cooperatives of small farmers in Lampung. This activity of giving the stakes of improved cultivars to any interested small farmer community continues up to the present. A massive distribution followed in 1988 and 1989. A total of approximately 6 million long stakes, enough to plant more than 3,000 ha, have been sold at a nominal price to large-scale plantations in Lampung, South Sumatra, West Sumatra and Palembang, and to extension units in South Sulawesi, South Kalimantan, and West-, Central-, and East Java. The area planted with Adira 4 is now estimated to be more than 100,000 ha in Lampung province alone (**Tables 2** and **3**; **Figure 1**). Adira 4 is still widely known as M-31, the UJF code name, in Lampung rather than as Adira 4, the BORIF/CRIFC official name. Since Adira 4 has spread to other provinces of Sumatra, as well as to other outer islands, the total Adira 4 acreage may now be much more than these figures.

The large-scale adoption of Adira 4 caused substantial economic gains first to the large plantations and factories; yet, it is now resulting in wide-spread economic benefits to tens of thousands of small farmers. We shall analyze these effect more in detail in the subsequent sections.

Analysis of Economic Benefits

1. Production data used

We used the sales value of the products as the basis for measuring economic effects. Value of sales includes production costs and net profits. The gross production costs are made up of expenditures for labor, equipment, supplies, maintenance, and depreciation. At the company management level, net profit rather than the value of sales may be more critical. However, in the national development context, value of sales may be a more important indicator of the socio-economic benefits, as it represents employment, purchasing power and the availability of useful products.

Table 1. Yield performance of three cassava cultivars at Umas Jaya Farm, Lampung, Sumatra.

Trial	Years	No. trials	Kretek (Traditional)			Adira 4			Kasetsart 50		
			FRY[1)]	SC[2)]	SY[3)]	FRY	SC	SY	FRY	SC	SY
Advanced	'83-'89	6	27.6	15.6	4.3	35.2	22.6	8.0			
Advanced	'89-'95	6	22.5	19.8	4.5	31.6	25.7	8.1	37.2	26.4	9.8
100 ha	'86/'87	1	20.2	18.1	3.7	28.7	23.4	6.7			

[1)]FRY=Fresh root yield (t/ha)
[2)]SC=Root starch content (% by Reihmann scale)
[3)]SY=Starch yield (t/ha)

Table 2. Cassava root and starch productions with cultivar Adira 4 and the additional economic value resulting from the adoption of Adira 4 at Umas Jaya Farm from 1985 to 1996.

Year	Area planted with Adira 4	Fresh root production ('000 t)	Additional production due to adoption of Adira 4 ('000 t)[1]	Additional fresh root value due to adoption of Adira 4 ('000 $)[2]	Additional starch production due to adoption of Adira 4 ('000 t)[3]	Additional starch value due to adoption of Adira 4 ('000 $)[4]	Additional total value due to adoption of Adira 4 ('000 $)
1985/86	50	1.44	0.43	10.8	0.08	14.4	25.2
86/87	250	7.18	2.13	53.3	0.38	68.4	121.7
87/88	1,200	34.4	10.20	255.0	1.82	327.6	582.6
88/89	3,000	86.1	25.50	637.5	4.56	820.8	1,458.3
89/90	3,000	86.1	25.50	637.5	5.09	916.2	1,553.7
90/91	0	0	0	0	0	0	0
91/92	25	0.72	0.22	7.7	0.04	8.0	15.7
92/93	2,300	66.0	19.55	684.3	3.50	700.0	1,384.3
93/94	2,100	60.3	17.85	624.8	3.20	640.0	1,264.8
94/95	2,600	74.6	22.10	773.5	3.95	948.0	1,721.5
95/96	550	15.8	4.68	163.8	0.84	201.6	365.4
96/97	0	0	0	0	0	0	0
Total			128.16	3,848.2	23.47	4,645.0	8,493.2

[1]Based on 8.5 t/ha yield difference of Adira 4 over the traditional cultivar Kretek.
[2]Based on $ 25/t for 1985-1991 and $ 35/t for 1992-1996.
[3]Based on 5.30% over Kretek.
[4]Based on $ 180/t for 1985-1990, $ 200/t for 1991-1994, and $ 240/t starch for 1995-1996.

Table 3. Estimation of root and starch productions with cultivar Adira 4 and the additional economic value resulting from the adoption of Adira 4 in Lampung province, Sumatra from 1985 to 1996.

Year	Total cassava area ('0000ha)	Area planted with adira 4 (%)	Area under other cultivars (%)	Total area under new cultivars (%)	Total area under new cultivars ('000ha)	Extra root production by new cultivars ('000 ha)[1]	Farmers' additional root sale due to varietal adoption ('000 $)[2]	Extra starch production due to higher starch content of new cultivars ('000 t)[3]	Factories additional starch sale due to higher starch content ('000 $)[4]	Total gross additional sales due to adoption of new cultivars ('000 $)
1985/86	68.2	0.1	-	0.1	0.05	0.43	10.8	0.08	14.4	252
86/87	78.0	0.3	-	0.3	0.25	2.13	53.3	0.38	68.4	1217
87/88	150.3	0.8	-	0.8	1.2	10.2	255.0	1.8	324.0	5790
88/89	162.3	2.1	-	2.1	3.5	29.8	745.0	5.3	954.0	1,6990
89/90	135.2	4.0	-	4.0	5.4	45.9	1,147.5	8.1	1,620.0	2,7675
90/91	138.8	8.2	-	8.2	11.4	96.9	2,422.5	17.1	3,420.0	5,8425
91/92	148.3	15.2	-	15.2	22.5	171.0	5,985.0	33.8	6,760.0	12,7450
92/93	136.1	27.5	0.1	27.6	37.6	285.8	10,003.0	56.4	11,280.0	21,2830
93/94	127.1	38.0	0.2	38.2	48.6	369.4	12,929.0	72.9	14,580.0	27,5090
94/95	146.6	51.2	0.2	51.4	75.4	573.0	20,055.0	113.1	27,144.0	47,1990
95/96	183.2	64.2	0.3	64.5	118.1	897.6	31,416.0	177.2	42,528.0	73,9440
Total						2,482.2	85,022.1	486.2	108,692.8	193,7149

[1]Based on 8.5 t/ha for 1986-91 and 7.6 t/ha for 1992-96 yield difference of new cultivars over the traditional cultivar Kretek.
[2]Based on $ 25/t for 1985-1991 and $ 35/t for 1992-1996.
[3]Based on 5.30% over Kretek.
[4]Based on $ 180/t for 1985-1990, $ 200/t for 1991-1994 and $ 240/t starch for 1995-1996.

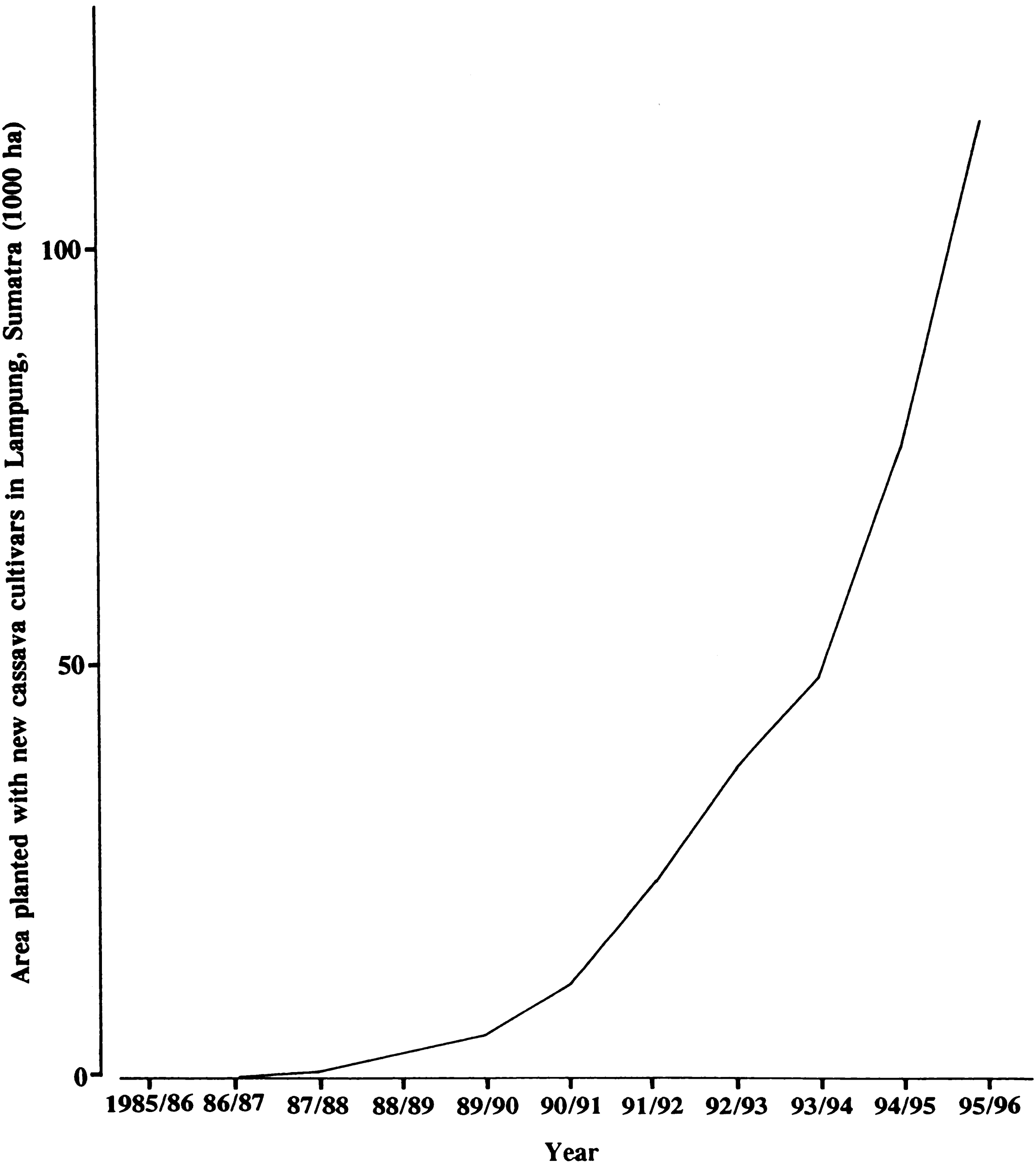

Figure 1. Area planted with new cassava cultivars (mostly Adira 4) in Lampung, Sumatra, Indonesia from 1985 to 1996.

To concentrate on the most direct monetary effects and avoid possible duplicates and exaggerations, we used only two measures for the economic gain: additional field production of fresh cassava roots due to the higher yield of Adira 4, and additional factory starch production due to the higher starch content of Adira 4. The additional factory profit generated by the gross additional availability of raw materials is not accounted for, let alone the additional production of numerous secondary products. Thus, the real gross additional economic effects are much more than described in this simple analysis.

The following hard data were available:

1. Area planted with Adira 4 within the UJF campus (**Table 2**).
2. Yield and starch content data from numerous trials as well as from large commercial plots (**Table 1**).
3. UJF survey on cassava planting at 62 municipalities in three regions of Lampung province during every month from Feb to Sept 1995.
4. Data about cassava acreage in Lampung province from 1985 to 1994 supplied by the Agriculture Department of Food Crops of Lampung province.
5. On-farm price of fresh cassava roots and starch price for the factory from 1985 to 1996. We used the low price in each 2-5 year period for the analyses.

We used the following information as semi-hard data:

6. UJF estimates of the percentage of total area planted to Adira 4 in three regions of Lampung.

2. Economic effects within UJF

The first analysis is on the additional monetary gain within the UJF campus in the past ten years (**Table 2**). This is strictly based on hard data, and probably the most reliable economic analysis of this kind, even though the scope is limited to a relatively small, closed scheme. The new cultivar has been planted in between 0 and 3000 ha depending on years; it produced an additional 128,000 tons of fresh cassava and 23,000 tons of starch, which led to the additional values of US$ 3.8 million and US$ 4.6 million, respectively, or a total of US$ 8.5 million. This analysis is well in line with the observations of the last author. The sales value includes a considerable proportion of production costs; thus, the net profit to the company is smaller than the values presented above. Nevertheless, it leaves little doubt that the new cultivar has brought in a profit vastly and positively disproportional to the research investment.

Economic effects in Lampung province

Our field survey estimates the proportion of Adira 4 in the total cassava planted area to be 75% in North Lampung, where UJF is located, 60% in Central Lampung, and

25% in South Lampung. More than 90% of the cassava roots brought by small farmers to the UJF factory are of Adira 4. In North Lampung, nearly all of the cassava planted near large starch factories are Adira 4. There are 21 large starch factories in Lampung. Thus, the projection above may be a reasonable estimate. Extrapolating from data sources 3, 4 and 6 mentioned above, the total area of Adira 4 is estimated to be presently about 118,000 ha in Lampung (**Table 3, Figure 1**). The total additional money received by the producers for the additional fresh root yield due to the adoption of Adira 4 is estimated to be US$ 85 million (**Table 3**). The total additional starch value generated by the higher starch content of Adira 4 is estimated to be US$ 109 million (**Table 3**). As of now, monetary benefits generated through the improved starch content of the new variety are even greater than that generated by the higher fresh root yield of the new variety (**Figure 2**). Yet, the total economic effects of US$ 194 million is the figure for Lampung province alone. The total effects for all over Indonesia must be significantly larger than this.

4. Estimating direct economic effects to small farmers

Since the great majority of the fresh root producers are now small farmers, we can happily and safely assume that the US$ 85 million additional profit for the higher fresh root production went directly to the pockets of small farmers in its near entirety. How much of the additional profit generated by the higher starch content of the new cultivar was returned to the farmers depends on what differential price the starch factory pays to the farmers. If the factory pays the same price for roots of different starch content (in other words, does not honor or recognize the breeders' and farmers' efforts to produce higher quality products), all the additional profit would be pocketed by the factory. At UJF, the factory is paying differential prices to the farmers; thus, a significant portion of the profit resulting from the higher starch content is being returned to the small farmers. Yet, there are many , mostly small, factories which do not yet pay according to starch content. Under any circumstances, larger operators have more access to larger profit making opportunities. Yet, in cassava as a cash crop for small farmers, a significant portion of the profit generated by new varieties is surely going directly to the multitude of small farm families.

Further Progress in Varietal Selection

Varietal selection continues and lines CM4049-2 and CM4031-10 were selected from the hybrid seed introductions from CIAT/Colombia. Through the CRIFC varietal naming and release scheme, the Research Institute for Legumes and Tuber Crops (RILET), located in Malang, East Java, and functioning under CRIFC, named them Malang 1 and Malang 2, respectively. These are equally high yielding as Adira 4 but not significantly superior. UJF did not multiply them in a big manner. They are now still planted in only small areas here and there. Kasetsart 50, a clonal introduction from

Thailand, showed excellent results (**Table 1**) and is currently being multiplied by UJF for planting in other sites outside UJF and for distribution to interested farmers.

Several new selections are passing through the breeding pipeline (**Tables 4** and **5**) and they may eventually prove superior to Kasetsart 50. While Kasetsart 50 has become a universal standard of selection in many parts of Asia, no breeding program outside Thailand has produced yet anything clearly superior to Kasetsart 50. Our selection at UJF may be the next program to attain this honor. Aside from the two highly functional cassava breeding programs in Thailand, one at Rayong Field Crop Research Center and the other at the site of the Thai Tapioca Development Institute conducted by Kasetsart University, our program at UJF may be the best functioning cassava breeding program in Asia.

Pineapple replaced cassava as the most profitable crop at UJF and we may discontinue large scale cassava plantings within UJF. If we view the on-going cassava breeding program at UJF as a short-term money making scheme, it might have accomplished very profitable functions already. On the other hand, since long-term contribution to the welfare of local communities is one of the important objectives of the UJF operation, we may continue the program. After all, this is virtually the only cassava varietal improvement and dissemination program that is producing results in Indonesia at present. CIAT collaboration here will continue as long as the opportunity for selecting superior genotypes for small farmers exists.

CONCLUSIONS

Our thirteen years of collaboration offers the following clear messages:

1. Indisputable success of cassava varietal improvement and dissemination took place through a private corporation (UJF), which fully utilized the materials and expertise offered by an international research organization (CIAT), i.e. breeding materials, training and technical guidance.
2. The contribution of varietal improvement can be quantitatively measured in terms of additional income generated to small farmers. A hundred million US dollars shared by hundreds of thousands of poor farmers as additional income has quite different social effects compared with the same amount of money made by a multi-national conglomerate.
3. Cassava varietal improvement proves to be one sure vehicle with which to improve the plight of small farmers.
4. The private sector can efficiently and effectively handle cassava varietal development, especially the multiplication and dissemination, when government research and extension institutions need additional research and dissemination capabilities.

Table 4. Results of an Advanced Yield Trial at Umas Jaya Farm, Lampung, Sumatra in 1994/95.

Clone	Parents	Dry root yield (t/ha)	Fresh root yield (t/ha)	Root dry matter content (%)	Total biomass yield (t/ha)	Harvest index
SM1650-2	CM3306-4	15.9	41.5	38.4	66.6	0.62
Malang 1	CM1015-19 x CM849-1	14.4	41.7	34.5	69.5	0.60
Kasetsart 50	R1 x R90	14.3	38.9	36.8	80.6	0.48
Rayong 90	CMC76 x V43	13.9	39.3	35.5	70.1	0.56
CMR30-56-1	CMR23-17-251 x R1	13.6	36.5	37.2	57.2	0.63
Mean of all 22 entries		11.2	30.8	36.3	55.0	0.56
Adira 4 (control)=BORIF 528		13.5	36.9	36.6	68.5	0.54
Kretek (local control)		10.1	33.5	30.0	71.5	0.47

Table 5. Results of a Preliminary Yield Trial at Umas Jaya Farm, Lampung, Sumatra in 1994/95.

Clone	Parents	Dry root yield (t/ha)	Fresh root yield (t/ha)	Root dry matter content (%)	Total biomass yield (t/ha)	Harvest index
Thai-CIAT clones						
CMR35-42-4	CMR29-60-15 x KU50	18.5	48.0	38.6	90.8	0.53
CMR35-20-1	R5 x CMR28-72-131	18.0	50.0	36.0	76.6	0.65
CMR35-118-7	R60 x CMR28-72-131	17.0	46.2	36.8	72.4	0.64
OMR35-30-3	OMR29-20-118	15.1	42.3	35.7	89.5	0.47
CMR35-110-3	R1 x R90	13.7	42.2	32.5	71.1	0.59
Mean of all 14 entries		12.7	34.9	36.5	64.8	0.54
CIAT/Colombia clones						
SM1812-6	SG804-5	20.0	52.8	37.8	92.1	0.57
SM1853-2	CG1141-1	17.2	50.0	34.4	81.8	0.61
SM1778-2	CG1320-10	16.3	42.7	38.3	77.0	0.55
SM1879-1	MPar 159	16.3	46.9	34.8	76.2	0.62
SM1787-1	HMC-1	15.6	46.7	33.5	88.5	0.53
Mean of all 20 entries		12.3	36.1	34.1	66.7	0.54
Adira 4 (control)=BORIF 528		13.1	35.9	36.5	67.8	0.53

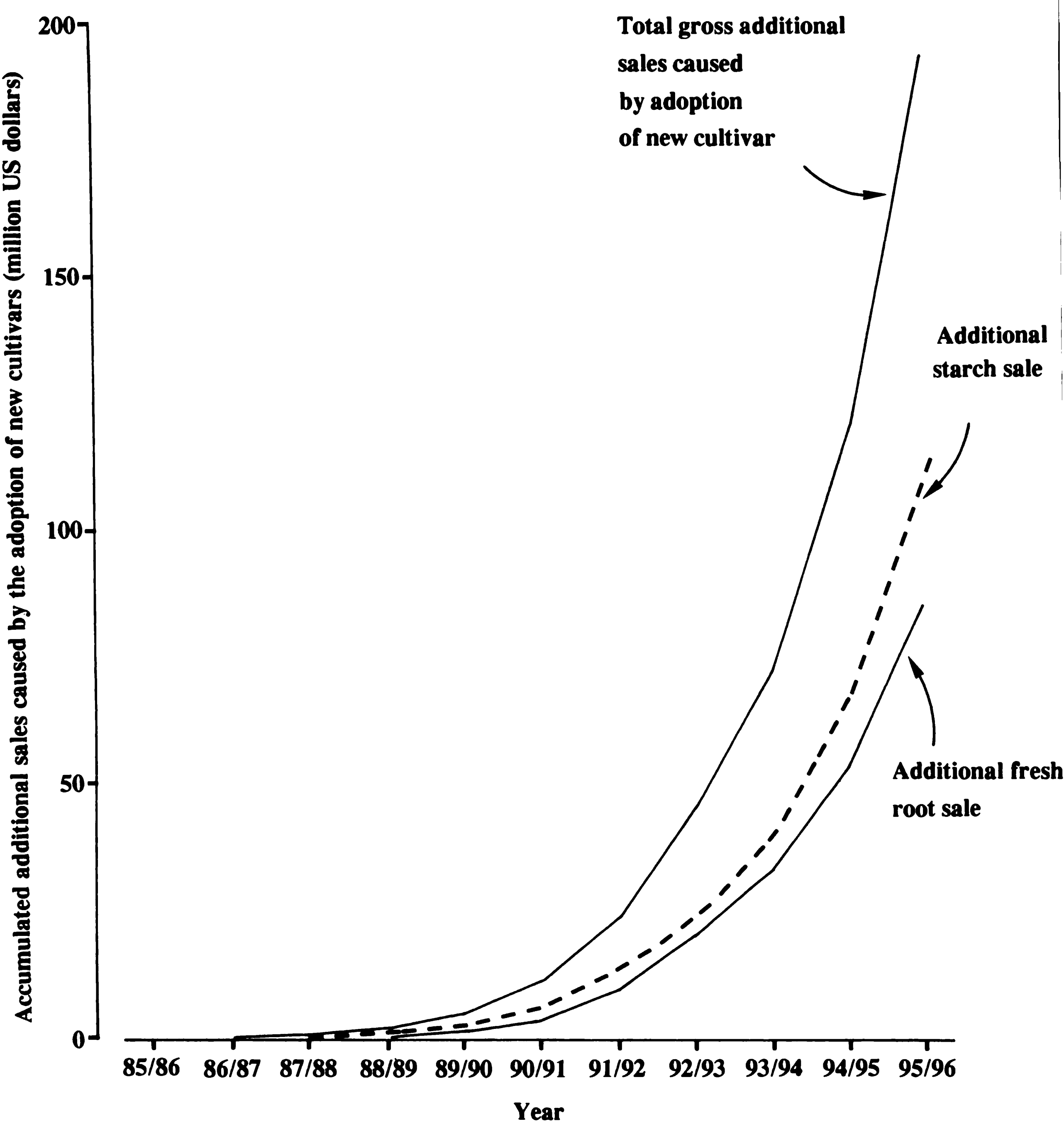

Figure 2. Additional economic effects generated by the adoption of new cassava cultivars in Lampung province of Sumatra, Indonesia from 1985 to 1996.

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SOCIO-ECONOMIC CONTRIBUTION OF CASSAVA VARIETAL IMPROVEMENT TO THE SMALL FARMER COMMUNITIES IN ASIA

Kazuo Kawano

ABSTRACT

The success or failure of any large-scale crop breeding program should be measured by achievement of the following step-by-step goals:

1) Establishment of a breeding program
2) Building of effective research capability
3) A large number of genotypes produced and evaluated
4) Selection of superior genotypes
5) A large number of cultivars released
6) A considerable area planted with new cultivars
7) Additional yield and quality as a result of the planting of new cultivars
8) Additional economic benefits generated by the adoption of new cultivars
9) The less privileged strata of society receive the greatest share of the profits
10) Beneficial social changes brought about by the planting of new cultivars

Accomplishing all of these was our wildest dream when we established a major cassava breeding program at CIAT headquarters in Colombia more than 20 years ago.

The first step towards achieving these goals came in the form of a distinctly higher yielding capacity of the breeding population within CIAT. When a major part of the CIAT cassava program extended to the collaborative program in Thailand, a significant improvement followed in root dry matter content and in adaptation to drier climates. Then, this progress was transferred to other major national cassava programs in Asia. Many new cultivars were developed and released, and thanks to the effective involvement of national and private research, extension and development institutions, the new cultivars are now planted in more than half a million ha in Asia. The additional economic benefits generated by the additional fresh root yield and higher starch content of these new cultivars are surpassing 500 million US dollars. More importantly, at least half of this additional benefit is going directly to the family income of hundreds of thousands of small farmers. It is fortunate that we have been able to work with the same basic strategy and the same fundamental objectives throughout the history of nearly a quarter century of our cassava varietal improvement program. Now, we are beginning to see many of the original goals being attained.

INTRODUCTION

The spectacular success of new high-yielding varieties of rice (initiated by IRRI) and wheat (initiated by Rockefeller/CIMMYT wheat program), adapted to high-input cultural conditions not only increased the production of major food commodities in many tropical countries, but also convinced administrators of both developed and developing countries of the benefit of investing in tropical agricultural research. The "Green Revolution", as it was called, swept the Asian continent in the late-sixties and seventies, but was limited to relatively well-off farmers in the irrigated areas. The next major challenge was to raise the productivity and incomes of small farmers in the upland areas. Cassava, being one of the major crops for small upland farmers in the tropics, but at the

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same time the least researched crop, was yet to be taken as a next target of international research attention. With this background and a clear expectation of repeating the success of IRRI's rice varieties with this little-known crop cassava, CIAT established its Cassava Program in 1972, and the CIAT cassava breeding efforts started in 1973.

Peter R. Jennings, the undisputed mastermind of the Rice Green Revolution of IRRI earlier in the 1960s, and the pundit of CIAT during the 1970s, challenged every novice breeder by indicating that any major crop breeding program of an International Agriculture Research Center should aim at a 100% yield increase, and the success of the program should be measured only by the area planted with the new varieties and the economic benefits that were generated by them. Both James H. Cock, then leader of the CIAT Cassava Program, and myself, who started the CIAT cassava breeding program, were young and ambitious with a measure of naivety, idealism and audacity. Borrowing a passage from the Gabriel Garcia Marques' master-piece "Hundred Years of Solitude": "The world was so new that many things even lacked a name", so free was our program in defining the basic research structure and so flexible was the administration of CIAT with a minimum of institutional strait jacketing. Our determination was to double the physiological productivity of cassava through breeding as a means to contribute to the improvement of small cassava farmers' income.

In retrospect and with a little bit of hindsight, our overall objective and ambition were to be measured by the achievement of the following ten intermediate goals, and our wildest dream was to accomplish all of these:

1) Establishment of a breeding program
2) Building of effective research capability
3) A large number of genotypes produced and evaluated
4) Selection of superior genotypes
5) A large number of cultivars released
6) A considerable area planted with new cultivars
7) Additional yield and quality as a result of the planting of new cultivars
8) Additional economic benefits generated by the adoption of new cultivars
9) The less privileged strata of society receive the greatest share of the profits
10) Beneficial social changes brought about by the planting of new cultivars

We were full of enthusiasm and optimism. We felt that we, the field workers, were the principal players of the whole game. Quixotic as it might have looked, this was the spirit of the young CIAT with which I started the cassava breeding program.

Organizing the CIAT Cassava Breeding Program and Enhancing National Programs

I have been writing on the history of CIAT headquarter breeding program and our collaborative breeding program with the Department of Agriculture, Thailand on many occasions, including in the CIAT Annual Reports and in the past Proceedings of this Asian Cassava Research Workshop. From these, at least the following points deserve special mention. We started the breeding program with a vast genetic diversity, i.e. a collection of 2,200 local cultivars from the center of origin and diversification, instead of basing the program on a small number of preselected elite germplasm. After many cycles of intensive hybridizations and selections, our breeding populations show no sign yet of reaching a plateau of yield selection. This may be a result of the inclusion of a large genetic variability from the beginning. As the big "bang" of organic evolution in the Cambrian period suggests, the condition in the beginning may hold a lasting influence up to the very late stages of development. Then, modeling after the development of the CIAT breeding program, many national cassava breeding programs were established and have been upgraded.

Generation and Distribution of Breeding Materials

Some 450 thousand hybrid seeds from CIAT/Colombia have been distributed to the national breeding programs in Asia (**Table 1**). Thanks to the cooperation of the Rayong Field Crops Research Center of the Department of Agriculture (DOA) of Thailand, another 100 thousand hybrid seeds have been distributed from the Thai-CIAT program to other Asian national programs as well as to CIAT/Colombia through the CIAT Asian Cassava Program (**Table 2**). These breeding materials have been offering immediate opportunities for varietal selection, as well as the means to organize and improve the breeding operations of the national programs.

Upgrading Yield Capacity and Adaptation of Breeding Populations

We continue our joint efforts by the collaborative program in Rayong, by CIAT headquarters in Colombia and by the cassava breeders of national programs. In the Thai-CIAT program, we have been using the mean yield data of all clonal entries in the Regional Trial network relative to control as a way to measure breeding progress, because this represent the value of immediately available materials, as well as the potential of on-going hybrid populations. These advanced clonal entries form the basis of the hybridization program at Rayong Center. Since the hybrid seeds from the Rayong program are now a vital source of selection in many national programs in Asia, the advance in clonal selection in Thailand also effects the potential of yield selection in other national cassava programs in the near future.

During the past years satisfactory progress was made in selecting for high fresh root yield (**Figure 1**), root dry matter content (**Figure 2**), and total biomass productivity (**Figure 3**). The harvest index has been stable at a relatively high level during the past ten years (**Figure 4**). Coming from the level of 1982 when data-taking started, we have made considerable progress. Adding to this the very substantial improvements made during the earliest years of CIAT headquarters breeding, which constituted the basis for the subsequent progress in Asia, the mean yield capacity of the present breeding population, i.e. the average yielding capacity of the hybrid seed population distributed to national programs, is 100% higher than of the population during the early 1970s.

Progress in each national program is reported by each program elsewhere in this Workshop Proceedings.

Varietal Dissemination

The number of CIAT-related cultivars officially released in Asian national programs has now passed 25. The number of clones pre-released and waiting for official release or left to the plantings by farmers, a very typical manner of varietal dissemination in many parts of the world even now, far exceeds this number.

In Thailand where statistics are available on the area planted with each cultivar from data collected by the Department of Agricultural Extension, the total area planted with five new cultivars is given as 376,250 ha in the 1995/96 planting season (**Figure 5**). In Indonesia, hard data and an extrapolation from these indicate that new cultivars are now planted in more than 110,000 ha (Palupi *et al.*, this Proceeding). In Vietnam, where the CIAT collaboration started much later than in other national programs, progress has been highly satisfactory, and good observation data show that the area planted with the new cultivars was more than 6,500 ha in the 1995/96 season, and is now estimated to be 15,000 ha in the middle of the 1996 planting season (**Figure 6** and also see other reports in this Proceeding). In the Philippines where no detailed data are available, the area with new cultivars is estimated to be at least 3,000 ha (see Mariscal and Bergantin, in this Proceedings). Thus, the total area planted to CIAT-related cassava cultivars in Asia appears to have just passed the half a million ha line this year.

Economic Effects

I used the sales value of the products as the basis for measuring economic effects. Value of sales includes production costs and net profits. The gross production costs are made up of expenditures for labor, equipment, supplies, maintenance and depreciation. For regular commercial operations, net profit rather than the value of sales may be more critical. However, in the national development context, value of sales may be a more important indicator of the socio-economic benefits, as it represents employment, purchasing power and the availability of useful products.

To concentrate mainly on direct monetary effects and avoid possible duplicates, I used only two measures for the economic gain; additional (or reduced) field production of fresh cassava roots due to the higher (or lower) yield of new cultivars, and the additional factory starch (or chips) production due to the higher starch (or dry matter) content of new cultivars compared with the traditional cultivars. The additional factory profit generated by the gross additional availability of raw materials is not accounted for, let alone the additional production of numerous secondary products. Thus, the real gross additional economic benefits are much greater than described in these simple analyses.

Table 1. Cassava F_1 hybrid seeds from CIAT/Colombia distributed to Asian programs from 1975 to 1996.

	Number of seeds							
Country	1975-1990	1991	1992	1993	1994	1995	1996	Total
Thailand	109,411	9,583	11,727	6,727	9,843	11,964	9,781	169,036
Indonesia	28,800	4,219	9,552	12,074	7,703	5,150	5,770	73,268
China	35,999	5,511	6,021	7,158	6,767	6,029	3,933	71,418
Vietnam	13,850	3,750	4,500	5,950	4,606	5,364	5,915	43,935
Philippines	30,736	7,679	4,297	4,061	3,076	3,575	3,289	56,713
Malaysia	11.440	2,918	2,079	1,077	1,073			18,587
India	10,700		1,200		1,648			13,548
Sri Lanka	1,500							1,500
Taiwan	1,700							1,700
Total	244,136	33,660	39,376	37,047	34,716	32,082	29,688	449,705

Table 2. Cassava F1 hybrid seeds from the Thai-CIAT program distributed to other Asian cassava programs from 1985 to 1996.

	Number of seeds							
Country	1975-1990	1991	1992	1993	1994	1995	1996	Total
Indonesia	13,813	1,139	1,393	3,869	1,613	2,805	1,718	26,305
China	5,871	741	1,793	4,713	1,790	2,330	2,292	19,530
Vietnam	4,700	1,435	2,441	4,730	3,025	2,740	3,309	22,380
Philippines	4,634	520		1,850	1,250	1,190	1,350	10,794
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		2,158		11,493
Total	43,389	3,835	5,627	21,717	7,678	11,223	8,669	102,138

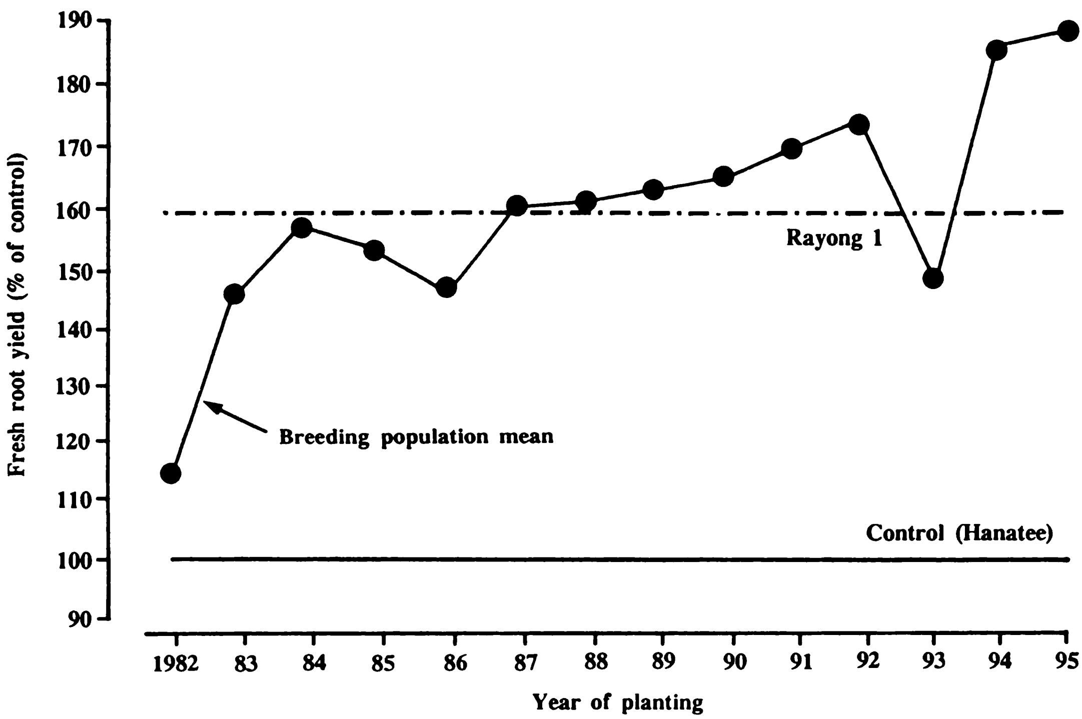

Figure 1. Change in the mean fresh root yield of the breeding population (all entry mean yield trials) in relation to that of Rayong 1 from 1982 to 1995 at the Thai-CIAT collaborative cassava breeding program in Rayong, Thailand.

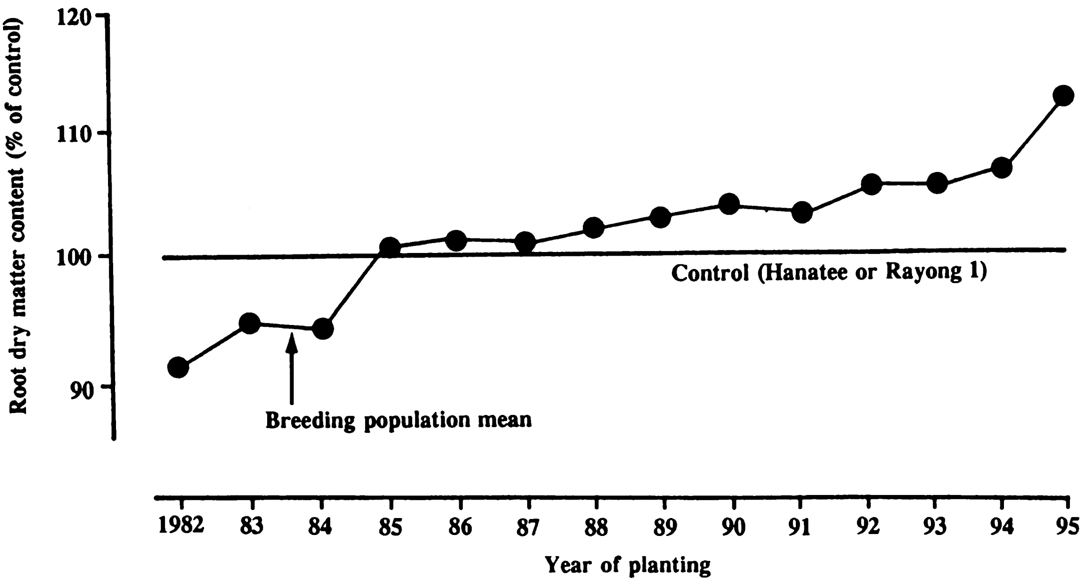

Figure 2. Change in the mean dry matter content of the breeding population (all entry mean in yield trials) in relation to those of the control varieties from 1982 to 1995 at the Thai-CIAT collaborative cassava breeding program in Rayong, Thailand.

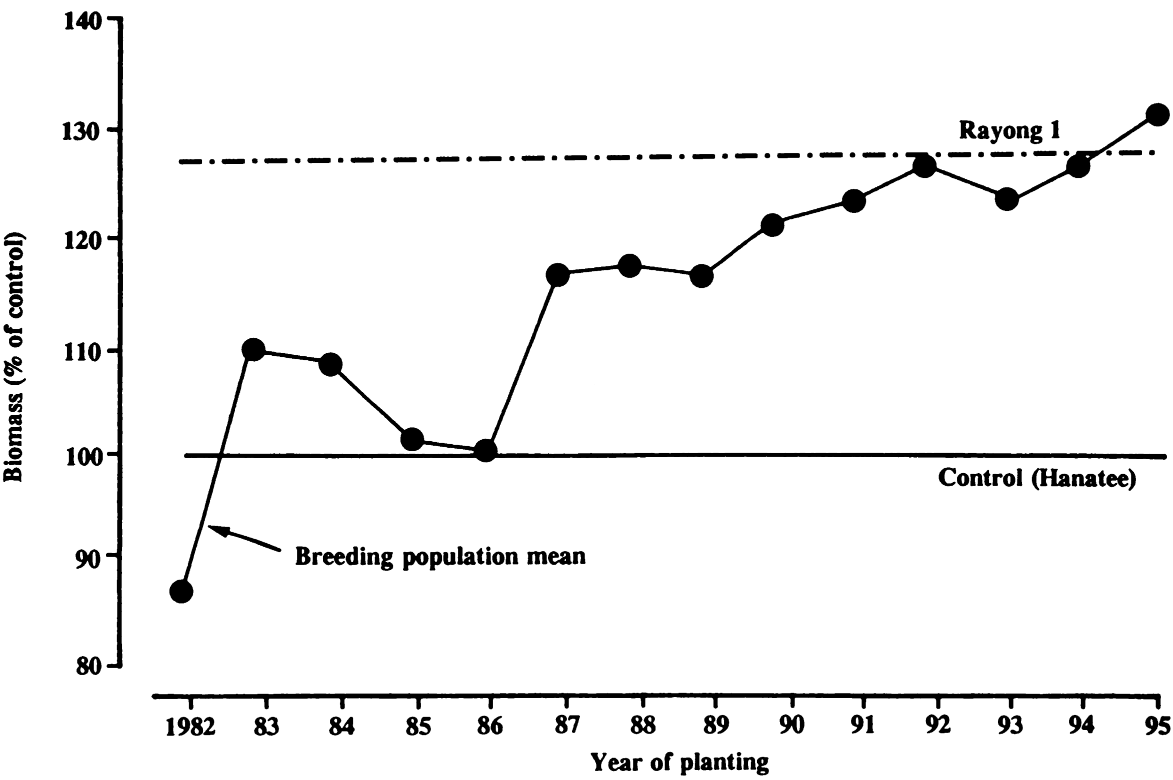

Figure 3. Change in the mean total biomass production of the breeding population (all entry mean in yield trials) in relation to Rayong 1 from 1982 to 1995 at the Thai-CIAT collaborative cassava breeding program in Rayong, Thailand.

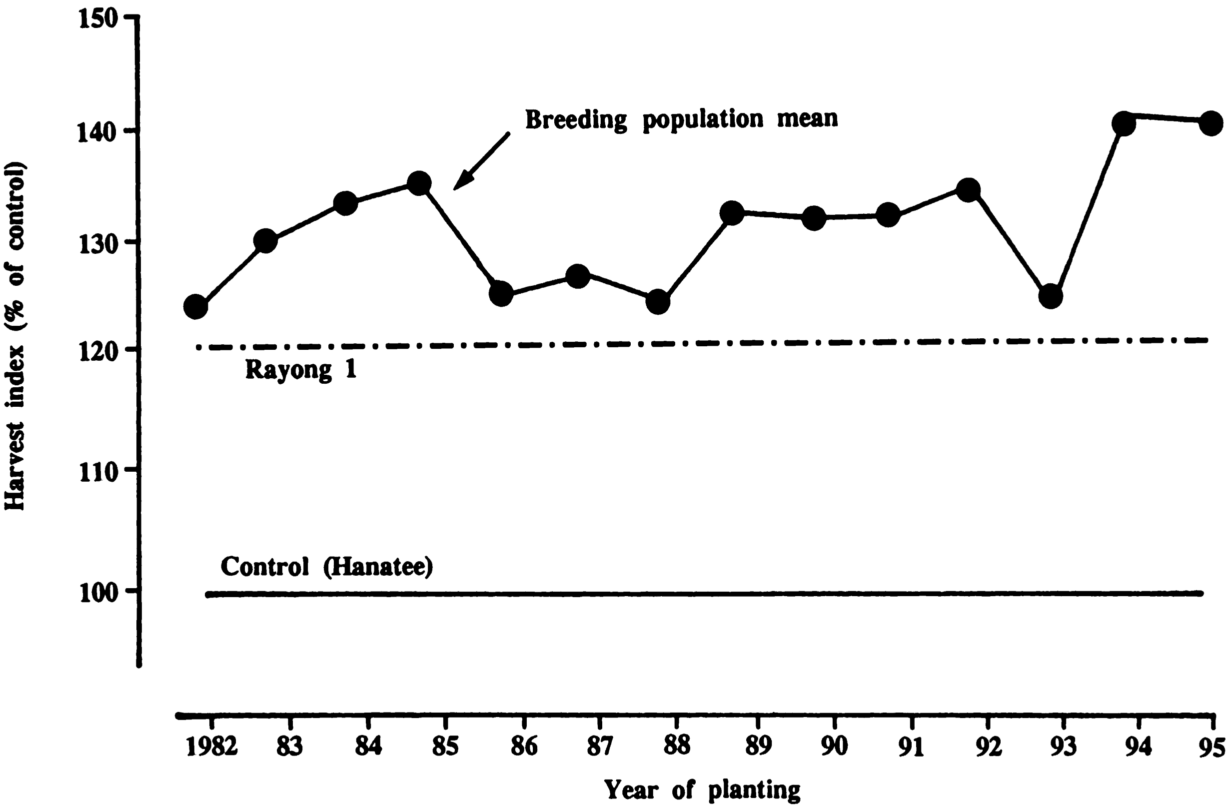

Figure 4. *Change in the mean harvest index of the breeding population (all entry mean in yield trials) in relation to Rayong 1 at the Thai-CIAT collaborative cassava breeding program in Rayong, Thailand from 1982 to 1995.*

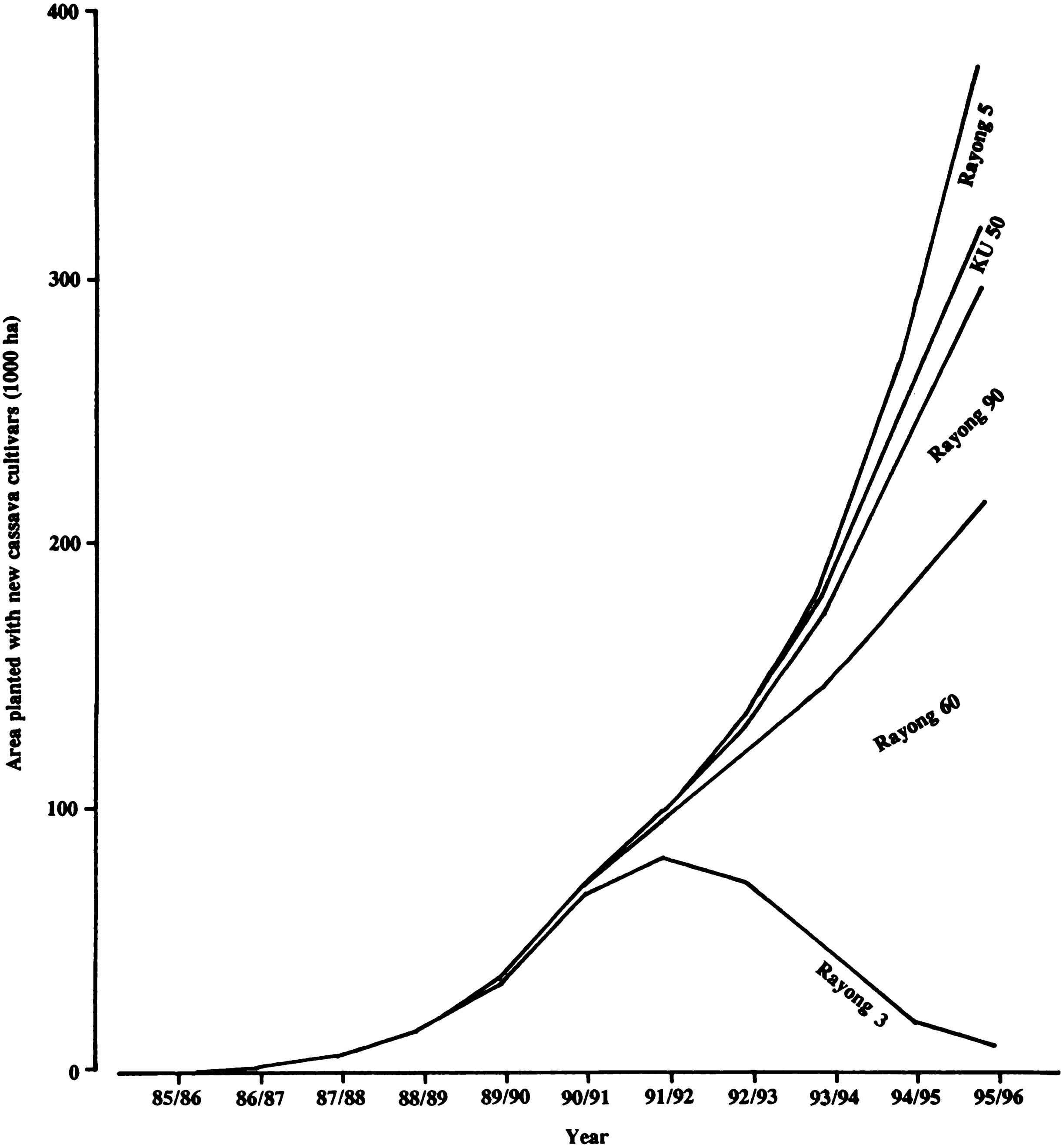

Figure 5. Change in area planted with various new cassava cultivars in Thailand from 1985/86 to 1995/96.
***Source**: Department of Agricultural Extension.*

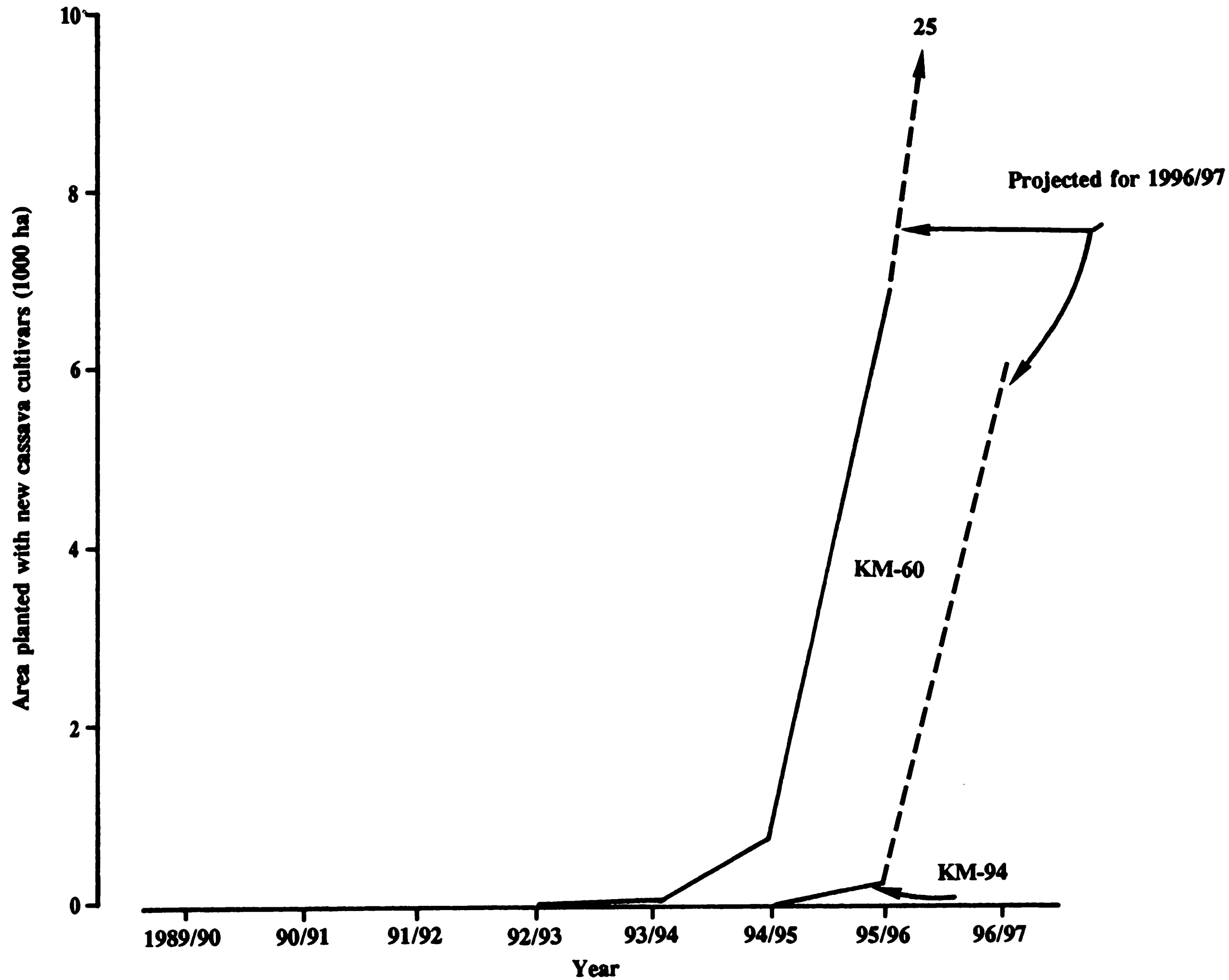

Figure 6. Change in area planted with two new cassava cultivars in South Vietnam from 1989/90 to 1996/97.
***Source** : Hung Loc Agricultural Research Center.*

For the yield and starch content advantage (or disadvantage) resulting from the adoption of new cultivars, I used the means of many regional trials and on-farm trials (**Tables 3** and **4**). The absolute yield figures represent what advanced farmers would be able to obtain in their fields and the yield difference from the traditional cultivar, which actually matter more, would represent what could be obtained under a wide range of farming conditions. For on-farm price of fresh cassava roots and factory starch price, I used the low price in each 2-5 year period from 1985 to 1996.

One nagging question that always arises when discussing cassava production is the issue of marketing. Such questions as "Can the farmers always find the market?" or "Can you assume that all the producers sold their fresh cassava at the market price?" are valid and these are real concerns, especially for small farmers who grow cassava for fresh human consumption. We have been dealing mainly with the increasing commercialization of cassava, i.e. the processing of starch or chips, and we have been developing new cultivars mainly suited for factory processing. Most farmers who adopt new cultivars are growing cassava as a cash crop for factory processing. The cassava market for starch processing is now rapidly expanding in Asia. It must be reasonably safe to assume that all the additional productions herein reported have led to additional cash income almost in their entirety, and the unabating adoption of new high-yielding cultivars is indirect proof for this. The subsequent analyses show that cassava is clearly an attractive means for small farmers to improve their cash income.

In Thailand the varietal adoption started with Rayong 3, which has a higher starch content that the traditional variety Rayong 1 but may produce lower fresh root yields. Farmers who adopted Rayong 3 have been actually losing money by the sales of fresh roots but gained money from its higher start content. Only recently, when new cultivars that have both high fresh root yield and high starch content started to replace Rayong 3, did benefits result from both higher starch and higher root yields (**Figure 7**). The additional economic effects caused by the higher starch content has been highly significant. Until recently, virtually all the economic benefits in Thailand have been due to the higher starch content of new cultivars.

In Indonesia, the advantage of new cultivars is clearly in both fresh yield and starch content; thus, the additional fresh root yields in the fields and the additional starch production in the factories both produced substantial economic gains (Palupi *et al.*, in this Proceedings).

Table 3. Yield data of cassava cultivars and monetary gain caused by their adoption in Thailand.

Cultivar	Year of release	Fresh root yield (t/ha)[1]	Root starch content (%)[2]	Difference from Rayong 1		Monetary gain[3]	
				Fresh root yield (t/ha)	Starch content (%)	by higher fresh root yield ($/ha)	by higher starch content of new cultivar ($/ha)
Rayong 1	Traditional	29.2	16.1	-	-	-	-
Rayong 3	1984	26.7	22.0	-2.5	5.9	-88	378
Rayong 60	1986	30.2	17.0	0.9	0.9	32	65
Rayong 90	1991	31.7	22.7	2.5	6.6	88	502
Kasetsart 50	1992	32.6	19.8	3.4	3.7	119	289
Rayong 5	1994	32.7	19.0	3.5	2.9	123	227

[1]Means from Regional Yield Trials in seven locations in 1994/95.

[2]Measured by Reihmann scale, roughly corresponding to the extracted starch % in cassava starch factories of low to medium technology level.

[3]Based on the lowest market price of $ 35/t for fresh roots during 1992-1996 and $ 240/t for starch during 1995-1996 in comparison with Rayong 1.

Table 4. Yield data of cassava cultivars and monetary gain caused by the adoption of new cultivars in three countries.

Cultivar	Year of release	Fresh root yield (t/ha)[1]	Root starch content (%)[2]	Difference from Rayong 1		Monetary gain[3]	
				Fresh root yield (t/ha)	Starch content (%)	by higher fresh root yield ($/ha)	by higher starch content of new cultivar ($/ha)
Sumatra/Indonesia	Traditional	20.2	18.1	-	-	-	-
	Adira 4	28.2	23.4	8.0	5.3	280	358
South Vietnam	Traditional	12.0	20.0	-	-	-	-
	KM-60	20.0	23.0	8.0	3.0	280	144
	KM-94	22.0	23.0	10.0	3.0	350	158
Mindanao/ Philippines	Traditional	10.0	19.0	-	-	-	-
	VC 5	16.0	19.0	6.0	0	210	0
Negros, Bohol/ Philippines	Traditional	10.0	19.0	-	-	-	-
	Lakan	15.0	22.0	5.0	3.0	175	108

[1]Means from large-plot yield trials in Indonesia. Means from on-farm yield trials in Vietnam and Philippines.
[2]Measured by Reihmann scale, roughly corresponding to the extracted starch % in cassava starch factories of low to medium technology level.
[3]Based on the lowest market price; \$34/t for fresh roots during 1992-1996 and \$240/t for starch during 1995-1996 in comparison with the traditional variety.

In Vietnam, more money has been made from the sale of planting stakes of new cultivars than from fresh root harvests and higher starch content, although the benefits caused by the additional fresh root production and the additional starch production will probably outstrip the stake sale as of the 1996/97 season (**Figure 8**).

Throughout all this process, the advantage of higher starch content was highly significant. It is the higher starch content rather than the higher fresh yield of new cultivars that accelerated the adoption of new cultivars. The total economic benefits due to the superior yield and quality of the new cultivars, accumulated up to now, is estimated to be 479 million US dollars.

In this article I am analyzing primarily the economic effects caused by the additional root yield and additional starch content of the CIAT-related new cultivars. Yet, when we consider the history of the whole cassava processing industry in Asia, the establishment and development of large export markets for cassava products by Thai entrepreneurs, and the selection of cultivar Rayong 1, which has been the backbone of the Thai cassava industry, are by far the most significant factors. The monetary contributions of these must be in the billions of US dollars. The greatness of Rayong 1 is not limited to the immensely successful field production in the past two or three decades, but also extends to its role as an effective cross parents, as it produced Rayong 60 and Kasetsart 50, among others, through hybridization with the introduced parents from CIAT/Colombia. The contribution of Thai farmers who selected Rayong 1 should always be remembered.

Profit to Small Farmers

Virtually all the cassava production takes place in small farmers' fields and all the roots in Thailand are sold to cassava processors. In Vietnam also, all the cassava is produced by small farmers, and at present, those advanced cassava farmers who have adopted the new cultivars sell virtually all the harvested roots to the processors. In Indonesia and the Philippines, some cassava is produced in large plantations; yet, the majority of production takes place in small farmers' fields. Thus, we can assume that virtually all the additional economic benefits generated by the higher fresh root yield of new cultivars are entering directly into the pockets of small farmers.

On the other hand, how much of the additional profit generated by the higher starch content of new cultivars is shared by the farmers depends on what differential price starch factories (or chipping plants) pay to the farmers. If the factory pays the same price for roots of different starch content (in other words, does not honor or recognize the breeders' and farmers' efforts to produce higher quality products), all the additional profit will be absorbed by the factory.

Analysis of a price scheme used at a starch factory in Rayong, Thailand indicates that more than half of the cost of starch production is the cost of fresh cassava, even using cassava roots of high starch content (**Table 5**), suggesting that in general a fair price is paid to the producers. More interesting is the question on what proportion of the additional starch produced due to the higher starch content of the new varieties is returned to the farmers (**Table 5**). Since the factory can benefit from the increased amount of final product, its business can still be viable even if the factory fully (100%) compensates the farmers for the higher starch content. In effect, most factories return between 55 and 100 % of the value of additional starch production caused by higher starch content of the raw material to the farmers.

All in all, the scheme is not entirely unfair to the farmers. The initial adoption of Rayong 3 testifies this (**Figure 5**). While the farmers were losing money by the reduced sales of fresh roots, due to the lower fresh root yield of Rayong 3 compared with that of the traditional cultivar Rayong 1, they must have been receiving reasonable compensation from the factories for the higher starch content of their products. If the factories had not given a fair compensation, the planting of Rayong 3 would have halted immediately. We can safely assume that a substantial portion, more than a half, of the 480 million US dollars so far generated by the adoption of new cassava cultivars has entered the household income of small farmers.

Social Effects

In addition to the very basic expectation of strengthening the cassava status as an efficient crop for increasing the cash income of small farmers, our work is expected to contribute to the improvement of the efficiency of factory processing as well. Higher production and processing efficiency could lead to a higher competitiveness of the products domestically and on international markets. All of these are taking place already although the magnitude of the effect differs among countries.

Cassava is often cited as a crop conducive to soil degradation. Much efforts are directed to identify and enhance adoption of soil management practices that lessen soil erosion or mineral nutrient exhaustion. While individual methods are important and indispensable components of soil management, a more fundamental requirement is to first upgrade the economic situation of farmers, so that farmers can consider the long term future of their farming operation and start adopting better soil management practices. As cassava processing becomes more lucrative, there will be stronger concerns for making the whole cassava production and processing industry more sustainable. It is yet to be seen whether the additional production efficiency generated by the new cassava cultivars would eventually add up to cutting the vicious cycle of poverty and environmental degradation.

Epilogue

It is fortunate that I have been able to work with the same basic strategy and the same fundamental objectives throughout the nearly a quarter century history of the CIAT Cassava Program. Generating useful breeding materials, offering them to national programs and participating in their selection have been the basic style of the CIAT cassava breeding program. Many of the national breeding programs represented in this Workshop have been highly responsive to utilizing our materials and expertise. They are now highly successful in selecting truly useful cultivars and contributing to the farmers. We are proud that, among so many so-called research networks, our Asian cassava breeding network is one that is producing truly meaningful results. Now that we are beginning to see the results of our collaborative work, it is all the more fortunate that we can measure the achievement of our long time goals by the same original criteria defined when I was full of boyish naivety and idealism 25 years ago.

Acknowledgement

None of the good results quoted in this report is the work of CIAT alone. They all are the result of our collaborative work with national programs. My personal involvement in producing research results ranges from nearly total, such as the development of Rayong 60 and Rayong 5 in Thailand and KM-60 in Vietnam, to marginal, such as the release of SC8002 in China. The breeding materials and technical data thus produced in our collaboration with national programs primarily belong to the national programs. I appreciate the good collaboration of national cassava breeding programs in Asia. Among these, the contribution of the Rayong Field Crops Research Center, Department of Agriculture, Thailand, has been particularly significant in jointly producing advanced breeding materials to be contributed to other Asian programs, as well as to enrich the germplasm and breeding populations back at CIAT Headquarters, Colombia. We are all greatly indebted to the collaboration from the Thai cassava research community.

Table 5. Fresh cassava and starch price scheme and distribution of additional profit caused by higher starch content of cassava roots between farmers and starch factories in Thailand.

Root starch content[1] (%)	Fresh cassava price (Baht/t)[2]	Raw material cost as proportion of value of starch produced[3] (%)	Share (%) of additional profit caused by 1% higher root starch content	
			Fresh root seller	Starch factory
30	920	51	65	35
29	900	52	65	35
28	880	52	64	36
27	860	53	63	37
26	840	54	62	38
25	820	55	61	39
24	800	56	61	39
23	780	57	59	41
22	760	58	58	42
21	740	59	57	43
20	720	60	56	44
19	690	61	83	17
18	660	61	82	18
17	630	62	81	19
16	600	63	80	20
15	570	63	79	21

[1]Determined by Reihamnn scale.
[2]Price data for different starch content at Rayong in Aug 1996; US$ 1.00 = Baht 25.00.
[3]Based on starch price of US$ 240/t.

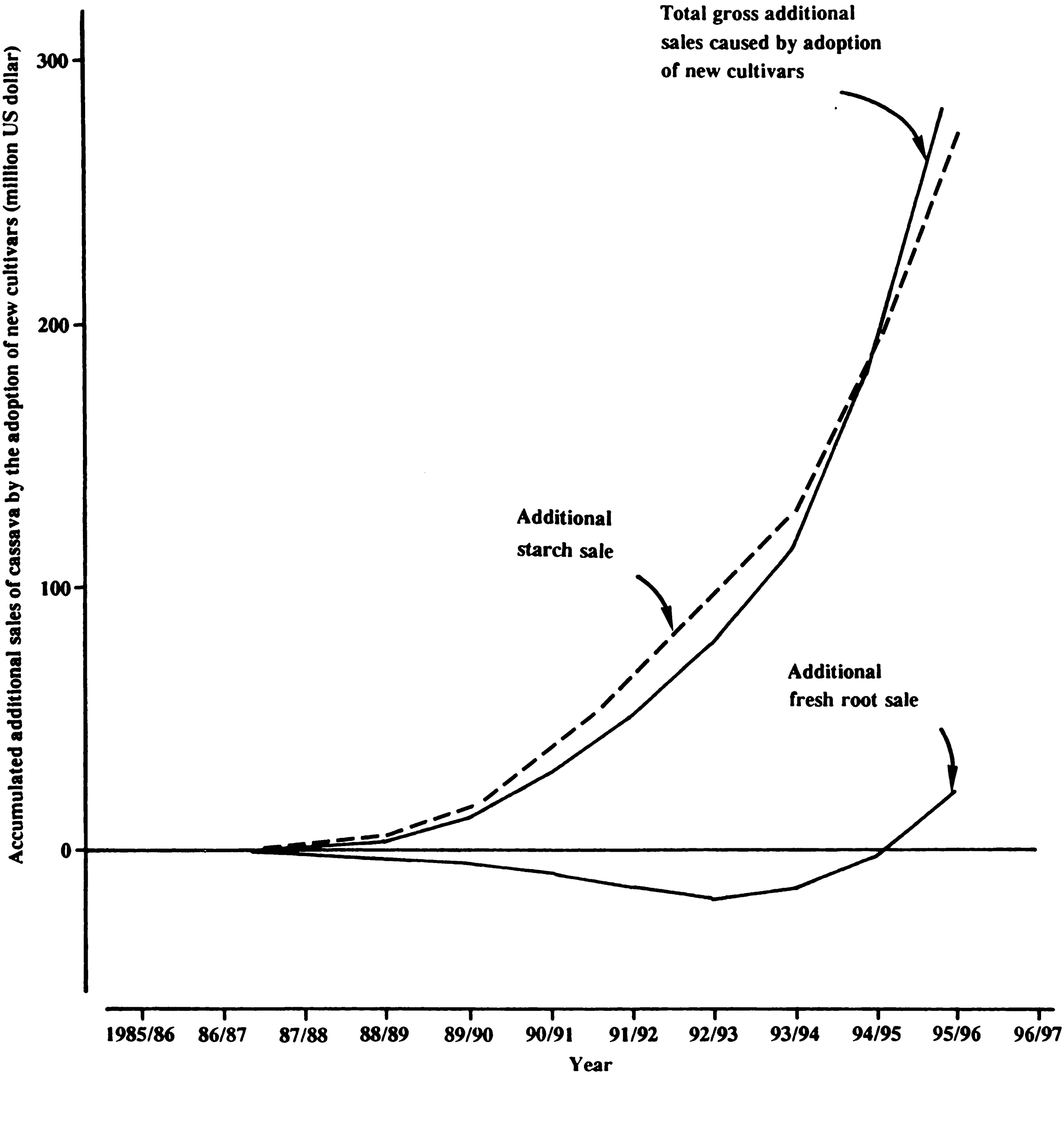

Figure 7. Additional economic effects generated by the adoption of new cassava in Thailand between 1985/86 and 1995/96.

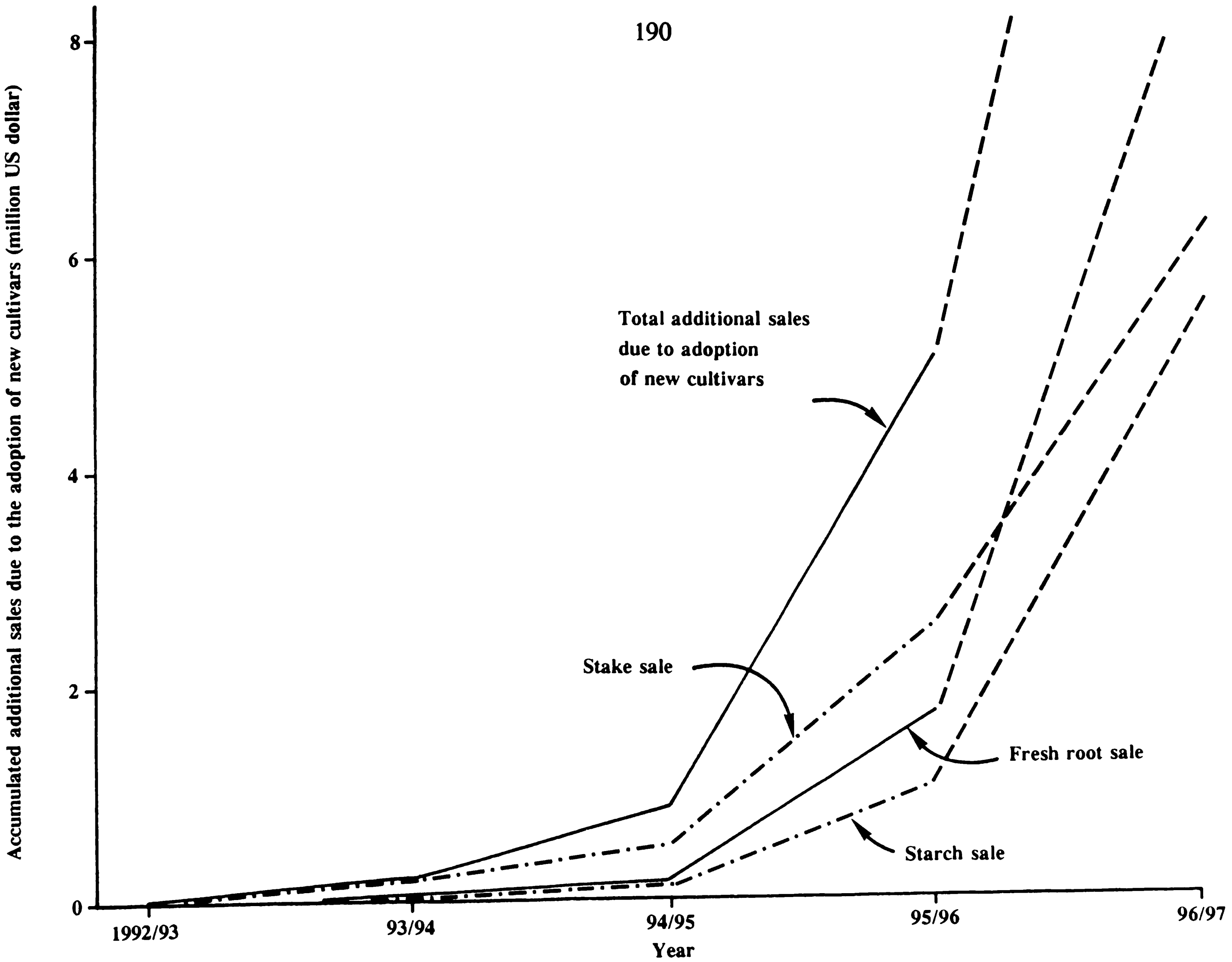

Figure 8. Addtional economic effects generated by the adoption of new cassava cultivars in South Vietnam between 1992/93 and 1996/97.

CASSAVA AGRONOMY RESEARCH IN CHINA

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ABSTRACT

Through cooperation with CIAT, national programs in China have paid more and more attention to cassava agronomy research and a lot of progress has been made. This paper describes briefly the most common cropping systems and production practices presently used by farmers. It also reviews the results of research on soil/crop management, with emphasis on soil fertility maintenance and soil erosion control, during the past decade.

In China, cassava is usually planted from Jan-May, while it is harvested from Nov-Mar. The plant population is about 10,000-12,000 plants/ha under normal conditions, while the population could increase to 15,000-18,000 plants/ha in poor soils.

Results of soil erosion control trials showed that two treatments, i.e. no-tillage but making a planting hole (30x30 cm) by hoe, or complete land preparation followed by contour ridging, not only increased cassava yields, but also decreased soil erosion. However, soil loss was very serious with complete land preparation but without ridging. Long-term fertilization trials conducted in CATAS, GSCRI and UCRI, indicate that cassava yields increased significantly with the application of N and K. Increasing the N application from 50 to 200 kg/ha while maintaining a constant rate of 100 kg K_2O and 50 kg P_2O_5/ha, cassava yields increased significantly, but the root starch content decreased. In contrast, both cassava yield and root starch content increased with an increase in K application from 50 kg to 200 kg K_2O/ha, while maintaining a constant rate of 100 kg N and 50 kg P_2O_5/ha. Cassava intercropped with watermelon produced the highest economic returns, but soil erosion was controlled most efficiently by intercropping with peanut.

INTRODUCTION

The Status of Cassava Production and Development in China

In China, cassava could be cultivated in the areas south of the Qinling mountain and Huaihe river, with mean annual temperatures above 18°C and a frost-free period of more than eight months of the year. Therefore, there is a tremendous potential for further expansion of the cassava production area. The total cassava area in China has now reached 450,000 ha. Recently, cassava processing and utilization have developed more in-depth, and the production of cassava-based products has increased from 30 to 70%. Cassava is turning into a very important upland crop in the southern part of China.

The production of cassava has changed from a scattered and backward crop into one that is farmed intensively. According to statistics in Hainan, there are now ten enterprises cultivating 100-300 ha of cassava, and the number of farmers who plant 3-10

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ha has been increasing year after year. Thus, cassava production is moving towards more mechanization and more intensive farming, with greater use of chemical fertilizers and other farm chemicals. According to the statistics of Hainan, about 30% of the total farm work is mechanized, which is achieved by working in commodity production units; this has reached 70% in a few units. Over 60% of these units use herbicides and chemical fertilizers.

Yunnan province is a new area for cassava production. According to the statistics, in 1990 the total cassava cultivated area was 7,000 ha. However, the area under cassava has recently increased as more and more planting material was introduced from Guangxi. Presently, in Honghe district of Yunnan alone, the area under cassava has reached 16,000 ha. It is estimated that the cassava area in Yunnan will be 20,000-30,000 ha.

Improved Varieties

Research on cassava breeding and cultivation in China began in 1914. Most of the cassava varieties have been introduced from abroad, like those presently known as SC201 and SC205; these were both introduced to China in the 1940s and 50s. At that time the number of cultivars was very limited. Since 1958 China has been collecting and evaluating cassava germplasm, and has been doing research on cassava breeding and agronomy. The edible cultivar SC6068 has been released and popularized in the early 1980s. In recent years, with the accelerated development of cassava production and processing, new varieties with high yield potential and starch content are urgently needed. In Guangdong, Guangxi and Hainan provinces, local institutes started research on cassava breeding. With the cooperation and support of CIAT, and after many years of hard work, CATAS released SC124, SC8013 and SC8002, and has selected some advanced clones, such as OMR33-10-4; Guangdong has selected Nanzhi 188, SC8002, and more recently 901531; while Guangxi selected SM1113-1.

CASSAVA AGRONOMY RESEARCH IN CHINA

Cultural Practices for Erosion Control

During spring and summer soil erosion is serious in southern China, due to the monsoon climate, characterized by high temperatures and heavy and concentrated rainfall. Farmers usually build terraced fields or practice contour ridging to prevent soil erosion. This method has been mostly adopted in Guangdong and Guangxi provinces. But in the plains or in areas with gentle slopes, which usually have a high population density and thus less available land, farmers generally plant cassava intercropped with early-maturing and short-statured crops. This is not only very effective in reducing soil loss, but also increases the multiple crop index and has economic benefits.

From 1990 to 1992, researchers at GSCRI in Nanning, Guangxi, conducted an erosion control trial on the effect of different cultural practices on cassava yields and soil loss due to erosion. It can be seen from **Table 1** that contour ridging with fertilizer application was most effective in reducing erosion, followed by intercropping with peanut and planting at closer spacing. Method of planting (vertical or horizontal) had no significant effect on erosion. Researchers at CATAS in Hainan also conducted erosion control trials and obtained similar results. It can be seen in **Table 2** that twice plowing, followed by twice discing and contour ridging increased the yield by 5% and reduced soil loss by 38% compared to the same tillage method but without ridging. Preparation of either big or small planting holes decreased yields by 0.8 and 8.7% and reduced soil loss by 40 and 36%, respectively, compared with twice plowing and discing but without ridging. Plowing and discing increased yields compared with minimum or zero tillage but also caused more soil erosion. As farmers in Hainan tend to have more land but less labor, they usually plant cassava with zero tillage. This practice results in somewhat lower yields, but is quite effective in reducing erosion. In Guangdong and Guangxi, there are more people but there is less available land. On flat or gently sloping land farmers normally use tractors or cattle to plow and disc, and then plant cassava intercropped with other crops; this can increase yields and economic benefits, reduce costs and erosion, while maintaining soil fertility.

Table 3 shows the results of erosion control trials conducted at CATAS. Fertilizer application with either contour ridging or peanut intercropping increased cassava yields by 37 and 26% and reduced soil losses by 42 and 29%, respectively, compared with the same non-fertilized treatments. Similar data from a soil erosion control trial conducted for three years at CSCRI in Nanning (**Table 4**) indicate that contour ridging, peanut intercropping and vetiver grass contour hedgerows were very effective in reducing erosion, while also increasing cassava yields.

In recent years, in the gently sloping and highly populated regions of Guangdong and Guangxi, farmers plant cassava intercropped with early-maturing and short-statured crops, such as watermelon, peanut, soybean etc. This not only increases yields and gross income, but also reduces soil losses due to erosion. However, with the development of a market economy, in order to increase profits farmers tend to plant cassava with intensive land preparation and without any cultural practices to control erosion. Soil erosion may become the major restriction for cassava production in the future.

Table 1. Effect of cultural practices on root yield and total dry soil loss due to erosion when cassava was grown on about 12% slope in GSCRI, Nanning, Guangxi, China in 1990 to 1992.

Treatments	Root yield (t/ha)				Dry soil loss (t/ha)			
	1990	1991	1992	Average	1990	1991	1992	Average
No ridges, no fertilizers, horizontal planting	18.5	18.0	13.6	16.7	11.0	27.6	13.9	17.5
No ridges, with fertilizers, horizontal planting	12.2	19.0	13.9	15.0	7.0	32.1	9.6	16.2
No ridges, with fertilizers, horizontal planting, closer spacing	20.5	14.0	13.9	16.1	9.5	20.7	4.3	11.5
Contour ridges, with fertilizers, horizontal planting	15.6	20.5	12.2	16.1	9.5	8.7	2.9	7.0
No ridges, with fertilizers, vertical planting	21.3	16.0	13.5	16.9	8.4	25.6	11.9	15.3
No ridges, with fertilizers, hor. planting, peanut intercrop	20.8	15.0	14.3	16.7	3.7	21.7	2.2	9.2

Table 2. Effect of land preparation on root yield and dry soil loss due to erosion when cassava was grown on 25% slope in CATAS, Hainan, China from 1989 to 1992.

Treatments	Root yield (t/ha)					Dry soil loss (t/ha)				
	1989	1990	1991	1992	Average	1989	1990	1991	1992	Average
Twice plowing, twice discing, contour ridging	26.3	34.6	17.0	22.8	25.2	71.1	117.0	186.9	79.3	113.6
Twice plowing, twice discing, no ridging	26.0	29.6	18.2	22.3	24.0	141.1	193.4	261.0	134.6	182.5
One time plowing, no ridging	21.3	30.5	19.1	18.6	22.4	91.0	104.8	167.5	119.8	120.8
Zero tillage, hand preparation of planting holes 30x30cm	25.6	27.6	20.6	21.3	23.8	45.3	97.4	203.3	90.8	109.2
Zero tillage, direct planting in small holes	22.6	29.2	16.5	19.3	21.9	59.8	88.0	201.2	115.9	116.2

Table 3. Effect of various cultural practices on root yield and dry soil loss due to erosion when cassava was grown on 15% slope in CATAS, Hainan, China, from 1989 to 1992.

Treatments	Root yield (t/ha)					Dry soil loss (t/ha)				
	1989	1990	1991	1992	Average	1989	1990	1991	1992	Average
No fertilizers; no ridging, horizontal planting	16.4	25.3	13.8	15.9	17.8	143.1	119.5	200.6	110.2	143.3
With fertilizers, contour ridging, horizontal planting	23.3	31.8	20.5	22.0	24.4	73.0	77.8	121.5	61.4	83.4
With fertilizers, no ridging, *Brachiaria* barriers	22.4	30.0	19.4	18.5	22.6	65.0	106.6	93.3	45.7	77.6
With fertilizers, no ridging, *Stylosanthes* barriers	20.6	29.2	18.8	17.6	21.7	151.8	100.4	139.4	62.4	113.5
With fertilizers, no ridging, peanut intercropping	-	32.7	17.9	16.5	22.4	-	87.1	152.9	63.6	101.2
With fertilizers, no ridging, closer spacing	27.0	32.2	21.6	-	26.9	101.5	118.6	168.2	-	129.4
With fertilizers, no ridging, vertical planting	23.2	27.8	23.7	-	24.9	73.7	106.6	183.2	-	121.2

Table 4. Effect of cultural practices on root yield and dry soil loss due to erosion when cassava was grown on about 12% slope in GSCRI, Nanning, Guangxi, China from 1993 to 1995.

Treatments	Root yield (t/ha)				Dry soil loss (t/ha)			
	1990	1991	1992	Average	1990	1991	1992	Average
Plowing + discing, no ridges, no fertilizers	18.3	13.8d	12.8	15.0	44.2a	11.5a	3.9a	19.9
Plowing + discing, no ridges, with fertilizers	23.8	19.7c	19.0	20.8	23.9b	4.8bc	1.8b	10.2
Plowing + discing, contour ridges, with fertilizers	20.4	25.4ab	21.4	22.4	8.3c	2.1c	2.3b	4.2
Plowing + discing, no ridges, with fertilizers, peanut intercropping	23.4	22.7bc	21.6	22.6	12.1c	2.9c	1.8b	5.6
Plowing + discing, no ridges, with fertilizers, *Crotalaria juncea* intercrop	21.6	23.0bc	20.0	21.5	23.6b	4.9bc	2.2b	10.2
Plowing + discing, no ridges, with fertilizers	21.6	18.4cd	18.2	19.4	22.5b	7.5b	2.2b	10.7
Plowing, no ridges, with fertilizers, vetiver grass contour barriers	22.5	28.1a	17.9	22.8	6.1c	1.8c	0.9b	2.9
F-test	NS	*	NS		**	**	*	
LSD (0.05)	-	4.79	-		8.06	3.97	1.39	
CV (%)	34.6	17.9	23.1		26.0	44.2	36.5	

Cropping Systems

Cassava is an annual crop in China. The cropping systems can be classified as either monoculture, intercropping, interplanting, continuous cropping or rotational cropping. Monoculture is the major cropping system, and is the common practice in the mountainous or semi-mountainous areas, where there are less people but there is more land. The common method of land preparation is either reduced tillage or zero tillage. Land preparation consisting of plowing and discing increases root yields but also increases the costs and may cause serious erosion. Therefore, in sloping areas, planting cassava in a monoculture system with intensive tillage should be done only with contour ridging, in order to reduce soil losses by erosion.

Intercropping and interplanting is usually carried out in the plains and on gentle slopes, where the population density tends to be high. Land preparation is intensive and results in a good income. According to an investigation done by GSCRI, when cassava was intercropped with watermelon, the income was increased by 30,000-75,000 yuan/ha, cassava intercropped with watermelon for seed increased income by 7,500-10,500 yuan/ha, while cassava intercropped with peanut increased income 4,500-7,500 yuan/ha. **Table 5** shows that when cassava was intercropped with peanut or watermelon for seed, both cassava yields and income were increased, while this system will also reduce soil loss. This cropping system should be popularized.

A cassava rotation cropping system is usually adopted in the mountainous regions, where the slopes are steep and soil loss is serious. Farmers rarely apply fertilizers, so, after planting cassava for 2-3 years, the soil nutrients are exhausted and yield have come down. In Yunnan and Hainan, farmers usually leave the land in fallow until the soil fertility has recovered. In the flat areas or gentle hills, farmers usually rotate with sugarcane or other crops. In sugarcane production areas, cassava is rotated with sugarcane after the latter has been planted for three years. This rotation can give good yields of both sugarcane and cassava.

Time of Planting and Harvesting

The climatical conditions in southern China are characterized by high temperatures and abundance of rainfall in the spring and summer, but rather cold and dry, sometimes with frost, in the autumn and winter. It is difficult for cassava to live through the winter. After many years of experience with cassava, farmers have determined the time of planting and harvesting that is most suitable for the climatical conditions in China. Cassava is usually planted in the spring, and when the temperature is high and there is abundance of rainfall in the summer, cassava grows rapidly. During the autumn the temperature and rainfall drop; this is a good time for cassava root production and the accumulation of starch. This is followed by the root harvest in winter.

From 1990 to 1994, an experiment was conducted at CATAS in Hainan to determine the optimum time for planting and harvesting cassava. In this trial, cassava was planted monthly and was harvested at either 8 or 12 months, using two varieties and four replications. The result (**Figure 1**) indicated that when cassava was harvested at 8 months, the highest yield was obtained when cassava was planted in Feb-May. When cassava was harvested at 12 months, the highest yield was obtained when cassava was planted in May-June, but in two out of three years cassava yields were not greatly affected by date of planting. The highest starch content was obtained by harvesting in Dec-March, inrespective of whether cassava was harvested at 8 or 12 months. The root yield at 8 months after planting was positively correlated both with the average temperature and rainfall during the 3d, 4th and 5th months after planting and this relationship was highly significant (**Figure 2**). The starch content was significantly and negatively correlated with the mean temperature during the last month before harvest: $r=-0.770^{**}$ and $r=-0.732^{**}$ for harvests of SC205 at 8 and 12 months, respectively (Zhang Weite, 1996). Root starch content was also negatively correlated with rainfall during the month prior to harvest, but the correlation was barely significant ($r=0.48^{*}$ for SC205 harvested at 8 months). These research results correspond well with the actual farmers practice. It made it clear that the time of planting and harvesting in China as practiced by farmers is very suitable for the existing climatical conditions. However, the research results indicate that in Hainan province cassava can be planted almost any time of the year as long as roots are harvested after a full 12-month cycle.

Table 5. Yield and gross income of two intercropping systems as compared to monoculture cassava in Qujiang county, Guangdong, China.

	Cassava root yield (t/ha)	Cassava income (Y/ha)	Intercrop yield (t/ha)	Intercrop income (Y/ha)	Total gross income (Y/ha)
Cassava	13.50	4500	-	-	4.500
Cassava+Peanut	15.12	5040	2.5	5.000	10.040
Cassava+watermelon seeds	18.00	6000	0.6	8.400	14.400

[1]Prices: cassava fresh roots: Y 0.33/kg
peanut dry pods: 2.00/kg
watermelon seeds: 14.00/kg

***Source:** Qujiang Agric. Bureau of Guangdong, 1988 (personal communication)*

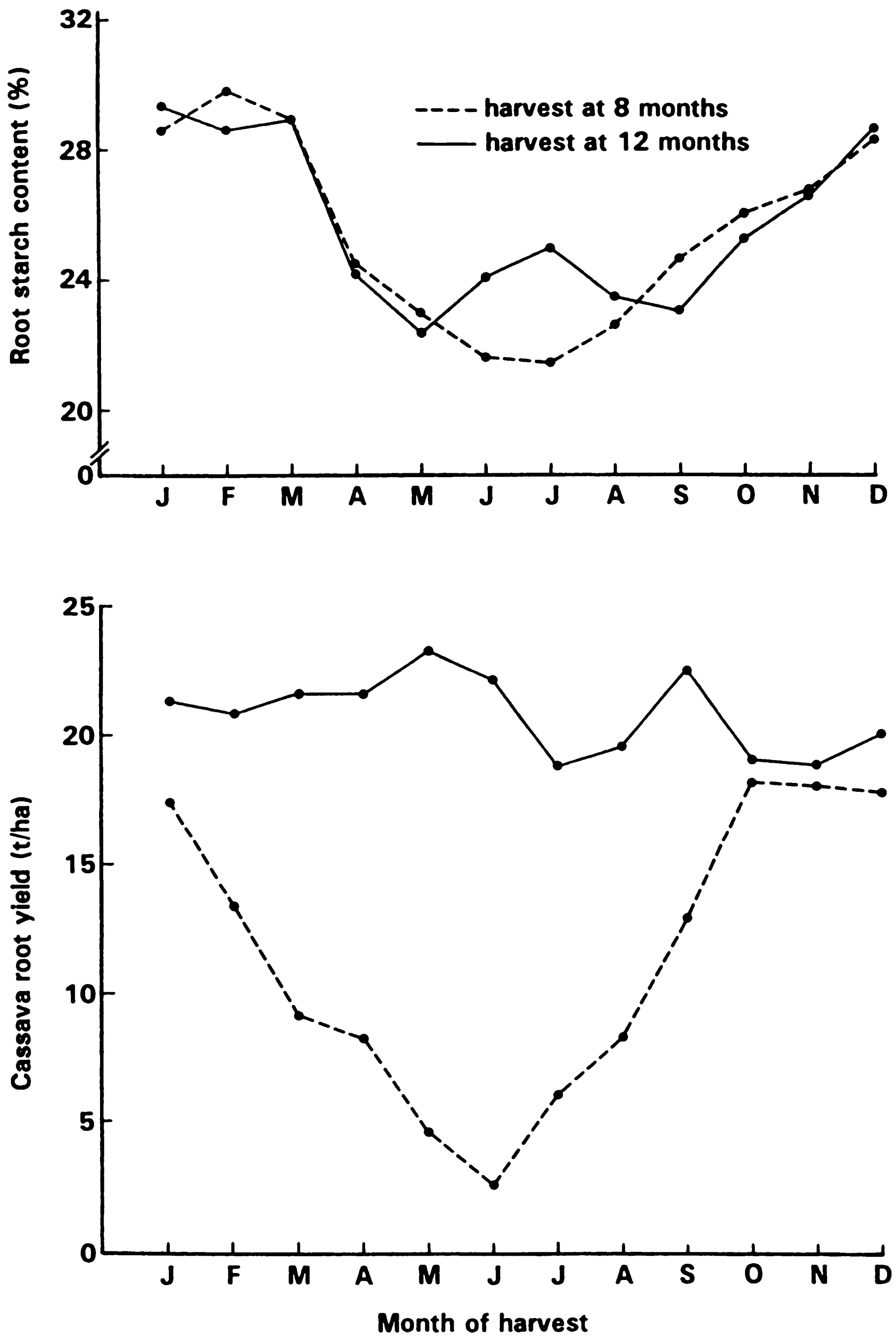

Figure 1. Cassava root starch content (top) and root yield (bottom) averaged over three varieties and three cropping cycles, when planted during different months of the year at CATAS, Danzhou, Hainan, China, and harvested after either 8 or 12 months.-

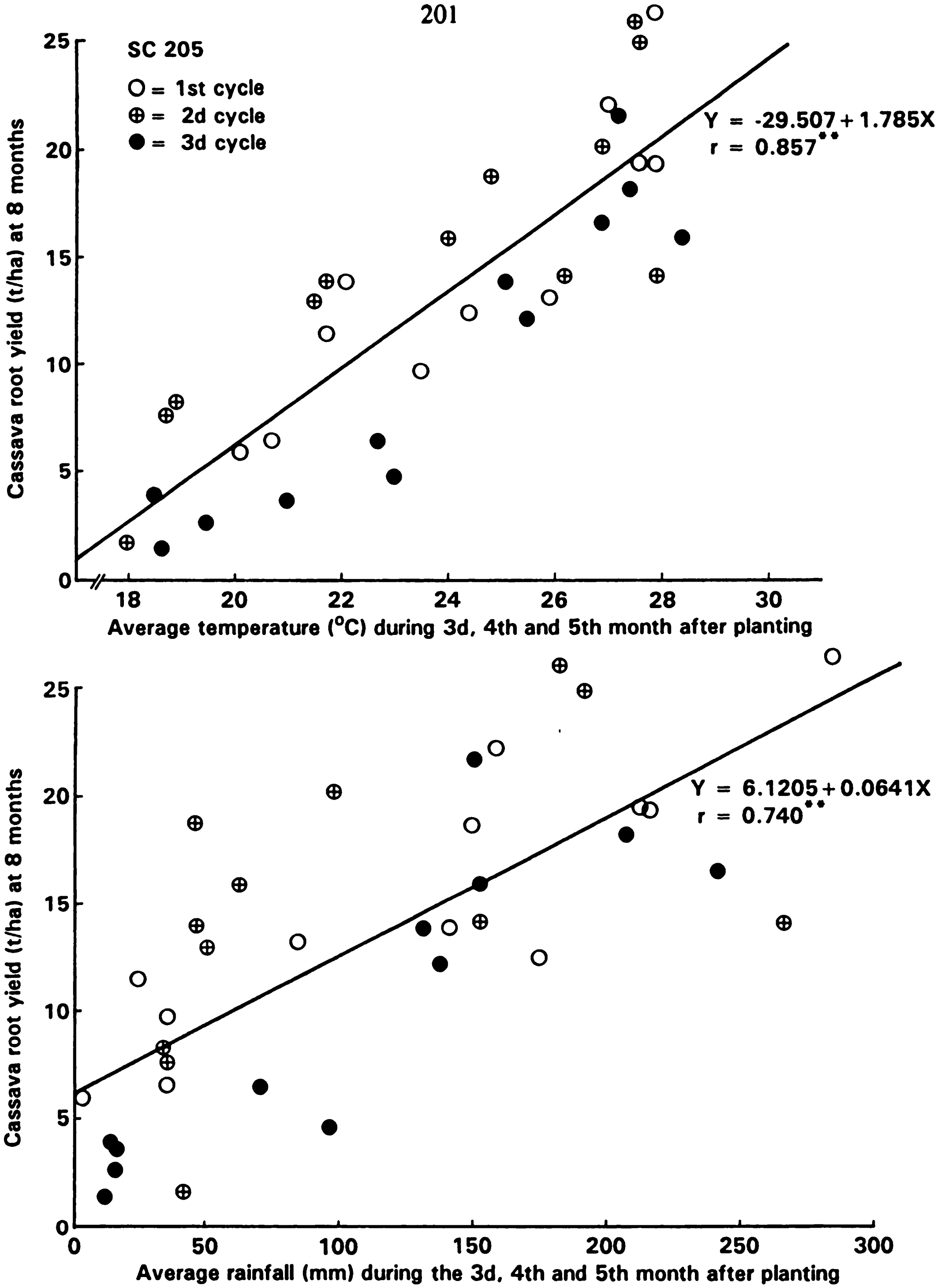

Figure 2. Relation between root yield of cassava cultivar SC205, harvested at 8 months, and the average mean temperature (top) or rainfall (bottom) during the 3d 4th and 5th month after planting in SCATC, Hainan, China. Data are for 36 monthly plantings from 1990 to 1993.

Planting Methods

In China, the method of cassava planting is different in different areas. Horizontal planting is normally practiced in steep land with zero tillage, while inclined planting is mostly used in the soft soil after tillage; vertical planting is sometimes adopted in regions with strong winds. Horizontal planting is easy to do and requires less labor, but sprouting is slow and percent germination may be low, resulting in lower yields. Vertical and inclined planting requires more labor, but the sprouting of stakes is fast and the percent germination is high; the root yield is also quiet good.

Table 6 shows the results of two planting method trials conducted at GSCRI from 1990 to 1992, and in CATAS in 1994. In both sites inclined planting produced highest yields, while horizontal planting produced the lowest. Vertical and inclined planting resulted in a higher percent germination at one month after planting than did horizontal planting. Ridging resulted in a lower percent germination than planting on the flat.

Table 6. Effect of stake planting position and ridging on cassava yield and germination at 1 month in GSCRI, Nanning, Guangxi, and in CATAS, Danzhou, Hainan, China. Data are the average for SC201 and SC205 in CSCRI, and for SC205 and SC124 at CATAS.

Planting Position		GSCRI (1990-1992)		CATAS (1994)
		Germination[1] (%)	Root yield[2] (t/ha)	Root yield (t/ha)
Horizontal				
	-ridging	61.5	11.7	20.0
	-no ridging	67.4	10.9	18.6
Inclined				
	-ridging	66.4	13.0	25.3
	-no ridging	78.1	11.5	16.9
Vertical				
	-ridging	82.8	11.1	19.4
	-no ridging	85.8	11.2	18.5

[1] Average of 1991 and 1992 (no data taken in 1990)

[2] Average of 1990 and 1992 (no harvest in 1991 due to drought)

Field Management of Cassava

As cassava is more and more produced under intensive farming practices, the old way of field management is no longer suitable. Cassava field management will move towards mechanized farming and more use of chemicals. In China weeds are usually controlled 2-3 times per year. Hand weeding costs too much labor, the work efficiency is low, one person weeding in one day on average 250-330 m^2 (30-40 mandays/ha). Due to the development of a market economy, the cassava planting area per farmer has been increasing year after year, now often being around 3-5 ha; in some areas more than 10 ha. Thus, hand weeding is no longer suitable for this type of cassava production. The use of pre-emergence herbicides is now in common use in Hainan; mechanized farming has also been introduced and has been practiced by some enterprises and companies, such as the Siyueten farm in Changjiang county of Hainan. Plowing, harrowing, stake cutting, contour ridging, planting, fertilizing, weeding, harvesting and root chipping are almost all done by machinery. In 1995 twenty ha and in 1996 one hundred ha of cassava were planted by machinery in this farm. The cost of production was reduced 30-40% and work efficiency has been raised 7-8 times. This is the way forward for intensive cassava farming in China.

Fertilization

The long-term fertility trials conducted in Guangdong, Guangxi and Hainan showed that when cassava was grown continuously in the same field, the combination of 100 kg N, 25 kg P_2O_5 and 100 kg K_2O/ha generally produced the highest yields and profits. In all three locations cassava responded mainly to the application of N, followed by K, while the response to P was generally not statistically significant, except at UCRI in Guangzhou (**Figure 3**). Application of 5-10 t/ha of pig manure in addition to modest rates of N, P and K further increased cassava yields in Nanning, but applications of "burned soil", i.e. a mixture of leaves and twigs slowly burned together with soil, had no significant effects on yield even at high application rates of 30-60 t/ha. Applications of K tended to increase the starch content of roots, applications of N tended to decrease starch while that of P had no significant effect (**Figure 4**).

In a rate of fertilizer application trial, conducted in CATAS, cassava yields increased with increasing amounts of fertilizer applied; the application of 400-900 kg/ha of 15-15-15 compound fertilizer gave the highest profits, as shown in **Table 7**.

Table 8 shows the effect of N, P and K, applied singly or combined, on cassava yields in a trial conducted at CATAS from 1989 to 1990. Combined application of N, P and K was better than that of any single nutrient, and the application of N alone or NK were better than that of P or K alone or in combination.

Table 9 shows the results of a time-of-fertilizer-application trial conducted at CATAS in 1988. A single application at 30 days after planting or a split application at

30 and 90 days resulted in higher yields than later applications. When fertilizer application was postponed, the yield and the number of roots decreased. There was no significant difference between a single application and a split application using the same total amount of fertilizer.

Table 7. Effect of different amounts of applied 15-15-15 compound fertilizer on cassava root yield and net income when cassava, SC205,was planted at CATAS, Danzhou, Hainan, China in 1988 and 1989.

Amount of fertilizer (kg/ha)	Cassava root yield(t/ha)			Gross income (Y/ha)[1]	Fertilizer costs (Y/ha)	Net income (Y/ha)[2]
	1988	1989	Average			
0	18.6	21.8	20.2	2828	0	2828
150	23.0	31.6	27.3	3822	75	3747
300	27.2	27.3	27.2	3808	150	3658
400	28.2	38.9	33.5	4690	200	4490
900	35.6	34.1	34.8	4872	450	4422
LSD (0.05)	7.2	4.2				
(0.01)	10.1	5.9				

[1] Prices: Cassava fresh roots: Y140/ton
15-15-15 fertilizers: 0.5/kg

[2] Net income=gross income minus fertilizer costs.

Table 8. Effect of N, P and K application, either single or in combination, on the fresh root yield (t/ha) of cassava, SC205, planted in CATAS, Danzhou, Hainan, China from 1988 to 1990.

Treatments	1988	1989	1990	Average
No NPK	15.0	23.1	17.5	18.5
N	16.3	29.5	28.0	24.6
P	20.0	25.3	21.7	22.3
K	19.3	28.6	19.7	22.5
NP	16.8	27.7	22.8	22.4
NK	21.8	31.1	33.7	28.9
PK	22.7	28.5	22.7	24.6
NPK	24.8	34.7	30.2	29.9

Table 9. Effect of time of application of fertilizers on cassava root numbers and root yield at CATAS, Danzhou, Hainan, China, in 1988.

		Root numbers/plant	Root yield (t/ha)
Check without fertilizers		8.5	14.5
Fertilizers applied at:			
	30 days after planting	11.8	27.2
	60 days after planting	9.0	24.8
	90 days after planting	8.5	24.2
	120 days after planting	7.9	22.0
Fertilizers applied at:			
	30 and 90 days	11.1	27.5
	60 and 120 days	9.7	23.7
LSD	(0.05)	2.3	4.9
	(0.01)	3.1	7.5

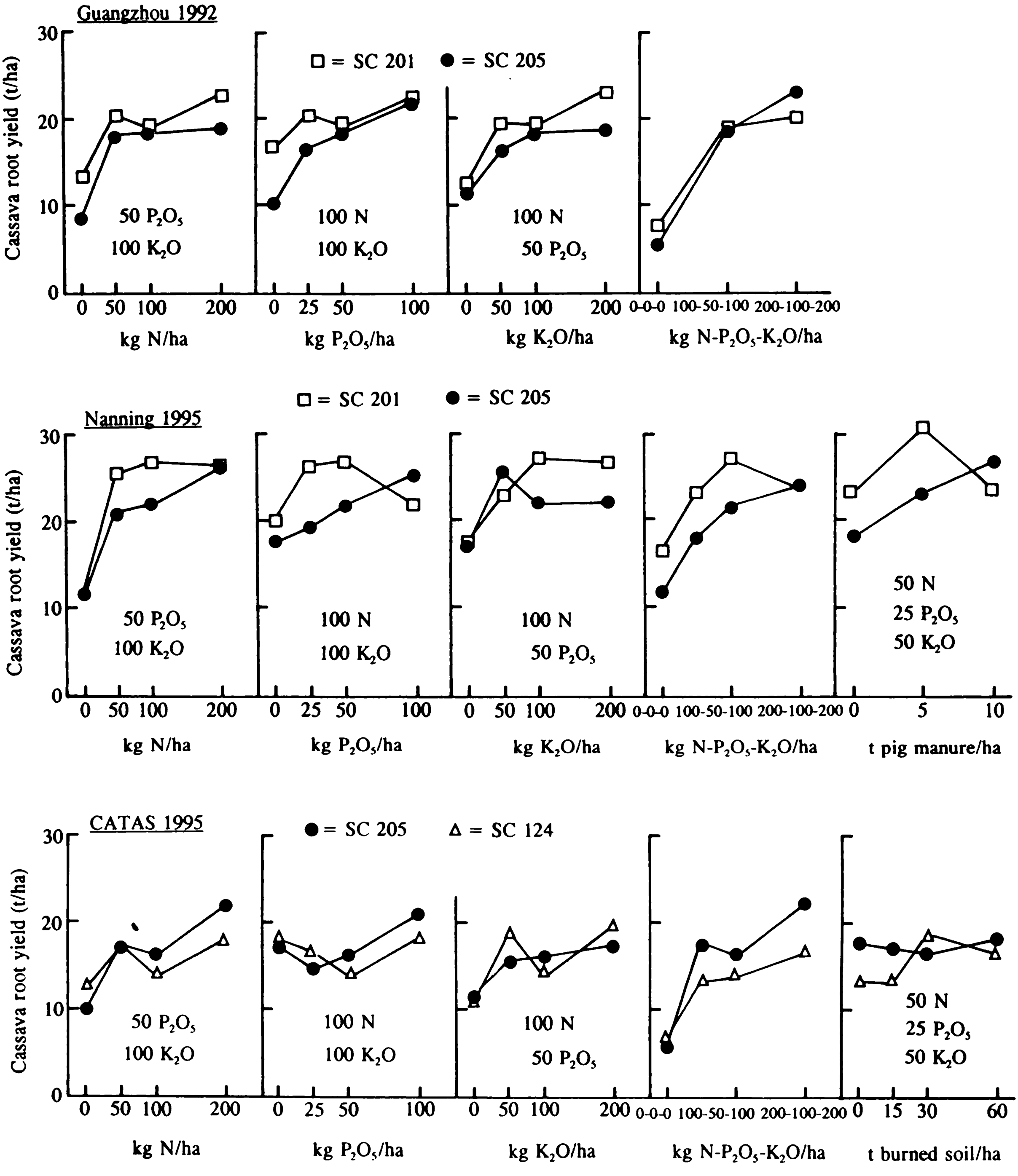

Figure 3. Effect of annual applications of various levels of N, P and K on the root yields of two cassava cultivars grown for the 4th consecutive year at UCRI in Guangzhou, Guangdong, for the 7th year at GSCRI in Nanning, Guangxi, and for the 4th year at CATAS in Danzhou, Hainan.

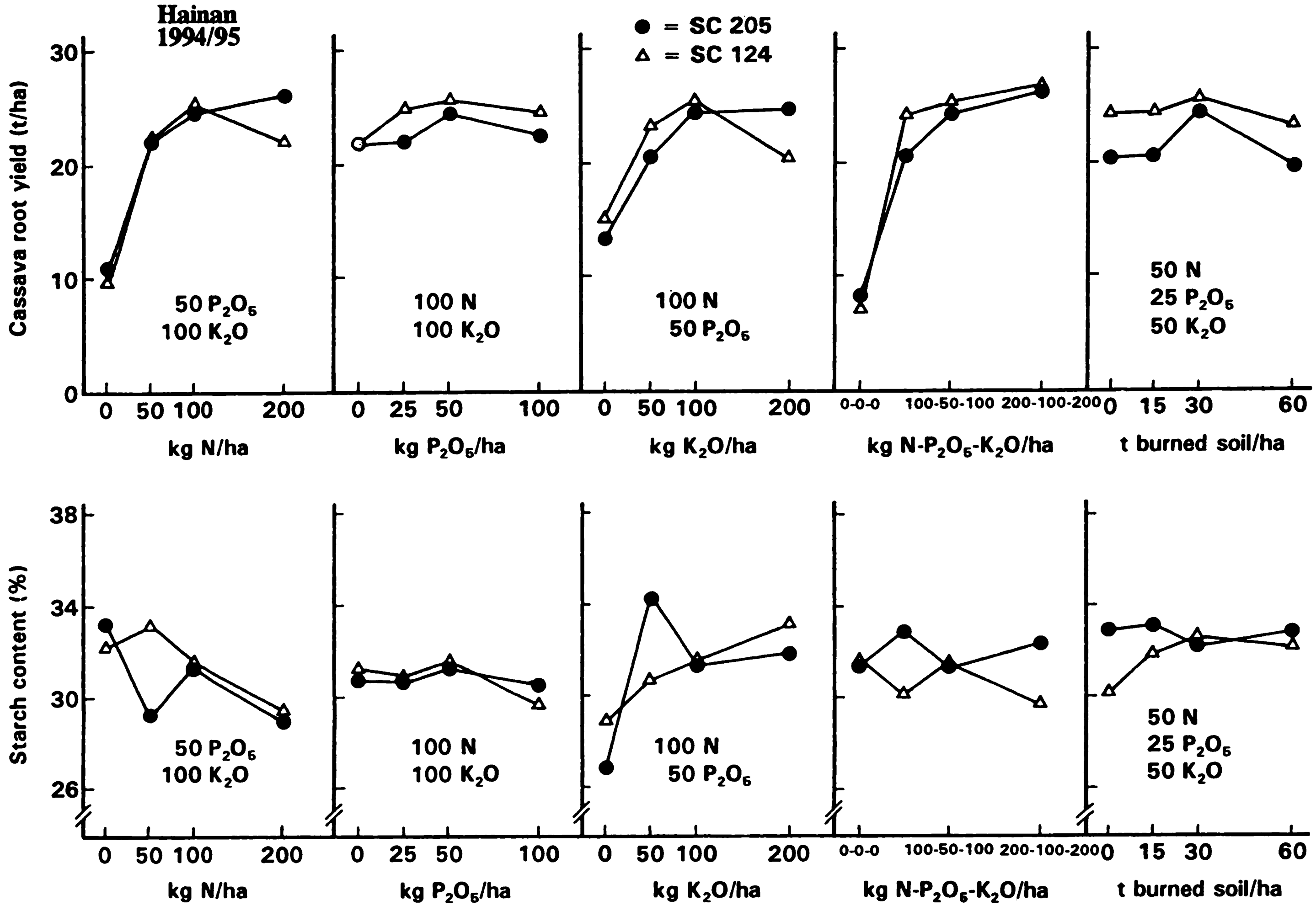

Figure 4. Effect of the annual application of various levels of N, P and K fertilizers or of "burned soil" on the fresh root yield and starch content of two cassava cultivars grown in CATAS, Hainan, in 1994/95 (3rd year).

Harvesting Methods

Cassava harvesting methods in China can be divided into hand harvesting and mechanical harvesting. Harvesting by hand is the most common. Hand harvesting requires heavy work and has low efficiency, usually requiring 30 mandays/ha. Mechanical harvesting is rather light work and has high efficiency; on average one machine can harvest 0.4-0.5 ha per day. In the 1970s and 80s, Xijiang State Farm in Guangxi was a special cassava farm; over 70% of cassava farming work was done by machinery. But later the farm changed to cultivate other crops, and the machinery was left unused. In 1995, Siyueten Farm in Changjiang county, Hainan, began to develop cassava machinery. Now 80% of cassava work on that farm is done by machinery. Production costs have been reduced by one-third, and productivity has increased markedly.

Stem Storage

Due to the cold and dry weather in winter, sometimes with frost, the cassava harvesting time in China is normally from Nov to March, and planting time from Jan to April. Harvesting must be done before the onset of frost to guarantee that good quality stakes can be stored for use next year. In the north, the cold weather arrives earlier and lasts longer. During the winter cassava may suffer seriously from frost. Thus, in the north the cassava harvest time is from Nov to Jan and planting time from March to April. Thus, the period of stake storage is 4-5 months. In the south, the cold weather arrives later and lasts only a short time, so cassava rarely suffers from frost. Therefore, the harvest is usually done from Dec to March and planting from Jan to April. Thus, the storage method of stakes is different in the south and the north. In the south stems are usually stacked under the shade of trees, and then the stems are covered with dry straw. If the weather is very dry, water is splashed on the stems. Stem storage is light work and easy to do. But in the north, the stems are normally stored in soil trenches or pits. Trenches or pits are dug in a southern exposure and in more elevated areas. The stems are bundled and placed in the trenches or pits, and are then covered with straw and soil, allowing some air ventilation. It is important to assure that the trenches do not get waterlogged. Stem storage in the northern regions is heavy work, and if something is done wrong, it can cause stake damage. This is a principal sector constraint for cassava production in the northern part of China.

General Recommendations

Table 10 summarizes some general recommendations for cassava production in China based on results obtained from research conducted at various institutes during the past ten years.

Table 10. Recommended cultural practices for sustainable cassava production in China.

1. Variety:	use high yielding and vigorous varieties: SC 201: tolerant to poor soils and cold climate SC 205: high yield in better soils SC 124: high yield and cold tolerant SC 8002: high yield and cold tolerant SC 8013: high yield and typhoon tolerant
2. Planting time:	Guangdong/Guangxi: March-April Hainan: Feb-May or year-round if harvested at 12 months
3. Land preparation:	plow once or twice at 15-20 cm depth with tractor or oxen; on gentle slopes: make contour ridges after plowing on steep slopes: plow with oxen or prepare planting holes with hoe
4. Planting material:	select healthy 10-11 month old plants; store stems in frost-free location; cut 15-25 cm long stakes after eliminating dry portion of stem
5. Planting method:	inclined or vertical with buds facing up, 5-10 cm deep; plant on ridges if soil is wet, on flat if very dry
6. Fertilization:	5-10 t/ha of manure incorporated before planting 50 kg N/ha as urea 20 kg P_2O_5/ha as simple or triple superphosphate (or thermo-phosphate if soil is low in Mg) 50-80 kg K_2O/ha as KCl
	N, P and K applied at first weeding at 1-2 months after planting.
7. Weeding:	2-3 times manually, at 30-45 days and 2-3 months later; or pre-emergence herbicide right after planting and post-emergence herbicide (using shield) at 2-3 months after planting.
8. Harvest:	at 10-12 months; incorporate leaves and stems back into the soil.
9. Intercropping:	cassava may be intercropped with two rows of peanut or mungbean, with one row of maize or with watermelon, squash etc.
10. Erosion control:	plant 1 row of vetiver grass (10-15 cm between plants) along the contour, with 1 m vertical distance between contour lines. Cut leaves back to 30 cm above ground at planting of cassava and at 4-6 months; spread the cut leaves on soil surface between cassava plants.

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RECENT PROGRESS IN CASSAVA AGRONOMY RESEARCH IN THAILAND

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ABSTRACT

Cassava agronomy research in Thailand during 1994-1996 emphasized mainly erosion control, soil fertility maintenance and weed control.

Regarding soil erosion control, the planting of cassava in April, at the start of the rainy season, and harvesting in March resulted in the highest soil loss compared with other planting dates. Planting at the start of the dry season in Dec and harvesting in Nov produced by far the highest cassava yield, while soil loss due to erosion was relatively low. Intercropping cassava with either peanut or pumpkin were found to be the best cropping systems to reduce erosion while also giving high gross incomes. Cassava planted on contour ridges at closer spacing (1.0x0.6 m) and with fertilizer application was the most promising package of cultural practices for reducing erosion and increasing yields.

Soil fertility maintenance through the use of legumes grown for *in-situ* production of mulch was studied at Rayong Research Center. The highest yield of cassava, 46.17 t/ha, was obtained when *Crotalaria juncea* was planted as a green manure and mulched, followed by planting cassava, which was then harvested after 18 months. When *Canavalia ensiformis* was intercropped with cassava, cut at 2 months and left as a mulch, the yield of cassava, harvested at 12 months, was as high as that obtained with a high rate of chemical fertilizers.

The sequential planting of fertilized Rayong 60 after unfertilized peanut, produced the highest yield at Kalasin in the Northeast. The cultivar Rayong 5 planted in either Sattahip or Banbung soils in the East produced a relatively high yield with application of 312 kg/ha of 15-15-15 together with 100 kg of urea and 78 of KCl/ha. In the Northeast the application of 25-25-25 kg/ha of N, P_2O_5 and K_2O produced a significantly higher yield of Kasetsart 50, Rayong 5, Rayong 60 and Rayong 90 than without fertilizer application.

Research on the long-term effect of soil management on cassava planted continuously for 15 years in Khon Kaen in the Northeast, showed that when cassava was rotated yearly with sequentially planted peanut and pigeonpea, this could maintain a relative cassava yield of 87% of that obtained in the first year. Similarly, the application of soil amendments (lime, rock phosphates and compost), as well as that of soil amendments with chemical fertilizers, could reduce the rate of yield decrease over time. However, after 15 years of continuous cropping the cassava yields in all treatments were lower than those obtained in the first year.

Research on the optimum period of weed control for Rayong 60 and Rayong 90, planted in both the early and late rainy seasons in the Northeast, indicate that both cultivars need to be free of weeds at least three months after planting in order to produce high yields.

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The most appropriate weeding method for cassava intercropped with either mungbean or peanut, was the application at planting time of the pre-emergence herbicide Metolachlor at the rate of 1.50 kg ai/ha, followed by spot application of the post-emergence herbicide Paraquat at the rate of 0.50 kg ai/ha whenever necessary.

INTRODUCTION

The Thai cassava breeding programs have recently released several new cultivars with high yield potential and high starch content, such as Rayong 90 and Rayong 5 and Kasetsart 50. Thus, the lack of good cultivars is now less of a problem to cassava farmers. But, appropriate cultural practices are still needed to attain the high yield potential of these cassava cultivars. Most research on cassava cultural practices has focused on soil fertility maintenance/improvement in those regions where the crop is grown continuously, with somewhat less emphasis on appropriate cultural practices to obtain high yield or income.

Regarding the decline in soil productivity by continuous production of cassava, research has focussed on erosion control and soil fertility maintenance, while research on cultural practices for the newly recommended cultivars, such as optimum rate of fertilizer application and weed control for both monoculture and intercropped cassava, had also high priority.

Soil Erosion Control

Research on cassava soil conservation has continued since the last Workshop in 1993. Several erosion control experiments were conducted at Rayong Field Crops Research Center and in Pluakdaeng town of Rayong province, where cassava experiments were planted on 4-6% slope with highly erodable sandy loam soils.

The objective of these experiments was to quantify the effects of different planting dates, intercropping and various cultural practices on both soil erosion and cassava yield. Eroded sediments were collected from plastic covered channels dug along the lower side of each plot. At monthly intervals the sediments from each plot were weighed and samples were taken to be dried, in order to determine soil losses on a dry weight basis. Results of some experiments conducted from 1994 to 1996 are as follows:

1. Effect of planting date on cassava yield and soil loss

Table 1 shows the effect of cassava planting date on the root yield and soil loss in an experiment conducted on 4.2% slope at Rayong Field Crops Research Center. The cultivar Rayong 90 was planted at six different times of the year; there were no replications. Rainfall received in the different planting date treatments varied from 777 to 1893 mm, while the total dry soil loss ranged from 7.5 to 12.8 t/ha, and the cassava yield varied from 15.5 to 46.4 t/ha.

Table 1. Effect of cassava planting date on total dry soil loss due to erosion, and on root yield and starch content of Rayong 90 planted at Rayong Field Crops Research Center in Rayong, Thailand in 1994/95/96.

Planting date (Planting-Harvest)	Rainfall received (mm)	Total dry soil loss (t/ha)	Plants harvested (#/ha)	Fresh root yield (t/ha)	Root starch (%)
June'94-May'95	777	7.68	9906	15.47	22.3
Aug'94-July'95	997	7.47	9906	24.68	20.0
Oct'94-Sept'95	1265	7.98	9806	38.09	29.2
Dec'94-Nov'95	1749	8.14	8175[1)]	46.44[1)]	28.0
Febr'95-Jan'96	1731	9.65	9038[1)]	39.04[1)]	33.0
April'95-March'96	1893	12.76	9806	37.52	28.6

[1)]Some irrigation was used to ensure establishment during the dry season.
***Source:** Rayong Field Crops Research Center, Annual Report 1996.*

The greater the amount of effective rainfall the higher the soil loss. Cassava planted in April and harvested in March received the highest amount of rain, which also caused the greatest soil loss of 12.8 t/ha and resulted in a root yield of 37.5 t/ha. But the highest root yield of 46.4 t/ha was obtained from planting in Dec and harvesting in Nov, which also received a lot of rain and caused a considerable amount of soil loss of 8.1 t/ha. Root starch content of Rayong 90 planted at different dates varied from a low of 20.0 to a high of 33.0% due to different months of harvest. The highest root starch content of 33% was obtained when Rayong 90 was harvested in the dry month of January.

2. Use of economic covercrops to increase cassava profitability and reduce erosion

Table 2 shows the results of an experiment on the use of economic covercrops to increase cassava profitability and reduce erosion, conducted in 1994 and 1995, on sandy loam soil with 5% slope in Pluakdaeng of Rayong province. Cultivar Rayong 90 was planted in ten different cropping systems without replication. In the 1994/95 experiment, the effective rainfall was only 589 mm, compared with 1592 mm in 1995/96. Nevertheless, soil loss due to erosion was high, ranging from 9.1-35.6 t/ha in 1994/95, but only 10.6-19.9 t/ha in 1995/96. This is due to very heavy rainfall of 188 mm during Oct 1994, which caused serious run-off in all plots, but particularly in two plots of sole cassava and cassava intercropped with watermelon. In both years the results show the same trend: intercropping cassava with peanut was the most effective in reducing soil loss due to erosion, while intercropping with cucumber or pumpkin was intermediately effective. When the intercrops were planted one month after cassava, they were less effective in reducing erosion.

Table 2. The effect of different cropping systems on soil loss due to erosion, on the yields of cassava and intercrops, and on total gross income when cassava, Rayong 90, was grown on 5% slope in Pluak Duang, Rayong, Thailand in 1994/95 and 1995/96.

Cropping pattern	1994/95					1995/96				
	Dry soil loss (t/ha)	Cassava		Intercrop yield (kg/ha)	Total gross income[1] (US$/ha)	Dry soil loss (t/ha)	Cassava		Intercrop yield (kg/ha)	Total gross income[1] (US$/ha)
		Fresh roots (t/ha)	Starch (%)				Fresh roots (t/ha)	Starch (%)		
1. Sole cassava	32.26	9.93	12.3	-	498.53	13.62	20.18	21.8	-	791.18
2. Cassava+peanut (2rows)	9.07	4.92	12.9	875	559.07	10.61	17.11	19.6	906	999.51
3. Cassava+watermelon	35.64	11.31	12.1	-[2]	567.65	16.61	18.11	18.8	2119	1082.84
4. Cassava+muskmelon	16.94	10.53	10.7	369	606.86	13.37	19.88	18.3	7125	2952.45
5. Cassava+cucumber	14.94	12.83	14.7	119	707.10	12.51	19.18	16.9	5831	1820.10
6. Cassava+pumpkin	18.75	11.06	11.8	2900	1123.53	10.93	20.96	22.4	2900	1190.93
7. Cassava+watermelon at 1 month	19.68	10.71	13.9	-[2]	554.17	15.43	16.38	19.1	-[2]	616.42
8. Cassava+muskmelon at 1 month	11.11	19.06	13.0	-[2]	971.32	19.88	25.63	17.6	-[2]	924.51
9. Cassava+cucumber at 1 month	13.54	11.94	17.2	-[2]	646.08	15.23	16.96	20.6	-[2]	651.72
10. Cassava+pumpkin at 1 month	10.79	9.33	13.4	331	541.18	13.98	25.07	18.3	-[2]	904.41

Note: In 1994/95: #rainy days: 64; rainfall received: 589 mm
In 1995/96: #rainy days: 105; rainfall received: 1592 mm

[1]Price of cassava: 1995 B 1.25/kg
1996 B 0.98/kg

[2]No yield of intercrops due to poor establishment or competition from cassava

***Source:** Rayong Field Crops Research Center, Annual Reports 1995 and 1996.*

Table 2 shows that some cropping systems produced no yield of intercrops due to either poor establishment or due to competition from cassava. In both years, most intercrops failed to grow well when planted one month after cassava, but nearly all established well and yielded better when planted simultaneously with cassava, i.e. peanut, muskmelon, cucumber and pumpkin yielded 875, 369, 119 and 2900 kg/ha, respectively, while all failed when planted one month after cassava, except pumpkin; but in that case the yield was only 331 kg/ha. Cassava yields ranged from 4.9-19.1 t/ha. Due to rather dry weather in 1994/95, with only 589 mm of rainfall in the experimental period, there was strong competition between crops for soil water. Intercropping cassava with peanut resulted in the lowest cassava yield of 4.9 t/ha, but this treatment was effective in reducing soil loss. Nevertheless, total gross income from the various intercropping systems was generally higher than that of sole cassava. The highest gross income was obtained from intercropping cassava with pumpkin, both crops planted at the same time.

In the 1995/96 experiment the same trends were observed. When the intercrops were planted simultaneously with cassava, the intercrops grew well and yielded much better than when they were planted one month after cassava. Peanut, watermelon, muskmelon, cucumber and pumpkin yielded 906, 2119, 7125, 5831 and 2900 kg/ha, respectively, but no intercrops planted one month after cassava could yield anything due to shading from cassava. Cassava yields ranged from 16.4 to 25.6 t/ha. Intercropping with peanut reduced cassava yields only about 15% due to less competition for soil moisture compared with the previous year. Total gross income for the intercropping systems with simultaneous planting was always higher than that of cassava monoculture. The highest gross income was obtained from cassava intercropped simultaneously with muskmelon. The gross income varied from year to year due to variations in the price of each crop.

Considering both the effectiveness in reducing soil loss and the gross income obtained, the systems of intercropping cassava with peanut or pumpkin, both planted at the same time as cassava, appeared the most promising.

3. Cultural practices for erosion control on farmer's fields

Table 3 shows the results of experiments on different cultural practices to control erosion in cassava, cv. Rayong 1, conducted on farmers' fields in four locations in Rayong province in 1994/95 and 1995/96. Each trial compared five "improved practices" with the "farmer's practice" without replication. In all locations the soil had a light sandy loam texture with slopes ranging from 4.3 to 6.7%. The overall average soil loss due to erosion in the different locations in 1994/95 ranged from 5.1 to 43.1 t/ha, and in 1995/96 from 7.2 to 18.0 t/ha. In both years the soil loss depended on the rainfall and the slope at each location, except that in Nongrai soil loss was very low because of natural terrace formation as a result of land preparation in the same trial conducted during two previous years.

Table 3. Slope and rainfall as well as the average dry soil loss due to erosion in on-farm erosion control trials conducted in four locations in Rayong province of Thailand in 1994/95 and 1995/96.

Location	Slope (%)	Rainfall (mm)	#Rainy days	Dry soil loss (t/ha)
1994/95				
1. DLD Center, Rayong	6.05	1071	80	43.10
2. Nongrai, Rayong	4.80	890	58	5.10
3. Nongbua I, Rayong	5.10	832	58	30.51
4. Nongbua II, Rayong	4.30	831	58	27.24
1995/96				
1. DLD Center, Rayong	6.05	1585	107	17.88
2. Nongrai, Rayong	4.80	1325	96	7.19
3. Mabka I, Rayong	6.70	1475	97	16.98
4. Mabka II, Rayong	5.50	1475	97	17.99

***Source:** Rayong Field Crops Research Center, Annual Reports 1995 and 1996.*

The actual "farmer's practice" varied from site to site each year. In the 1994/95 experiments, three of the four farmers planted cassava on contour ridges and all applied 15-15-15 fertilizers at a rate of about 206 kg/ha. In the 1995/96 experiment all farmers planted cassava on contour ridges and again applied 15-15-15 fertilizer at a rate of 206 kg/ha.

Table 4 shows the effect of different cultural practices on cassava yield and soil loss in the 1994/95 and 1995/96 experiments. In the 1994/95 experiments, the average dry soil loss caused by different cultural practices ranged from 20.5 to 38.6 t/ha, while the cassava yields ranged from 11.7 to 18.8 t/ha. Best results were obtained from cassava planted at 0.8 x 0.8 m on contour ridges and with fertilizer application; this produced the highest cassava yield of 18.8 t/ha with the least soil loss of 20.5 t/ha. There were some questionable data on soil erosion at Nongbua II during the first month (July) with rainfall as high as 319 mm in 14 days; this heavy rain broke some contour ridges in treatment 3, thus causing higher than normal levels of erosion. To solve the problems of runoff water entering the plots from fields above, it was suggested to partially dig into the soil narrow strips of zinc sheet along the upper side of the plots.

Table 4. Effect of various cultural practices on cassava yield and on soil erosion in on-farm trials conducted in four locations of Rayong province, Thailand in 1994/95 and 1995/96. Data are averaged over those locations.

Treatments	1994/95				1995/96			
	Plants harvested (#/ha)	Fresh root yield (t/ha)	Starch content (%)	Total dry soil loss (t/ha)	Plants harvested (#/ha)	Fresh root yield (t/ha)	Starch content (%)	Total dry soil loss (t/ha)
1x1 m, No ridge,No fertilizers	8,331b	11.81b	17.20	23.56	9,363c	11.50c	17.70	18.50ab
1x0.6 m, No ridge, +fert.[1)]	14,088a	14.56ab	16.65	38.63	15,481a	18.56ab	17.73	26.75a
1x0.6 m, Contour ridge+fert.	14,106a	17.75a	16.88	27.94	15,750a	21.75a	19.35	8.56b
1x0.6 m, No ridge,No fert.	14,631a	11.75b	19.25	24.75	15,269a	13.00bc	20.05	15.31ab
0.8x0.8, Contour ridge, +fert.		18.78a	18.38	20.49		22.78a	20.30	10.23b
Farmers' practice	14,306a	15.38ab	17.20	23.81	13,656b	19.75a	18.05	10.69b
F-test	**	**	NS	-	**	**	NS	**
CV(%)	6.86	14.68	10.77	-	4.63	15.42	7.80	39.99

[1)] +Fert. = 15-15-15 fertilizer applied at the rate of 312.5 kg/ha

***Source:** Rayong Field Crops Research Center, Annual Reports 1995 and 1996.*

In the 1995/96 experiment, soil loss from different cultural practices ranged from 8.6 to 26.7 t/ha and cassava yields ranged from 11.5 to 22.8 t/ha. The best results were again obtained from cassava planted at either 0.8x0.8 m or 1.0x0.6 m on contour ridges and with fertilizer application; those treatments resulted in the highest cassava yields of 22.8 and 21.7 t/ha, with relatively low soil loss of 10.2 and 8.6 t/ha, respectively. When cassava was planted without contour ridges the soil loss was higher, ranging from 15.3 to 26.7 t/ha. The results of these two years of experiments show clearly that contour ridge planting can reduce soil erosion in cassava fields while increasing cassava yields; they also indicate that fertilizer application will generally increase yields, but contrary to previous results obtained, it also increased erosion.

Soil Fertility Maintenance

Several studies on the maintenance of soil fertility in cassava fields through the use of green manures, chemical fertilizers or soil amendments were conducted in the East and Northeast of Thailand, where cassava is the major upland crop. The overall objective was to maintain or improve the soil fertility in fields of continuously grown cassava in order to sustain a high long-term productivity.

Results of a study on soil fertility maintenance through the use of green manures conducted from 1988 to 1994 at Pluakdaeng in Rayong province have shown that legume species such as *Crotalaria juncea, Mucuna fospeada* and *Canavalia ensiformis*, when planted as green manures, could improve soil fertility and increase cassava yields (Tongglum *et al.*, 1992; Sittibusaya *et al.*, 1995). In the 1991/92 experiment these legume species produced 7.31, 4.83 and 5.17 t/ha of above-ground dry matter, respectively, which contained 123, 157 and 136 kg/ha of total N. The yield of cassava increased from 3.6 t/ha without green manure to 7.7, 7.0 and 6.0 t/ha when these green manures were used.

It was found that incorporating the green manures into the soil had no significant effect on cassava yield compared to leaving the cut green manures as a mulch on the soil surface, resulting in average yields of 8.3 and 7.4 t/ha, respectively (RFCRC, 1994).

1. Effect of green manures grown as in-situ production of mulch on cassava yield

In 1994/95 a new study was conducted at Rayong Field Crops Research Center with the objective of determining the most appropriate management of green manures grown for *in-situ* production of mulch, which would produce high yields of cassava and maintain soil productivity. Rayong 90 was used as the test variety in the experiment and four species of green manures, i.e. *Crotalaria juncea, Canavalia ensiformis*, pigeonpea ICP 8094 and *Mucuna fospeada*, were planted, in three systems: 1. simultaneously intercropped in cassava and cut off and mulched at 2 MAP; 2. interplanted into 6-7 month old cassava and mulched before the next cassava planting; or 3. planted as a normal green manure, cut and incorporated before planting of cassava, which would then be harvested at 18 months. In addition, in two treatments cassava was intercropped with cassava which was either pulled up or cut off at 2 months and mulched. These various green manure treatments were compared with two treatments of sole cassava with fertilizer 13-13-21 applied at rates of either 156.25 or 468.75 kg/ha.

Table 5 shows that among the green manures *Crotalaria juncea* always produced the highest above-ground dry matter, ranging from 1.44 to 9.89 t/ha, which contained 39.9 to 262.1 kg/ha of total N. Pigeonpea was the next most productive green manure, followed by *Canavalia ensiformis*, while *Mucuna fospeada* failed to germinate. *Crotalaria juncea, Canavalia ensiformis* and pigeon pea planted as intercrops in a 6-7 month old cassava stand, produced higher above-ground dry matter, which contained also more N than other management treatments, since these green manures were left to grow and were cut only after 4.5 months (at cassava harvest).

Cassava yields ranged from 8.75 to 46.17 t/ha. Very high cassava yields, ranging from 38.8 to 46.2 t/ha were obtained when cassava was harvested at 18 months for a 2-year cycle. The highest cassava yield of 46.2 t/ha was obtained when *Crotalaria juncea* was planted as a green manure and then cut and mulched before planting cassava, which was then harvested at 18 months. Of those treatments harvested at 12 months, lowest yields were obtained when cassava was intercropped with cassava, which was cut at 2 months at 30 cm above ground level to serve as mulch, as well as the interplanting of *Crotalaria juncea* into a 6-7 month old cassava stand, due to the strong competition from the intercropped cassava or *Crotalaria*. The other treatments produced cassava yields ranging from 15.9 to 23.8 t/ha, which were not significantly different from the treatment without green manure but with high fertilizer application. The intercropped *Crotalaria juncea* planted at 6-7 MAP cassava exerted a strong competitive effect on cassava, resulting in a yield reduction; intercropping cassava with cassava also reduced yields, not only by the competitive effect but also because the cassava intercrop produced the lowest amount of mulching material. According to the objective, the intercrop residues were left as mulch for the next cassava crop. However, the results in **Table 5** show only the competitive effect on the yield of cassava in the first year, but the residues of these green manures are to be mulched for the next cassava crop, which may show a positive effect on cassava yield in the second year. With regard to the usual harvest of cassava at 12 months, when *Canavalia ensiformis* was planted as an intercrop at the same time as cassava, cut at 2 months and left as mulch, this increased the cassava yield to 26.9 t/ha, nearly as high as that of sole cassava with a much higher fertilizer rate of 469 kg/ha of 13-13-21.

Table 5. The effect of green manures grown as *in-situ* production of mulch on the yield of cassava grown at RFCRC in Rayong, Thailand in 1994/95/96.

Treatment	Green manures (t/ha)	Total N (kg/ha)	Plants harvested (#/ha)	Fresh root yield (t/ha)
1. Cassava+Fert.13-13-21 (156 kg/ha)	-	-	8613	17.56
2. Cassava+Fert.13-13-21 (469 kg/ha)	-	-	9169	29.78
3. Cassava+*Crotalaria juncea* (cut at 2 months)	1.92	44.75	8888	23.75
4. Cassava+*Canavalia ensiformis* (cut at 2 months)	0.94	20.13	9025	26.94
5. Cassava+Pigeon pea ICP 8094 (cut at 2 months)	1.09	27.00	8613	21.39
6. Cassava+*Mucuna fospeada* (cut at 2 months)	-	-	9444	20.28
7. Cassava+cassava (pulled out at 2 months)	0.36	11.75	8750	18.25
8. Cassava+cassava (cut at 2 months)	0.09	1.69	8613	12.00
9. Cassava+*Crotalaria juncea* (6-7 months)	9.89	262.13	8888	8.75
10. Cassava+*Canavalia ensiformis* (6-7 months)	1.54	36.63	9306	22.83
11. Cassava+Pigeon pea ICP 8094 (6-7 months)	8.92	221.69	9725	15.86
12. Cassava+*Mucuna fospeada* (6-7 months)	-	-	9025	17.25
13. *Crotalaria juncea*-Cassava(18 months)	1.44	39.94	8888	46.17
14. *Canavalia ensiformis*-Cassava(18 months)	0.93	18.38	9725	42.98
15. Pigeon pea ICP 8094-Cassava(18 months)	1.05	25.63	8056	38.81
16. *Mucuna fospeada*-Cassava(18 months)	-	-	9306	38.86
LSD(0.01)	-	-	-	13.45
F-test	-	-	NS	**
CV(%)	-	-	7.28	23.88

Note: Treatments 9-12: green manures were cut at 4.5 months (at harvest of cassava)
Treatments 6, 12 and 16: *Mucuna fospeada* failed due to poor germination and stem rot
Treatments 3-16: 156 kg/ha of 13-13-21 were applied to cassava
Treatments 1-12: cassava was harvested at 12 months
Treatments13-16: cassava was harvested at 18 months

***Source:** Rayong Field Crops Research Center, Annual Report 1996.*

Table 6. Soil pH and organic matter(OM), before planting and after harvest of cassava in different treatments of green manures at RFCRC, Rayong, Thailand in 1994/95/96.

Treatments[1)]	Before planting		After harvest	
	pH	%OM	pH	%OM
1. Cassava+Fert.13-13-21 (156 kg/ha)	5.60	0.51	5.20	0.54
2. Cassava+Fert.13-13-21 (469 kg/ha)	5.60	0.46	5.00	0.52
3. Cassava+*Crotalaria juncea* (cut at 2 months)	5.90	0.49	5.20	0.49
4. Cassava+*Canavalia ensiformis* (cut at 2 months)	5.70	0.53	5.40	0.56
5. Cassava+Pigeon pea ICP 8094 (cut at 2 months)	5.60	0.54	5.20	0.61
6. Cassava+*Mucuna fospeada* (cut at 2 monthsa)	5.50	0.59	5.00	0.63
7. Cassava+cassava (pulled out at 2 months)	5.60	0.44	5.30	0.52
8. Cassava+cassava (cut at 2 months)	5.60	0.45	5.30	0.45
9. Cassava+*Crotalaria juncea* (planted at 6-7 months)	5.70	0.48	5.20	0.47
10. Cassava+*Canavalia ensiformis* (planted at 6-7 months)	5.80	0.43	5.20	0.50
11. Cassava+Pigeon pea ICP8094 (planted at 6-7 months)	5.70	0.46	5.10	0.63
12. Cassava+*Mucuna fospeada* (planted at 6-7 months)	5.60	0.56	5.10	0.65
13. *Crotalaria juncea* green manure-Cassava (18 months)	5.60	0.44	4.90	0.41
14. *Canavalia ensiformis* green manure-Cassava (18 months)	5.50	0.48	5.20	0.59
15. Pigeon pea ICP 8094 green manure-Cassava (18 months)	5.80	0.56	5.10	0.59
16. *Mucuna fospeada* green manure-Cassava (18 months)	5.60	0.57	5.00	0.47

[1)]Treatments 3-16: 156 kg/ha of 13-13-21 were applied to cassava
Source: *Rayong Field Crops Research Center, Annual Report 1996.*

Soil chemical analysis data, shown in **Table 6**, indicate a decreasing trend in soil pH both with and without green manures, as compared to the soil analysis before planting. Although *Crotalaria juncea* had the highest above-ground dry matter production in all patterns of green manure management, this did not result in an increase in soil OM. However, these results are still very preliminary and it will take a few years to confirm the effect of green manures on the yield of cassava and on soil fertility.

2. Effect of plant spacing and fertilization on the yield of Rayong 5

In 1995/96, a study on the effect of plant spacing and rate of fertilizer application was conducted in Banbung and Sattahip soil series of Rayong province in the eastern part of Thailand. The objective was to determine the optimum spacing and rate of fertilizer application for the new Rayong 5 cultivar. **Table 7** shows that plant spacing at 0.8x0.8 or 1.0x1.0 m had no significant effect on either yield or starch content of Rayong 5 in both Banbung and Sattahip soil series. This suggests that Rayong 5 could be planted at any plant spacings corresponding to a plant population ranging from 10,000 to 15,625 plants/ha in both soils.

Table 7. The effect of plant spacings and rate of fertilizer application on the yield and starch content of Rayong 5 planted in Banbung and Sattahip soil series, Rayong, Thailand in 1995/96.

	Banbung soil series		Sattahip soil series	
	Fresh root yield (t/ha)	Starch content (%)	Fresh root yield (t/ha)	Starch content (%)
Spacings(S)				
0.8x0.8 m	28.50	18.03	33.25	22.04
1.0x1.0 m	29.00	17.85	29.94	21.35
F-test(S)	NS	NS	NS	NS
Rates of fertilizer(R)				
$N-P_2O_5-K_2O$(kg/ha)				
0-0-0	18.00c	14.50b	23.06c	21.13
46-23-46	26.06bc	17.23ab	27.25c	22.00
92-46-92	30.06b	19.32a	35.75b	22.57
138-69-138	32.69ab	18.98a	34.19b	21.20
184-92-184	37.00a	19.67a	40.56a	21.57
F-test(R)	*	*	*	NS
F-test(SxR)	NS	NS	NS	NS
CV(%)	25.92	15.26	14.71	5.47

***Source:** Rayong Field Crops Research Center, Annual Report 1996.*

The effect of chemical fertilizers applied in the ratio 2:1:2 of $N:P_2O_5:K_2O$ by using combinations of compound fertilizer 15-15-15 with urea and KCl at four different rates, in comparison with the non-fertilized check, is shown in **Table 7.** In Banbung soil series, there was a significant response to fertilizer rates both in terms of cassava yield and starch content. Application of fertilizers at the rate of 92 kg N, 46 P_2O_5 and 92 K_2O/ha produced a significantly higher root yield of 30.1 t/ha than did the check without fertilizer (18.0 t/ha). The highest yield of Rayong 5 was obtained with the application of 184 kg N, 92 P_2O_5 and 184 K_2O/ha applied as 625 kg/ha of 15-15-15 supplimented with 200 kg of urea and 156 kg of KCl/ha, which produced a yield of 37.0 t/ha. The treatment without fertilizer application also resulted in the lowest starch content of Rayong 5 at only 14.5%, compared to 19.7% when the highest rate of fertilizers was applied. The results indicate that Rayong 5 cultivar, planted in Banbung soil series needs application of fertilizer 15-15-15 at least at the rate of 312 kg/ha with 100 kg of urea and 78 kg of KCl/ha to produce a high root yield and starch content.

In the Sattahip soil series, the response to fertilizers was also significant in terms of root yield. The intermediate rate of 92 kg N, 46 P_2O_5 and 92 K_2O/ha, applied as 312 kg/ha of 15-15-15 with 100 kg of urea and 78 kg of KCl/ha, produced a significantly higher root yield of 35.8 t/ha than the check without fertilizer (23.1 t/ha). The highest root yield of Rayong 5 was again obtained with the highest rate of applied fertilizers, i.e. 625 kg/ha of 15-15-15 with 200 kg of urea and 156 kg of KCl/ha, which produced a yield of 40.56 t/ha. But, fertilizer application did not result in any significant difference in starch content of Rayong 5, which ranged from 21.1 to 22.6%. The results indicate that Rayong 5 planted in Sattahip soil series also needs the same application of fertilizer 15-15-15 at least at the rate of 312 kg/ha supplimented with 100 kg/ha of urea and 78 kg/ha of KCl to produce a high root yield and starch content.

3. Use of legumes as green manures to sustain the productivity of cassava at Kalasin]

A study on the use of grain legumes as green manures to sustain the productivity of Rayong 60 was conducted in 1994/95 in Kalasin province in the northeast of Thailand, where cassava has been a major field crop.

The experiment consisted of eight cassava-based cropping systems, in which three grain legume species, i.e. cowpea for grain, cowpea for green pods and peanut were planted in rotation with cassava, cv. Rayong 60. Leaving the land in fallow before planting cassava was another treatment used for comparison; in this case fertilizers were not applied or were applied as 12-24-12 at a rate of 156 kg/ha. In the legume rotation treatments either 15-15-15 fertilizer at the rate of 125 kg/ha was applied to cassava but without fertilizer for the legume, or 12-24-12 fertilizer at the rate of 156 kg/ha was applied to the legumes without fertilization of cassava. Legumes were planted in June and harvested in Sept. Cassava was planted in Oct and harvested in May of each year on Korat soil series with pH 5.54, 0.60% OM, 110 ppm available P and 46 ppm exchangeable K.

The results of the first year experiment, shown in **Table 8**, indicate that with fertilizer application, all grain legumes produced higher yields (863-2300 kg/ha) than without fertilizer (663-1938 kg/ha). Cassava yields differed significantly depending on the various cropping systems. Cassava yields tended to be significantly higher when fertilizers were applied to cassava rather than to the preceding legume. When fertilizers were applied to cassava there was no significant effect of the preceding grain legume, but when no fertilizers were applied to cassava, yields were significantly higher after the grain legumes than after bare fallow. This indicates that the residual effect of fertilized legumes could help maintain soil fertility for cassava production. The highest yield of 22.5 t/ha was obtained from planting fertilized cassava after unfertilized peanut. The root starch contents of cassava in the various cropping systems were not significantly different among treatments. The experiment needs to be repeated several years with soil analysis data to be able to conclude whether any of these cropping systems improves the long-term sustainability of cassava production in these poor northeastern soils.

Table 8. The effect of several cassava-grain legume rotation systems on the yield and starch content of cassava, Rayong 60, as well as the yields of the grain legumes grown at Kalasin, Thailand in 1994/95.

Cropping systems[1)]	Grain legumes yield (kg/ha)	Cassava plants harvested (#/ha)	Cassava fresh root yield (t/ha)	Starch content (%)
1. Cowpea (Seed)+F -Cassava-F	863	9256	16.38b	20.53
2. Cowpea (Seed)-F -Cassava+F	663	8775	19.13ab	22.68
3. Peanut+F -Cassava-F	1750	8938	18.06b	21.14
4. Peanut-F -Cassava+F	1000	9063	22.50a	23.70
5. Green Cowpea+F -Cassava-F	2300	9125	18.56b	20.80
6. Green Cowpea-F -Cassava+F	1938	8875	19.38ab	22.80
7. Fallow -Cassava-F	-	8750	15.38c	20.40
8. Fallow -Cassava+F	-	9125	18.88ab	20.55
F-test	-	NS	*	NS
CV(%)	-	10.50	17.50	12.60

[1)] +F=with fertilizer ;-F=without fertilizer
156 kg/ha of 12-24-12 were applied to legumes in treatments 1, 3 and 5
125 kg/ha of 15-15-15 were applied to cassava in treatments 2, 4, 6 and 8

Source: *Khon Kaen Field Crops Research Center, Annual Report 1995.*

4. The fertilization of new high-yielding cassava varieties

In 1994/95 a study on the effect of chemical fertilizers on the yields and starch contents of newly released cassava varieties was conducted at Udon Thani and Khon Kaen provinces in the northeast of Thailand. Three cultivars were tested in each location, i.e. Kasetsart 50, Rayong 5 and Rayong 60 tested in Udon Thani, and Kasetsart 50, Rayong 90 and Rayong 60 in Khon Kaen.

The results shown in **Table 9** indicate that in Udon Thani the yields of the three varieties were not significantly different, ranging from 28.5 to 34.1 t/ha. The root starch content of Rayong 60 was significantly lower than that of Kasetsart 50, and slightly but not significantly lower than that of Rayong 5. There were also no significant effects of rates of chemical fertilizer in terms of yield and starch content. Nevertheless, there was an increasing trend in root yield with increasing rates of chemical fertilizers applied: at higher rates all cassava cultivars tended to produce higher yields.

Table 9. The effect of chemical fertilizers on the yield and starch content of three cassava cultivars grown in Udon Thani and Khon Kaen, Thailand in 1994/95.

	Udon Thani		Khon Kaen	
	Fresh root yield (t/ha)	Starch content (%)	Fresh root yield (t/ha)	Starch content (%)
Cultivars(C)				
Kasetsart 50	33.05	25.0a	16.10a	22.6
Rayong 90	-	-	10.49b	22.6
Rayong 5	34.07	23.0ab	-	-
Rayong 60	28.51	21.0b	8.36b	17.4
F-test(C)	NS	*	*	NS
Rates of fertilizer(R);kg/ha				
0-0-0	24.44	23.0	8.36b	22.4
25-25-25	30.24	22.0	12.74a	21.9
50-50-50	35.78	23.0	13.33a	20.6
75-75-75	37.03	23.0	12.16a	18.4
F-test(R)	NS	NS	*	NS
F-test(CxR)	NS	NS	NS	NS
CV(%)	24.8	8.03	28.50	13.20

***Source:** Khon Kaen Field Crops Research Center, Annual Report 1995.*

At Khon Kaen, the yields were much lower, but the yield of Kasetsart 50 was significantly higher those of Rayong 90 and Rayong 60. There were no significant differences in root starch content between these cultivars.

On average, chemical fertilizer, applied at the rate of 25-25-25 kg/ha of N, P_2O_5 and K_2O, produced significantly higher yields than without fertilizer application, which produced only 8.36 t/ha. At higher rates of fertilizer application the effect on cassava yields was not significant. Although there was a trend of decreasing starch content with increasing rates of fertilizers, differences were not statistically significant.

There were no significant interactions between cultivars and rates of chemical fertilizer on yield and starch content at both Udon Thani and Khon Kaen.

5. Long-term effect of cropping system on cassava productivity in the Northeast

Since 1980, a semi-demonstration study on the long-term effect of various soil management treatments on cassava production has been conducted at Khon Kaen Field Crops Research Center in the Northeast of Thailand.

The cropping systems of sole cassava, cassava intercropped with peanut and cassava rotated with sequentially planted peanut and pigeonpea were tested with and without fertilization and with and without soil amendments. The objective of the trial was to determine the most appropriate soil management system to maintain soil fertility and sustain high cassava yields. Rayong 1 was used as the test cultivar in this long-term experiment.

Table 10 shows the cassava yields obtained in the different cropping systems with various soil management treatments. In the first year (1980) sole cassava produced the highest average yield of 27.4 t/ha, compared to 24.0 t/ha for cassava rotated with peanut-pigeon pea, and 25.5 t/ha for cassava intercropped with peanut. During the first year, cassava could still produce a rather high average yield of 25.6 t/ha without any fertilizers or soil amendments. When only fertilizers were applied, cassava produced the highest yield of 28.7 t/ha, or 12% higher than without fertilizers, while soil amendments slightly decreased cassava yields, both in the absence and presence of chemical fertilizers.

In the 15th year (1994), the highest average cassava yield of 20.9 t/ha was obtained when cassava had been rotated with sequentially planted peanut and pigeon pea, while the continuous planting of sole cassava produced a lower yield of 16.8 t/ha. The lowest cassava yield of 12.9 t/ha was obtained when cassava had been intercropped with peanut during the past 15 years, probably due to competition from the intercropped peanut. Considering the soil management effect on cassava yields in the 15th year, the lowest average yield at 11.2 t/ha was obtained in the check plots without fertilizers or soil amendments. When only chemical fertilizers had been applied, cassava produced the highest yield of 20.0 t/ha, or 78% higher than without fertilizers. Soil amendments alone or in combination with chemical fertilizers resulted in yields of 17.5 and 18.7 t/ha, or 56 and 67%, respectively, higher than the check plots.

When the average yields in the 15th year are compared to those of the first year, it is clear that neither cropping systems nor soil management treatments could maintain or increase cassava yields. The overall average yield of all cropping systems and soil management treatments in the 15th year was only 66% of that of the the first year. Only the rotation of cassava with sequentially planted peanut and pigeon pea could maintain a relatively high yield of cassava, corresponding to 87% of the yield obtained with the same cropping system in the first year. Among soil management treatments, the check plots without any fertilizers or soil amendments produced the lowest relative yield of

44% of that obtained in the first year. Only the treatments of cassava rotated with peanut-pigeonpea and with either chemical fertilizers alone or in combination with soil amendments could produce high cassava yields in the 15th year that were comparable to those obtained in the first year.

Table 10. A semi-demonstration study on the long-term effect of soil management on the yield (t/ha) of cassava grown at Khon Kaen, Thailand from 1980 to 1994.

Cropping system	Soil management				
	Check	Fertilizer[1]	Soil amendment[2]	Fertilizer+Soil amendment[3]	Average
1st Year(1980)					
Cassava	30.13	32.38	20.38	26.63	27.38
Cassava/Peanut-Pigeon pea[4]	27.88	26.81	18.63	22.88	24.05
Cassava+Peanut[5]	18.81	27.00	27.31	28.81	25.48
Average of 1st year	**25.61**	**28.73**	**22.11**	**26.11**	**25.64**
15th Year(1994)					
Cassava	8.81	21.68	19.81	16.87	16.79
Cassava/Peanut-Pigeon pea[4]	15.68	24.50	20.25	23.12	20.88
Cassava+Peanut[5]	9.18	13.81	12.56	16.12	12.91
Average of 15th year	**11.22**	**19.99**	**17.54**	**18.70**	**16.86**
Relative to 1st year(%)	44	70	79	72	66

1) Applied 50-50-50 kg/ha of N-P_2O_5-K_2O to cassava
or 18.75-56.25-37.50 kg/ha of N-P_2O_5-K_2O to peanut in crop rotation treatment[4]

2) Applied 1250 kg/ha of lime and rock phosphate(3%P_2O_5)with 18.75 t/ha of munucipal compostin the 1st, 5th, 9th, and 13th year(1980, 1984, 1988 and 1992)

3) 1)+2).

4) Cassava and peanut-pigeon pea were planted in alternate years
After the harvest of sequentially planted legumes, the residues were incorporated into the soil before the following years' planting of cassava.

5) 2 rows of peanut were intercropped between cassava rows.
After harvest of peanut the residue was used as mulch.

***Source:** Khon Kaen Field Crops Research Center, Annual Reports 1992 and 1995.*

Weed Control

Weeds are known as a major problem, causing serious cassava yield reductions. Nowadays, labor for weed control is hard to find and the cost of manual weeding is getting higher and higher each year. To solve these problems several studies were conducted at Khon Kaen and Rayong Research Centers during two years from 1993 to 1995 to determine the best methods and times of weed control in cassava.

1. Weed control for three cassava cultivars

Experiments on weed control for cassava were conducted in 1993/94 at Khon Kaen Field Crops Research Center in the northeast of Thailand. Rayong 1, Rayong 60 and Rayong 90 cultivars were planted in both the early and late rainy seasons. Plots were maintained weed free for either 0 (non-weeded check), 2, 3 or 4 MAP by manual weeding, compared to a typical "farmer" practice of manual weeding only at 2 MAP and with no fertilizer application. The objective was to determine the optimum period for controlling weeds, which would produce high yields when cassava was planted in either the early or late rainy season.

Table 11 shows that yields of Rayong 1, Rayong 60 and Rayong 90 cultivars, averaged over two years and two seasons, were not significantly different, ranging from 17.6 to 20.2 t/ha. There were no significant interactions between cultivars and weed-free periods when cassava was planted in either the early or late rainy seasons. However, weed control treatments produced highly significant differences in yield (averaged over cultivars and seasons/years), ranging from 20.1 to 23.4 t/ha, compared to only 7.7 t/ha in the non-weeded check. The results indicate that weed control is extremely important during the first two months after planting, but that weed control beyond 2 MAP did not significantly increase yields any further. The highest cassava yields were obtained when plots were maintained weed-free for 3 MAP. Thus, when cassava was planted in either early or late rainy season these three cassava cultivars needed to be free of weeds about 2-3 months after planting to produce highest yields.

2. Weed control for cassava intercropped with mungbean and peanut

Experiments on weed control for cassava intercropped with mungbean or peanut were conducted during two years (1994-1996) at Rayong Field Crops Research Center in the East of Thailand. The objective of the experiment was to determine the most appropriate methods of weed control in cassava-legume intercropping systems, which would produce high yields of intercrops and cassava, resulting in a high income. Cassava, cv. Rayong 90, was planted in three cropping systems, i.e. sole cassava, intercropped with mungbean or with peanut. Four different methods of weed control involved various combinations of pre-emergence herbicide Metolachlor (1.5 kg ai/ha, a post-emergence herbicide Paraquat (0.5 kg ai/ha), and manual weeding. Weeds were controlled by either Metolachlor (alone), Metolachlor followed by hand weeding or Metolachlor followed by application of Paraquat, as compared to hand weeding alone. In sole crops of peanut and mungbean, weeds were controlled by either Metolachlor (1.50 kg ai/ha) or by hand weeding; these functioned as check plots of the intercrops.

Table 11. Effect of weed control on yield (t/ha) of Rayong 1, Rayong 60 and Rayong 90 planted in the early and late rainy seasons at Khon Kaen, Thailand in 1993/94 and 1994/95.

	1993/94		1994/95		Average 2 years		Average 2 seasons
	ER	LR	ER	LR	ER	LR	
Cultivars(C)							
Rayong 1	28.33	19.53	10.86	17.23	20.97	18.38	19.67
Rayong 60	23.33	27.68	15.11	14.59	19.22	21.13	20.18
Rayong 90	25.03	21.88	11.33	12.25	18.18	17.06	17.62
F-test(C)	NS	*	*	NS	NS	*	NS
Weed-free period(W)							
0 month (check)	2.61	13.48	4.49	5.63	5.83	9.56	7.69
2 months	31.98	26.43	16.71	15.52	24.34	20.98	22.66
3 months	34.71	26.03	13.84	19.20	24.28	22.61	23.44
4 months	31.47	24.96	13.73	17.54	22.59	21.25	21.93
"Farmer" practice[1)]	27.07	24.25	13.39	15.54	20.23	19.89	20.06
LSD(0.05)for W	6.73	7.38	4.97	5.82	5.51	4.70	3.56
F-test(W)	**	**	**	**	**	**	**
F-test(CxW)	NS	NS	**	NS	NS	NS	NS
CV(%)	27.00	29.60	41.40	40.70	42.60	37.40	39.90

[1)]"Farmer" practice=manual weed control at 2 months with no fertilizers applied
***Source:** Khon Kaen Field Crops Research Center, Annual Report 1995.*

Table 12 shows that the yields of mungbean, both when grown as intercrops and as sole crops in 1994/95 and 1995/96 were not significantly affected by different weeding methods; yields ranged from 319 to 450 kg/ha in 1994 and from 175 to 231 kg/ha in 1995. The same results were obtained with peanut, the yield of which ranged from 419 to 556 kg/ha in 1994, and from 300 to 356 kg/ha in 1995. The results indicate that neither cassava competition nor weeding method were significantly affecting the yields of the two legumes.

Table 13 shows the cassava yields in three different cropping systems as affected by different weeding methods. In 1994/95, there was no significant effect of cropping system on cassava yield, but the highest yield of 16.9 t/ha was obtained when cassava was intercropped with peanut. However, this same treatment resulted in a significantly lower cassava yield in 1995/96. Cropping systems had no significant effect on cassava root starch content in either year. There were also no interaction effects between cropping systems and weeding methods, both in terms of cassava yield and starch content. However, the effects of different weeding methods on cassava yields were highly significant in both years, with the lowest yields of 7.14 and 7.46 t/ha obtained in 1994/95 and 1995/96, respectively, when weeds were controlled by application of Metolachlor only at planting. Thus, in that treatment cassava yields were significantly depressed by weed competition. The other three weeding methods resulted in yields that were not significantly different, ranging from 14.4 to 18.4 t/ha in 1994/95 and from 11.5 to 14.2 t/ha in 1995/96. The highest cassava yields of 18.4 t/ha in 1994/95 and 13.8 t/ha in 1995/96 were obtained with application of Metolachlor at 1.50 kg ai/ha, followed by two manual weedings. The weeding methods caused no significant differences in cassava root starch contents.

The net income obtained with the various cropping systems and methods of weed control are shown in **Table 14**. With respect to weeding methods in each cropping system the highest net income in the 1994/95 experiment was obtained by intercropping cassava with peanut (1153 US $/ha) or when grown as a monocrop (832 US $/ha), when weeds in both cropping systems were controlled by application of Metolachlor followed by two manual weedings. In contrast, the highest net income of 938 US $/ha in the cassava-mungbean intercropping system was obtained when weeds were controlled by application of Metolachlor followed by two spot applications of Paraquat.

In the 1995/96 experiment (**Table 13**), there was a highly significant competitive effect when cassava was intercropped with peanut, resulting in the lowest yield at 10.2 t/ha. The yield of cassava intercropped with mungbean was not significantly different from that of sole cassava, since mungbean has a shorter crop duration and thus causes less competition than peanut. Root starch contents of cassava were not significantly different in all cropping systems. There were again no interaction effects between cropping systems and weeding methods, both in terms of yield and starch content. However, the different weeding methods caused highly significant differences in cassava yields, with the lowest yield of 7.5 t/ha obtained when weeds were controlled by only one application of Metolachlor at planting. The highest cassava yield of 14.2 t/ha was obtained with three manual weedings. The application of Metolachlor followed by hand weeding was not significantly different from hand weeding alone. Weeding methods had no significant effect on root starch content except that the application of Metolachlor alone resulted in a higher starch content than hand weeding alone. Since the last hand weeding was done at 2.5 months before the cassava harvest, the mulch of dead weeds might have increased soil moisture causing a reduction in starch content.

Table 12. Effect of different weed control methods on the yields of mungbean and peanut, grown either intercropped in cassava or as a monocrop in Rayong Field Crops Research Center, Rayong, Thailand in 1994/95 and 1995/96.

Treatment	Mungbean[1] 1994/95 (kg/ha)	Mungbean[1] 1995/96 (kg/ha)	Peanut[2] 1994/95 (kg/ha)	Peanut[2] 1995/96 (kg/ha)
Intercropped with cassava				
1. Metholachlor (1.50 kg ai/ha)	325	175	419	300
2. Metholachlor (1.50 kg ai/ha) +hand weeding	344	181	425	306
3. Metholachlor (1.50 kg ai/ha) +Paraquat (0.50 kg ai/ha)	344	187	444	350
4. Hand weeding	319	206	506	356
Sole crops				
5. Hand weeding	356	206	494	331
6. Metholachlor (1.50 kg ai/ha)	450	231	556	319
F-test	NS	NS	NS	NS
CV (%)	29.72	10.25	20.29	17.72

[1]Yield of dry grain
[2]Yield of dry pods
Source: Rayong Field Crops Research Center, Annual Reports 1995 and 1996.

Table 14 shows that the highest net incomes of 314 and 269 US $/ha in the intercropping systems with peanut and mungbean were obtained when weeds were controlled by application of Metolachlor followed by three spot applications of Paraquat. The highest net income of 273 US$/ha in sole cassava was obtained when weeds were controlled by application of Metolachlor only at planting.

The results from both years show some contrasting effects of cropping systems and weed control methods on cassava yields and net income, depending on the season of planting in each year. With the variation in the prices of the various crops, in rainfall and thus in weed condition and weeding costs, the net incomes varied from year to year. Nevertheless, in both years the best method for controlling weeds when cassava was intercropped with mungbean was the application of pre-emergence herbicide Metolachlor at planting, followed by spot treatments with the post-emergence herbicide Paraquat. The experiment will be repeated in 1996/97 to refine the results.

Table 13. The effect of three cropping systems and four methods of weed control on the yield and starch content of Rayong 90 planted at Rayong Field Crops Research Center, Rayong, Thailand in 1994/95 and 1995/96.

	1994/95		1995/96	
	Root yield (t/ha)	Starch (%)	Root yield (t/ha)	Starch (%)
Cropping system(C)				
Intercropped with mungbean	11.46	22.07	12.18ab	24.74
Intercropped with peanut	16.90	23.77	10.18b	24.69
Sole cassava	13.74	23.28	12.96a	24.69
F-test(C)	NS	NS	**	NS
CV (%) a:	35.61	7.25	9.63	8.63
Weeding methods(W)				
1. Metholachlor (1.50 kg ai/ha)	7.14b	23.38	7.46c	26.21a
2. Metholachlor (1.50 kg ai/ha) +hand weeding	18.39a	23.24	13.83ab	24.59ab
3. Metholachlor (1.50 kg ai/ha)	16.17a	23.00	11.54b	24.50ab
4. Hand weeding	14.43ab	22.53	14.24a	23.53b
F-test(W)	**	NS	**	**
F-test(CxW)	NS	NS	NS	NS
CV (%)b:	39.61	7.05	14.90	5.44

***Source:** Rayong Field Crops Research Center, Annual Reports 1995 and 1996.*

Recommended Cultural Practices

Table 15 shows the currently recommended varieties and their major characteristics, as well as the recommended cultural practices, based on research results obtained by various research institutes in Thailand during the past 30 years.

FUTURE RESEARCH PRIORITIES

Studies on the effect of cassava production on soil fertility, and studies on soil conservation using combinations of cropping systems and soil management practices for erosion control and fertility maintenance, so as to sustain high cassava yields in the major cassava producing areas, will remain of high priority. Studies on optimum cultural practices, ie. rate, time and method of fertilizer application, weed control for various cassava-based cropping systems and for the newly recommended cultivars, will also continue.

Table 14. The effect of three cassava-based cropping systems and four methods of weed control on the total net income obtained at Rayong Field Crops Research Center, Rayong, Thailand in 1994/95 and 1995/96.

	Net income (US$/ha)[1]					
	1994/95			1995/96		
	C+M[2]	C+P[2]	C[2]	C+M	C+P	C
Weeding Methods						
1. Metholachlor (1.50 kg ai/ha)	315	716	310	235	238	273
2. Metholachlor (1.50 kg ai/ha) +hand weeding[3]	713	1153	832	230	189	153
3. Metholachlor (1.50 kg ai/ha) +Paraquat (0.50 kg ai/ha)[3]	938	1116	663	269	314	260
4. Hand weeding[3]	499	800	684	228	247	167

[1] Net income is total gross income minus weeding costs.
[2] C+M=Cassava intercropped with mungbean.
C+P=Cassava intercropped with peanut.
C=Cassava sole crop.
[3] in 1994/95 hand weeding and application of Paraquat were done twice, while in 1995/96 this was one three times.

Source: Rayong Field Crops Research Center, Annual Reports 1995 and 1996.

Table 15. Recommended cultural practices for cassava production in Thailand in 1996.

Varieties:	Rayong 1:	high yield stability, bitter
	Rayong 2:	good eating quality
	Rayong 3:	high starch content, bitter
	Rayong 60:	high yield even when harvested at 8-10 months, relatively high starch content, bitter
	Rayong 90:	high starch content, higher yield and longer stems than Rayong 3, bitter
	Rayong 5:	high yield, relatively high starch content, bitter
	Kasetsart 50:	high yield, relatively high starch content, bitter

Planting time:	May-June or Oct-Nov.
Land preparation:	Plowing once or twice at 15-20 cm depth with tractor; followed by once or twice disc-harrowing; ridging by oxen or tractor.
Planting material:	Select healthy 10-12 month old plants, cut mature stems, store in shade (less than 30 days), cut stakes of 15-25 cm length
Planting method:	Planting on ridges is needed when soil is wet and contour ridges are also very effective in reducing erosion on sloping land; flat planting when soil moisture is low; plant vertically at 5-10 cm depth;
Plant spacing:	80-100cm between rows, 80-100 cm between plants.
Fertilization:	100kg N, 50 P_2O_5, and 100 K_2O/ha applied as compound fertilizers (such as 15-15-15) supplimented with urea and KCl; side-dressed after first weeding at 1-2 months. On sloping land; application should be split as follows: 50 kg N, 50 P_2O_5 and 50 K_2O/ha applied as compound fertilizer, side-dressed after first weeding at 1-2 months; followed by 50 kg N/ha as urea and 50 kg K_2O/ha as KCl, side-dressed at 2-3 months.
Weeding:	2-3 times manually, at 30-45 days and 2-3 months later; or application of Metholachlor (1.5 kg ai/ha) directly after planting, followed by 1-2 hand weedings or spot application of Paraquat (0.5 kg/ha)
Harvest:	At 10-12 months, during dry season
Intercropping:	Cassava may be intercropped with two rows of peanut or mungbean; 20 cm between rows, 10 cm between plants.

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RECENT PROGRESS IN CASSAVA AGRONOMY RESEARCH IN VIETNAM

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ABSTRACT

In recent years the National Root and Tuber Crops Program of Vietnam, with the cooperation and assistance of the Centro Internacional de Agricultura Tropical (CIAT), has drawn up a plan for strengthening the research and development capacity, with the objective of improving cassava production in Vietnam.

In the area of cassava agronomy, the program has obtained the following results:

- Among various intercropping systems, the interplanting of cassava with peanut, mungbean or maize were the most promising on high fertility soils, while intercropping with peanut was promising on the poorer soils.
- Intercropping cassava with black bean or peanut and planting contour hedgerows of *Tephrosia candida* was the best way to control soil erosion. Cassava intercropped or alley cropped with hedgerow species did not show a significant benificial effect on cassava yield at Hung Loc Center, but the effect may be observed in the long term.
- The cassava population of 10,000-14,000 plants/ha and 12,000-16,000 plants/ha should be recommended for the red Latosol and the grey Podzolic soils, respectively.
- Long term N, P and K trials have shown that the response of cassava to fertilizers is very different for the various types of soils; on the more fertile Latosols the response was not significant even in the fourth year of cropping, but on the grey Podzolic soil in the South and on red-yellow Ferralsols in the north the response of cassava was highly significant already in the first year, with the main response to N and K, respectively.
- Short term N, P and K trials showed a high response of cassava to K in Vinh Phu province, as well as a higher income due to fertilizer application in Dong Nai province.

INTRODUCTION

In Vietnam, the statistical data for 1992 show that agriculture accounted for 43% of the national gross production and 51.3% of the national income. Crop production accounted for 76% of the total agricultural production, in which food crop production plays an important role, occupying 98% of the total area cultivated to annual crops. Rice production is the most important, followed by maize and cassava. The annual cassava cultivated areas is about 280,000 ha, accounting for 25% of the food crop area; the cassava production areas are distributed in all the different regions of the country (**Figure 1**).

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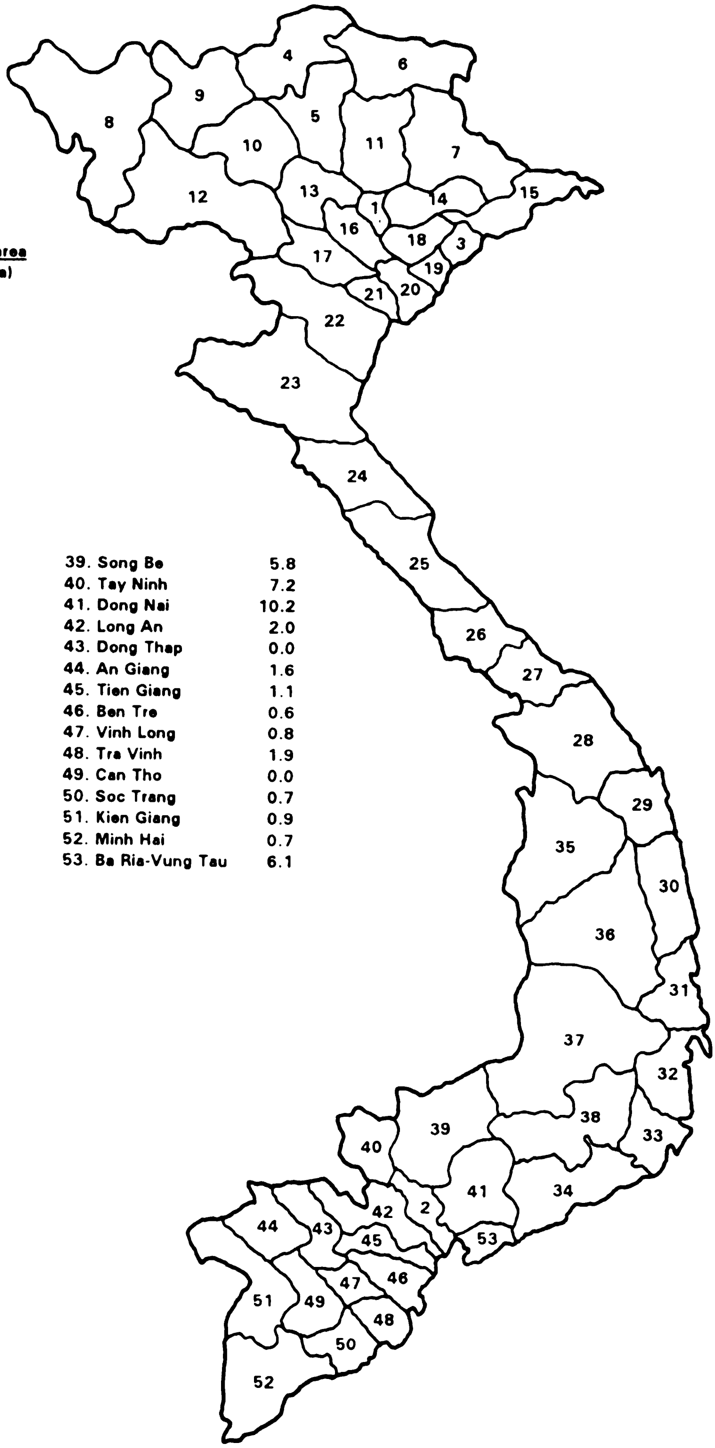


Provinces	Cassava area ('000 ha)
1. Ha Noi	0.7
2. Ho Chi Minh	0.7
3. Hai Phong	0.4
4. Ha Giang	6.5
5. Tuyen Quang	8.1
6. Cao Bang	2.1
7. Lang Son	3.5
8. Lai Chau	8.8
9. Lao Cai	5.8
10. Yen Bai	10.1
11. Bac Thai	4.8
12. Son La	13.7
13. Vinh Phu	13.2
14. Ha Bac	9.5
15. Quang Ninh	3.3
16. Ha Tay	4.3
17. Hoa Binh	14.8
18. Hai Hung	0.3
19. Thai Binh	0.0
20. Nam Ha	0.7
21. Ninh Binh	1.9
22. Thanh Hoa	16.2
23. Nghe An	14.1
24. Ha Tinh	2.3
25. Quang Binh	4.4
26. Quang Tri	3.8
27. Thua Thien-Hue	6.2
28. Quang Nam-Da Nang	17.0
29. Quang Ngai	11.3
30. Binh Dinh	12.2
31. Phu Yen	4.8
32. Khanh Hoa	7.5
33. Ninh Thuan	1.1
34. Binh Thuan	5.8
35. Kon Tum	7.2
36. Gia Lai	9.7
37. Dac Lac	4.8
38. Lam Dong	2.6
39. Song Be	5.8
40. Tay Ninh	7.2
41. Dong Nai	10.2
42. Long An	2.0
43. Dong Thap	0.0
44. An Giang	1.6
45. Tien Giang	1.1
46. Ben Tre	0.6
47. Vinh Long	0.8
48. Tra Vinh	1.9
49. Can Tho	0.0
50. Soc Trang	0.7
51. Kien Giang	0.9
52. Minh Hai	0.7
53. Ba Ria-Vung Tau	6.1

Figure 1. Cassava planted area in the various provinces of Vietnam.

Ranked in third position among food crops, cassava is of special importance because it is not only a human food but is also used as a source of feed for animals and as a raw material for the processing industry. Cassava is also an important crop for poor farmers in the nutrient poor soil areas, where other crops can not be planted. The soils cultivated to cassava are generally slopy or hilly, degraded and often eroded. And these soils are often of low pH, have low levels of organic matter, are deficient in K and may lack some micronutrient elements (data of soil analysis by CIAT; Howeler, 1995).

Grown mainly on nutrient poor soils, farmers generally plant cassava at a population from 10,000 to 15,000 plants/ha, dependent on the type of soil, the variety and the time of cassava planting, as well as the tradition of the farmers. In some small areas, cassava is usually intercropped with legume crops, such as peanut, mungbean, and cowpea, or with contour hedgerows of leguminous trees to reduce erosion and improve soil fertility. The importance of intercropping varies between regions; it occupies about 10% in the north and 30% in the south of Vietnam (Pham Van Bien and Hoang Kim, 1996).

Until now, the inputs used for cassava production are still very low and the total production costs varies between regions, ranging from US$116.69 to 224.83 (**Figure 2**). Depending on the local conditions and the likely benifits obtained, farmers plant cassava with or without fertilizers, the cost of fertilizer application being about 19% of the total cost in the north and 12% in the south of Vietnam (**Figure 3**).

RESEARCH RESULTS

Intercropping

In Vietnam many people believe that intercropping of cassava can increase soil fertility and reduce erosion, but some experimental results indicate that the net return is lower than for cassava monocropping. Research by Hoang Kim and Buresova(1987) on cassava intercropping with peanut, mungbean and winged bean showed that most of the intercropping systems gave higher economic returns. Other intercropping trials have been conducted on the red Latosol soil at Hung Loc Research Center in South Vietnam for four years, using various grain legumes and maize, with the objective of controlling weeds, preventing soil erosion, improving soil fertility and increasing income. The results showed that on the red Latosol soil cassava intercropped with peanut, mungbean or maize were the most promising systems. But cassava monocropping still gave higher economic returns than any other intercropping system, while cassava planted in single rows gave higher profits than planting in double rows (Nguyen Huu Hy *et al.*, 1995).

Two intercropping trials were also conducted on red-yellow Ferralsols and on grey Podzolic soils at the Agro-forestry College in Thai Nguyen of Bac Thai province and in Thuan An of Song Be province, respectively. The results of both trials (**Table 1**) indicate that on these nutrient poor soils, cassava intercropped with peanut produced by far the highest total gross income in both locations, followed by mungbean. Cassava intercropped with maize and soybean produced the lowest gross income.

Table 1. Effect of various intercropping systems on the yield of cassava and intercrops as well as total gross income in Agro-forestry College # 3, in Bac Thai, north Vietnam (A), and in Thuan An, Song Be, south Vietnam (B), in 1993.

Cropping systems[1]	Cassava root yield (t/ha)	Intercrop yield (t/ha)	Gross income ('000d/ha)
A. Agric. College, BacThai (Av. 4 years)[1]			
Cassava monoculture	21.9	-	4,927
Cassava+peanut	20.2	0.815	7,071
Cassava+black bean	17.0	0.376	5,141
Cassava+mungbean	21.2	0.135	4,242
Cassava+soybean	20.4	0.170	5,270
Cassava+maize	17.5	1.257	5,320
B.Thuan An, Song Be (1 year)[2]			
Cassava monoculture	41.5	-	11,620
Cassava+peanut	38.1	0.70	13,132
Cassava+cowpea	40.2	-	11,256
Cassava+cucumber	39.5	-	11,060
Cassava+mungbean	38.2	-	10,696
Cassava+maize	23.8	-	7,364

[1] variety: Vinh Phu
prices :
cassava: 225 d/kg fresh roots
peanut: 3,100 d/kg dry pods
blackbean: 3,500 d/kg dry grain
mungbean: 3,500 d/kg dry grain
soybean: 4,000 d/kg dry grain
maize: 1,000 d/kg dry grain

[2] variety: KM 60
prices:
cassava: 280 d/kg fresh roots
peanut: 3000 d/kg dry pods
maize: 2000 d/kg dry grain

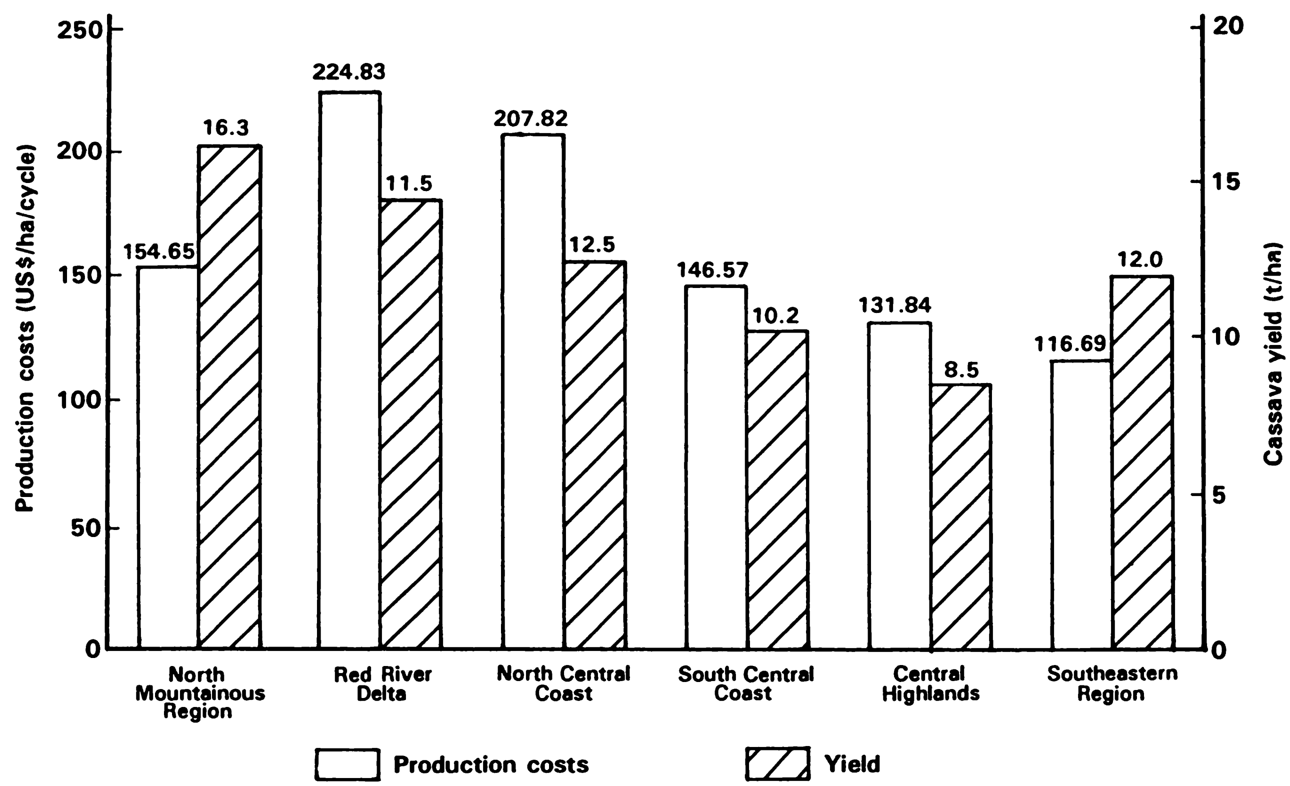
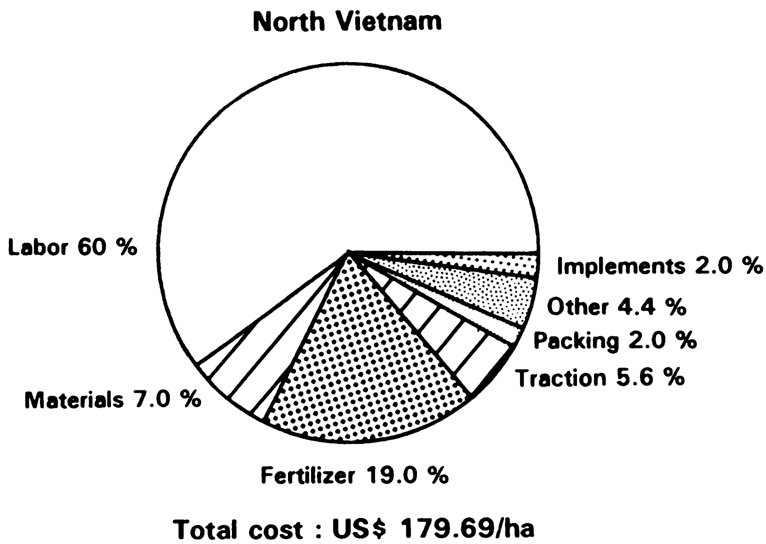


Figure 2. Cassava yield and production costs for different agro-ecological regions in Vietnam, 1991.
***Source:** Pham Thanh Binh et al., 1996.*



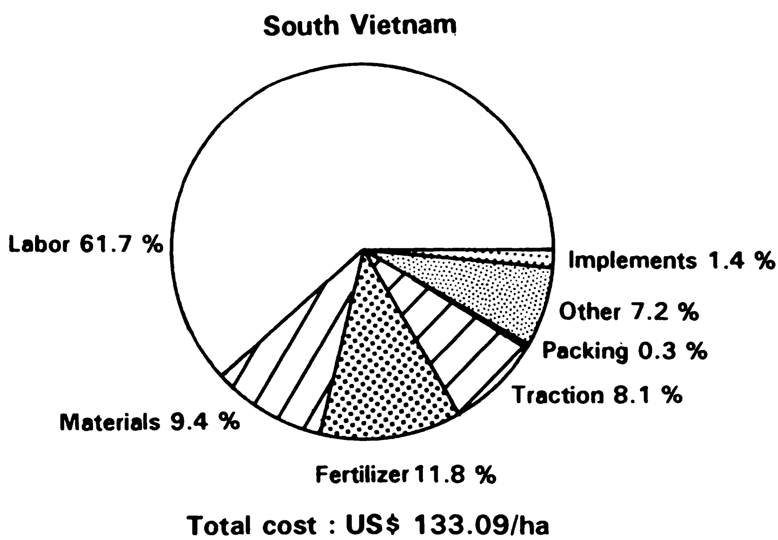


Figure 3. Relative cassava production cost shares in North and South Vietnam in 1991.
Source: Phan Thanh Binh et al., 1996.

Crop Management Practices for Soil Erosion Control and Soil Fertility Maintenance

In Vietnam, about 55% of cassava is grown on flat land and 45% on slopy or hilly land (Pham Van Bien and Hoang Kim, 1996). Because of the long crop cycle of cassava and its slow early growth, soil loss due to erosion is a serious problem, especially during the first three to four months after planting. Studies on crop management practices have been conducted at some locations in Vietnam on slopes ranging from 10 to 20%. **Figure 4** shows that on 10% slope at the Agro-forestry College in Bac Thai, cassava intercropped with black bean and with contour hedgerows of *Tephrosia candida,* or planting cassava on contour ridges, reduced soil losses significantly. In another trial on the same site, the intercropping with black bean and *Tephrosia* hedgerows resulted in low levels of erosion, high cassava yield and the highest gross income (**Table 2**).

A trial on intercropping cassava with legumes and leguminous tree species, with the objective of improving soil fertility, has been conducted at Hung Loc Research Center for four years. The results (**Table 3**) show that during the fourth year cassava intercropped with *Centrosema acutifolium* gave the highest yield, while alley cropping with *Gliricidia sepium* or *Leucaena leucocephala* increased cassava yields only slightly. The beneficial effect of these treatments is expected to increase over time.

Cassava Plant Population

The most suitable cassava plant density and population depends on soil conditions, on the variety, on the inputs used, and on the experience of the farmers. Cassava population trials were therefore conducted on a red Latosol soil and a grey Podzolic soil at Hung Loc Research Center and in Ho Nai 4 village of Dong Nai province, respectively, with the objective of determining the most suitable cassava plant density and population in the two main types of cassava soils in South Vietnam. **Figure 5** shows that on the more fertile Latosol the best plant population for two cassava varieties (KM60 and KM94) ranged from 10,000 to 14,000 plants/ha, as these populations gave the highest yield and harvest index. On the more infertile Podzolic soil the population range of 12,000-16,000 plants/ha gave the highest yield and profits of two cassava varieties (**Table 4**). However, the starch content in the roots of these cassava varieties varied from treatment to treatment.

Table 2. Effect of various agronomic practices on soil erosion and on the yield of cassava and intercropped black beans rown-on about 20% slope at Agro-forestry College in Bac Thai, Vietnam. Data are average values for two years (1994-1995).

Treatments	Dry soil loss (t/ha)	Cassava yield (t/ha)	Bean yield (kg/ha)	Gross income[2] ('000d/ha)
1.0x1.0 m, no ridges, no intercropping	30.0	20.0	-	10,000
1.0x1.0 m, contour ridges, no intercropping	15.0	18.4	-	9,200
1.0x1.0 m, no ridges, black bean intercropping	14.4	19.5	312	11,622
1.0x1.0 m, no ridges, black bean intercrop, *Tephrosia* hedgerows[1]	11.4	21.4	262	12,272
0.8x0.7 m, no ridges, no intercropping	29.1	23.3	-	11,650

[1] *Tephrosia candida* contour hedgerows spaced at 6m intervals
[2] prices: cassava 500 d/kg fresh roots
black bean 6000 d/kg dry grain

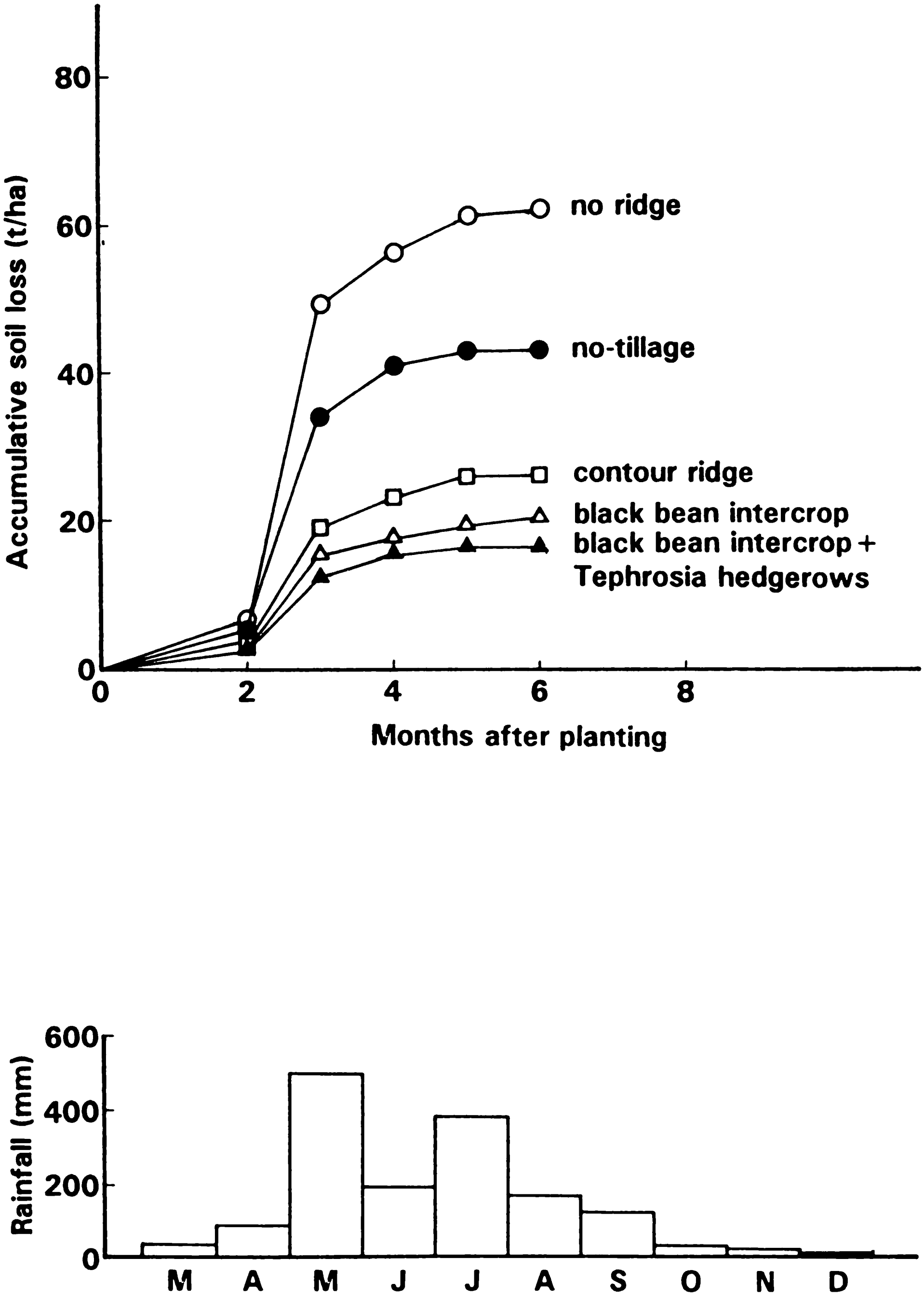


Figure 4. Effect of various agronomic practices on the accumulative dry soil loss due to erosion in cassava planted on about 10% slope in Agro-forestry College of Bac Thai, North Vietnam, in 1993.

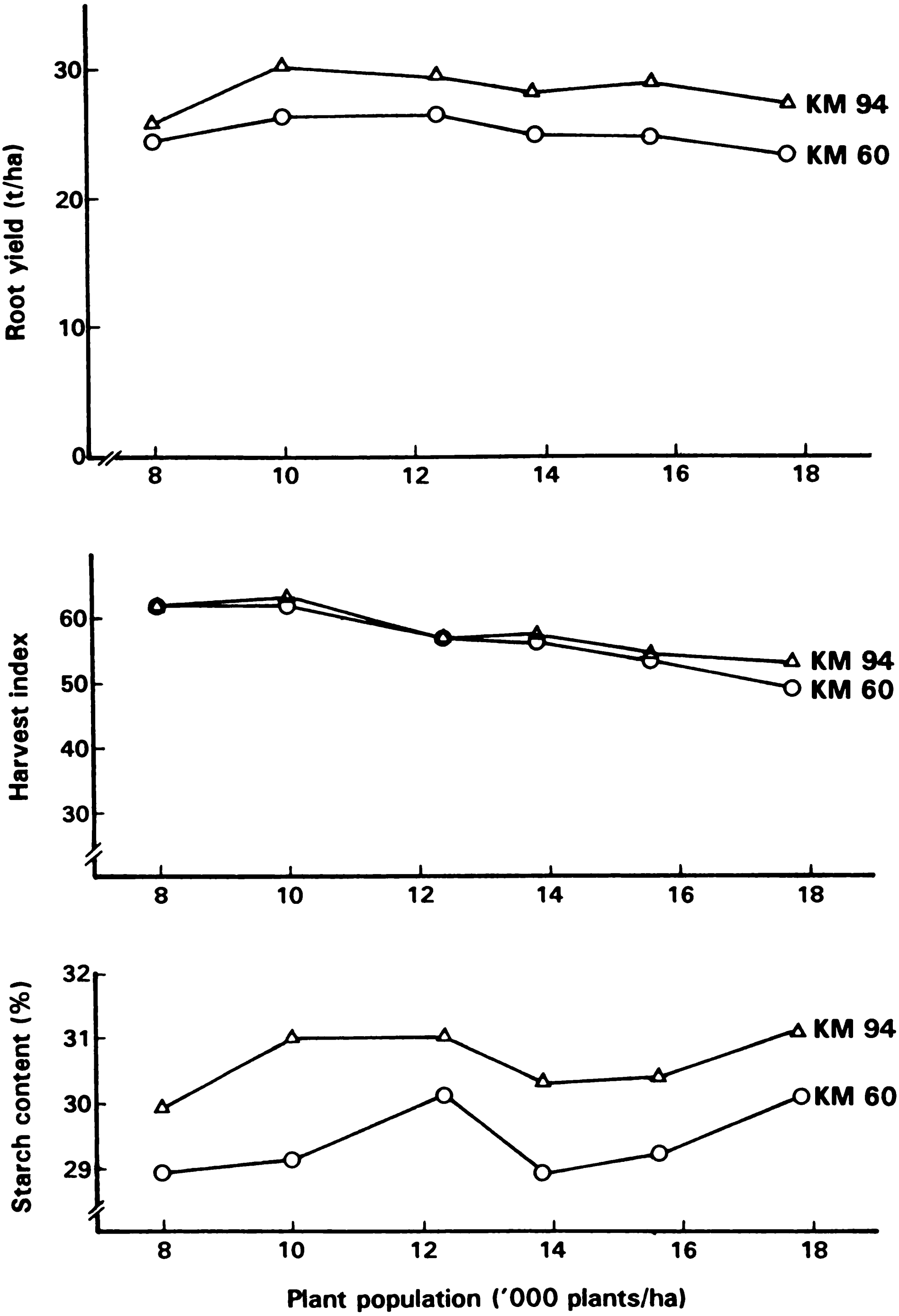


Figure 5. Effect of plant population on root yield, harvest index and starch content of two cassava cultivars grown in Hung Loc Research Center, in Dong Nai province of Vietnam in 1995/96.

Table 3. Effect of intercropping and alley cropping on the yield and starch content of cassava, KM-60, grown in Hung Loc Research Center in 1995/1996 (4th year).

Treatment[1)]	Root yield (t/ha)	Top yield (t/ha)	Harvest index	Starch content(%)
Cassava monoculture	25.48bc	16.87	0.66	29.25
C+C for forage production	25.51bc	17.19	0.67	29.13
C+C for mulch application	24.42c	16.04	0.65	29.40
C+*Tephrosia candida* hedgerows	27.92ab	17.82	0.63	28.48
C+Cowpea intercrop	29.83a	19.27	0.64	29.65
C+*Canavalia ensiformis* intercrop	27.25abc	18.02	0.66	29.50
C+*Leucaena leucocephala* hedgerows	26.05bc	16.78	0.64	29.30
C+*Gliricidia sepium* hedgerows	26.48bc	18.56	0.70	29.55
F-test	*			

[1)]C=cassava

Long-term Fertility Maintenance

Cassava is a crop that is easy to plant and which can be grown on nutrient-poor soils. But to produce high yields, to obtain high economic returns and maintain soil fertility it is necessary to apply fertilizers or manure. Long-term NPK trials were therefore conducted at various locations having two main types of cassava soils in both the north and south of Vietnam. The results indicate that on the red Latosol soil at Hung Loc Research Center in South Vietnam the response of cassava to fertilizers was not statistically significant during the first three years of cropping. But in the fourth year (**Figure 6**) there was a significant response to NPK application and in the fifth and sixth year (**Figure 7A**) the response of cassava to fertilizers was very clear. The application of 80:40:80 and 160:80:160 in kg/ha of N, P_2O_5 and K_2O gave higher yields than other treatments.

Figure 8 shows the response to annual N, P and K application during the first six years of cropping in Hung Loc Center, as well as the relative response and the levels of exchangeable K and available P in the soil. The latter indicate that these soils are quite high in P and K, but that with continuous cassava cropping the P and K levels decreased. Although cassava yields in almost all treatments increased with successive cropping, mainly due to a change to higher yielding varieties in the 4th and subsequent years, the relative yield of the K-check plot decreased, indicating an increasing response to K application.

Another trial was conducted on the same red Latosol soil at Hung Loc Research Center, but planting at the end rather than at the beginning of the rainy season. The results, shown in **Figure 7B**, indicate that there was a significant response of cassava to N, P and K already in the first year, and the application of 80:40:80 produced the highest yield.

Table 4. The results of a cassava population trial conducted on grey Podzolic soil in Ho Nai 4 village of Thong Nhat, Dong Nai in 1995.

Plant population (plants/ha)	Variety KM 94				Variety KM 60			
	Root yield (t/ha)	Gross income ('000d/ha)	Production costs ('000d/ha)	Net income ('000d/ha)	Root yield (t/ha)	Gross income ('000d/ha)	Production costs ('000t/ha)	Net income ('000d/ha)
8,000	19.70	9,259	4,750	4,509	18.31	8,065	3,750	4,885
10,000	24.53	11,259	5,250	6,279	21.82	21,820	10,255	4,000
12,345	22.65	10,645	5,650	4,995	24.88	11,693	4,193	7,500
13,840	23.91	11,237	6,210	6,027	24.74	11,627	4,480	7,117
15,625	25.58	12,022	6,350	5,672	24.67	11,594	4,403	7,191
17,778	24.13	11,341	7,090	4,251	23.59	11,087	4,872	6,215

Other long-term NPK trials were conducted at four locations on light-textured red-yellow Ferralsols and grey Podzolic soils of Vietnam. The results, shown in **Figure 9**, indicate that in Agro-forestry College in Bac Thai the response of cassava to fertilizers was already very clear even in the first year, especially the response to K; in subsequent years the response to N and K increased, while the response to P was usually significant but did not change much over time. The application of 160 kg N, 80 P_2O_5 and 160 K_2O/ha gave highest yields during the sixth year of continuous cropping (**Figure 10**). Similarly, results from trials conducted in Thu Duc in Ho Chi Minh City and in Ho Nai 4 of Thong Nhat in Dong Nai province (**Figures 11** and **12**) indicate that the response of cassava to fertilizer application was clear already in the first year; the application of 80:40:80 and 160:80:160 again gave highest yields. **Figure 12** also indicates that increasing levels of applied N decreased, while increasing levels of K tended to increase root starch contents. P application had little effect on root starch content.

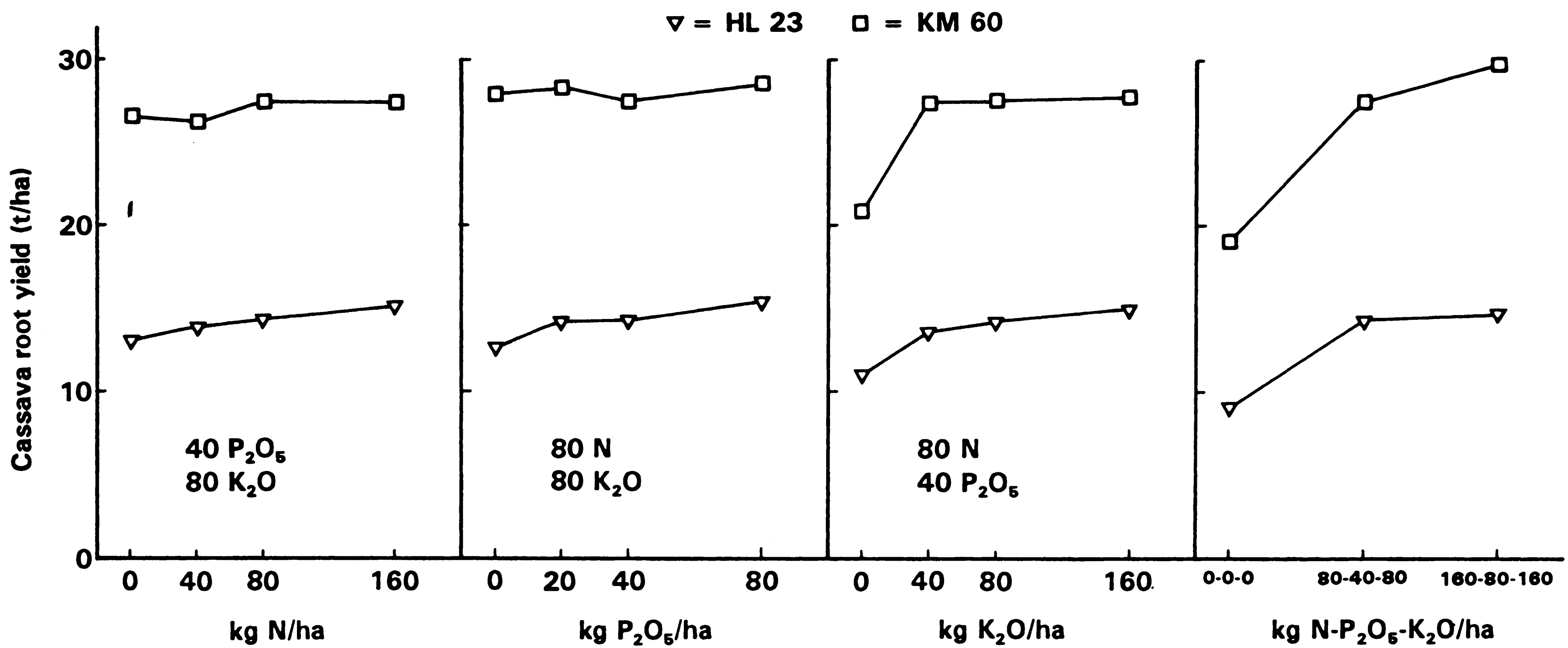


Figure 6. Response of two cassava cultivars to the annual application of various levels of N, P and K during the fourth consecutive planting in the early wet season in Hung Loc Research Center in Dong Nai province of South Vietnam in 1993/94.

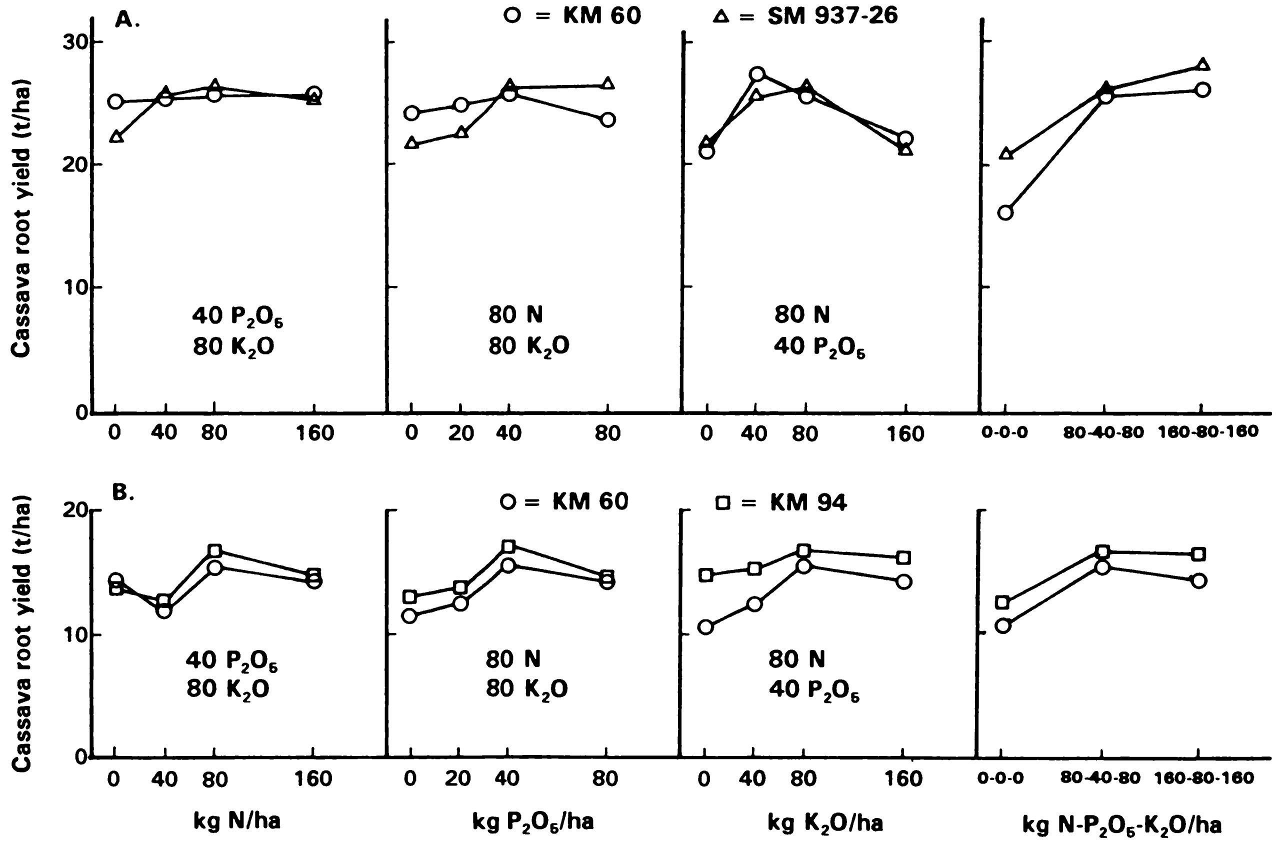


Figure 7. Response of two cassava cultivars to the annual application of various levels of N, P and K during the sixth year of planting in the early wet season (A), and the first year of planting in the late wet season (B) in Hung Loc Research Center in Dong Nai province of South Vietnam in 1995/96.

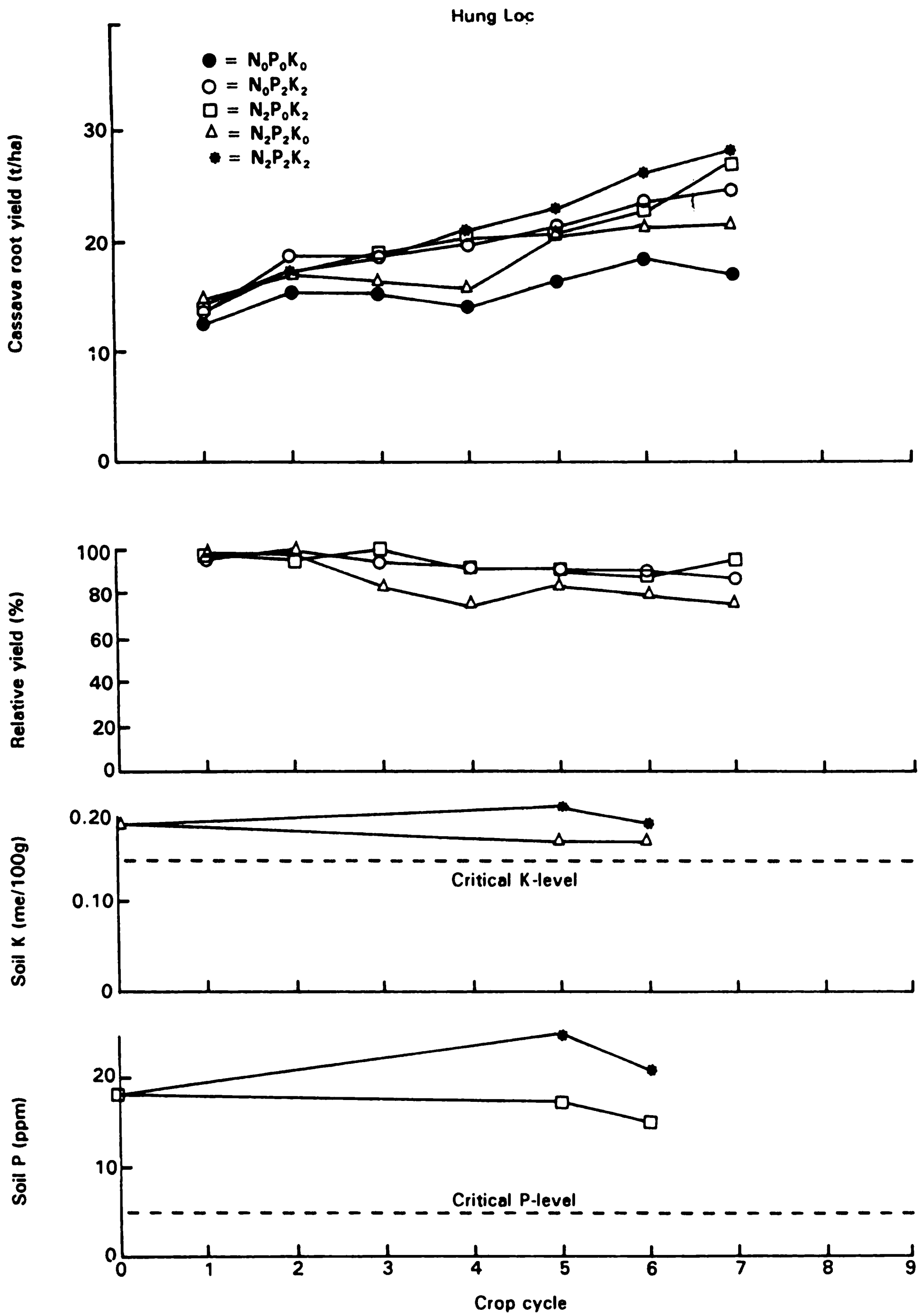


Figure 8. Effect of annual application of N, P and K on cassava root yield, relative yield (yield without the nutrient over the highest yield with the nutrient) and the exchangeable K and availabel P (Bray 2) content of the soil during seven years of continuous cropping in Hung Loc Research Center, Dong Nai, South Vietnam.

Short-term NPK Requirements

In 1993 and during 1993/94 two short-term NPK trials were conducted in Tang Hoa, Vinh Phu province, and in Xuan Thanh, Thong Nhat, Dong Nai province. **Table 5** shows that in Tang Hoa there was a marked response of cassava to K application. The application of 160 kg K_2O/ha gave the highest yields, while without K yields were lowest, both at intermediate and high rates of application of N and P. Analyses of leaf samples indicate that K concentrations in YFEL-blades were lowest in those treatments without K application.

Table 6 shows that on the red Latosol soil at Xuan Thanh in Dong Nai province application of 60 kg N, 60 P_2O_5 and 120 K_2O/ha, with or without application of 500 kg lime and 40 kg $MgSO_4$/ha, produced the highest cassava yields and economic returns.

Future Direction

The following research topics are considered of highest priority in the future:
- Intensification of research on various cropping systems involving cassava.
- Development of management practices that reduce soil erosion when cassava is grown on slopes.
- Release of new agronomic technologies to increase yields and reduce production costs.
- Establishment of a fertilizer program to improve the efficiency of fertilizer use.
- Research on more effective weed control methods.

Table 5. Effect of application of various levels of N, P and K on cassava root yield, the nutrient concentration in YFEL blades at 6 months after planting in Tang Hoa, Vinh Phu province in 1993.

Fertilizers applied (kg N-P_2O_5-K_2O/ha)	Root yield (t/ha)	Nutrient concentration(%) in YFEL blades		
		N	P	K
N40 P40 K0	10.2	3.87	0.31	0.83
N40 P40 K80	13.2	3.47	0.27	1.42
N40 P40 K160	14.9	3.43	0.20	1.44
N80 P80 K0	10.3	3.50	0.32	0.92
N80 P80 K80	14.5	3.72	0.30	1.52
N80 P80 K160	15.3	3.64	0.25	1.62

Source: *Nguyen Huu Hy et al., 1995a.*

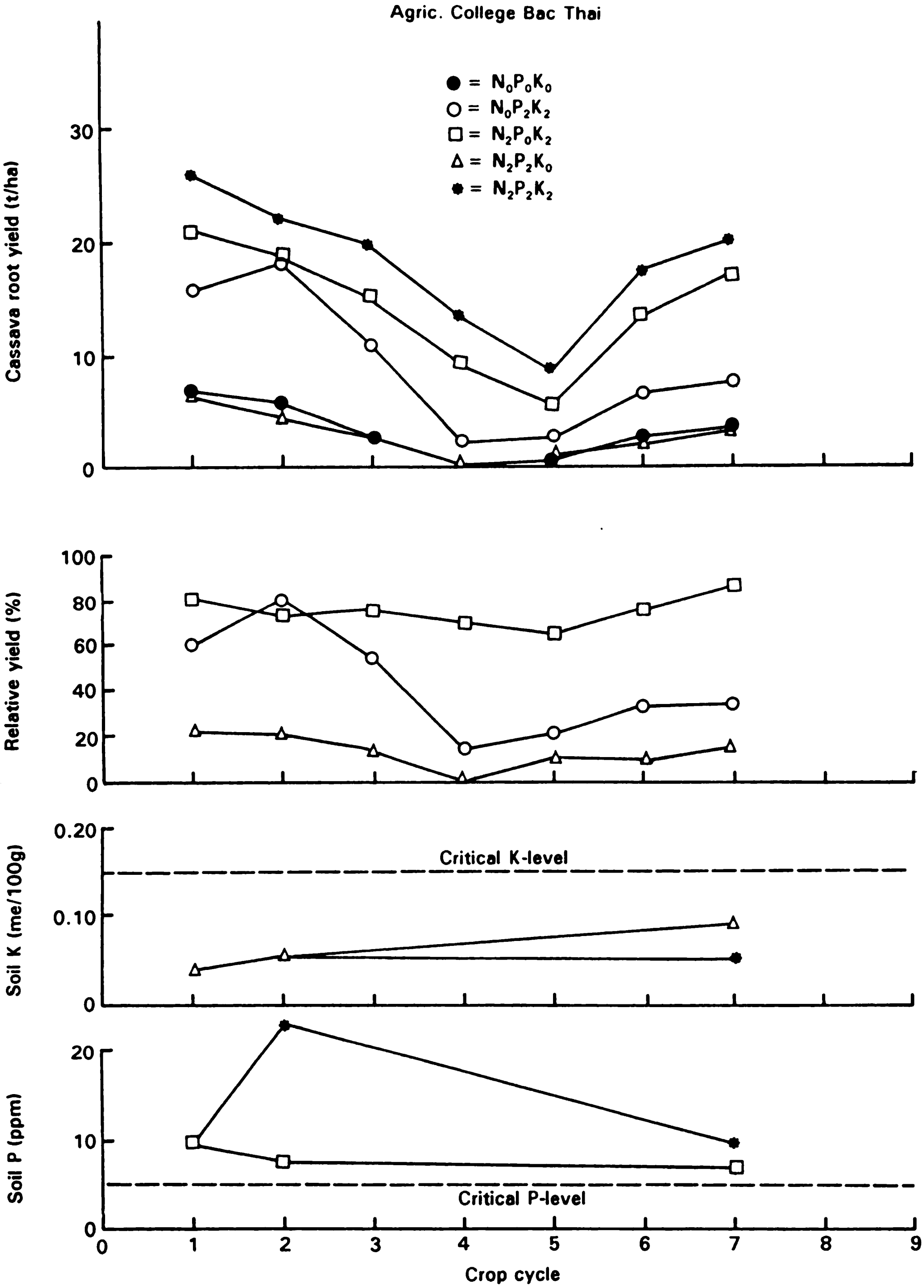


Figure 9. Effect of annual applications of N, P and K on cassava root yield, relative yield (yield without the nutrient over the highest yield with the nutrient) and the exchangeable K and available P (Bray 2) content of the soil during seven years of continuous cropping in Agro-forestry College of Bac Thai, North Vietnam.

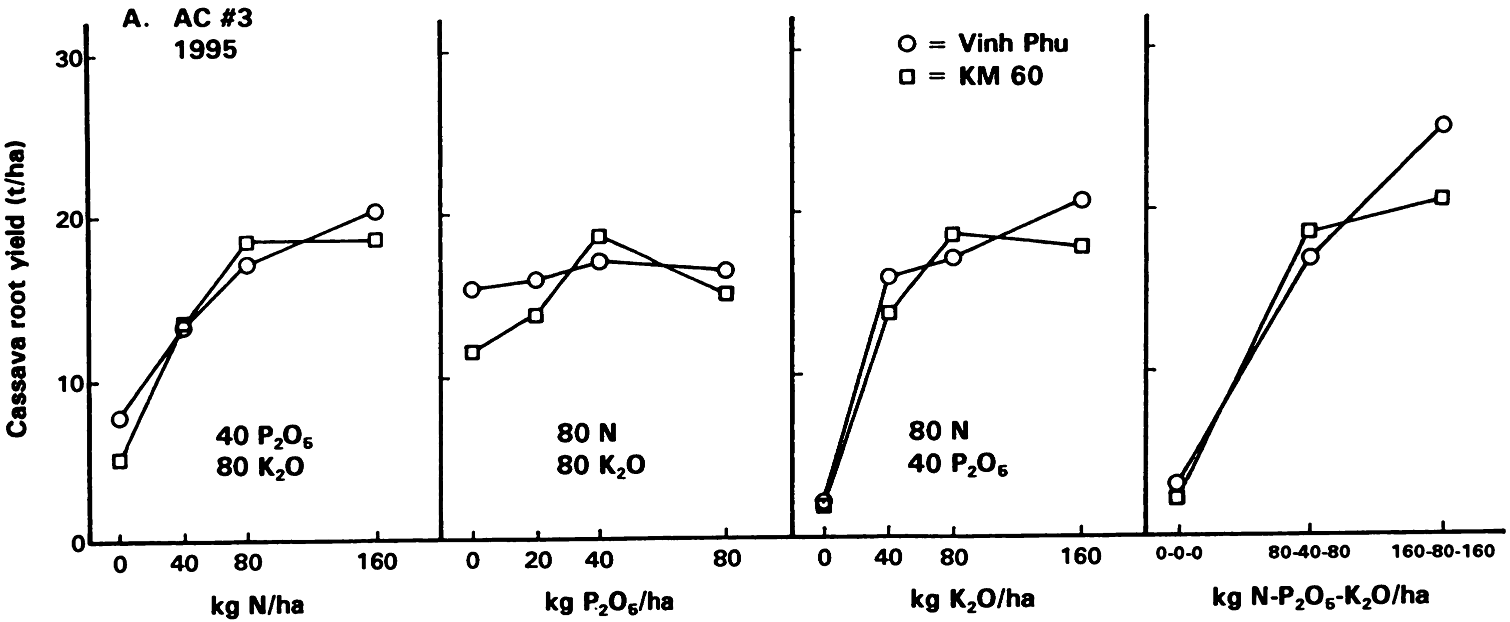


Figure 10. Response of two cassava cultivars to the annual application of various levels of N, P and K in the sixth year of cropping in Agro-forestry College of Bac Thai, North Vietnam in 1995.

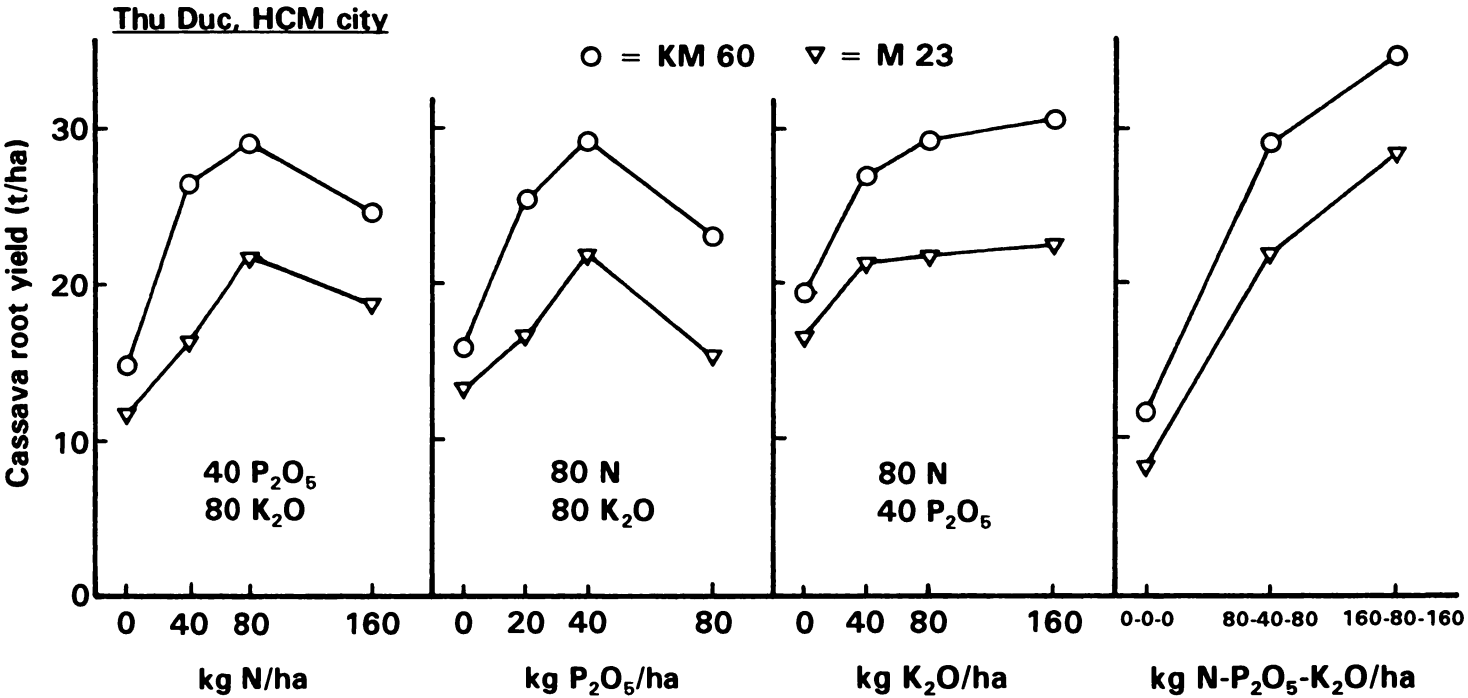


Figure 11. Response of two cassava cultivars to the application of various levels of N, P and K in the first year of cropping in Thu Duc, Ho Chi Minh city, Vietnam in 1994/95.

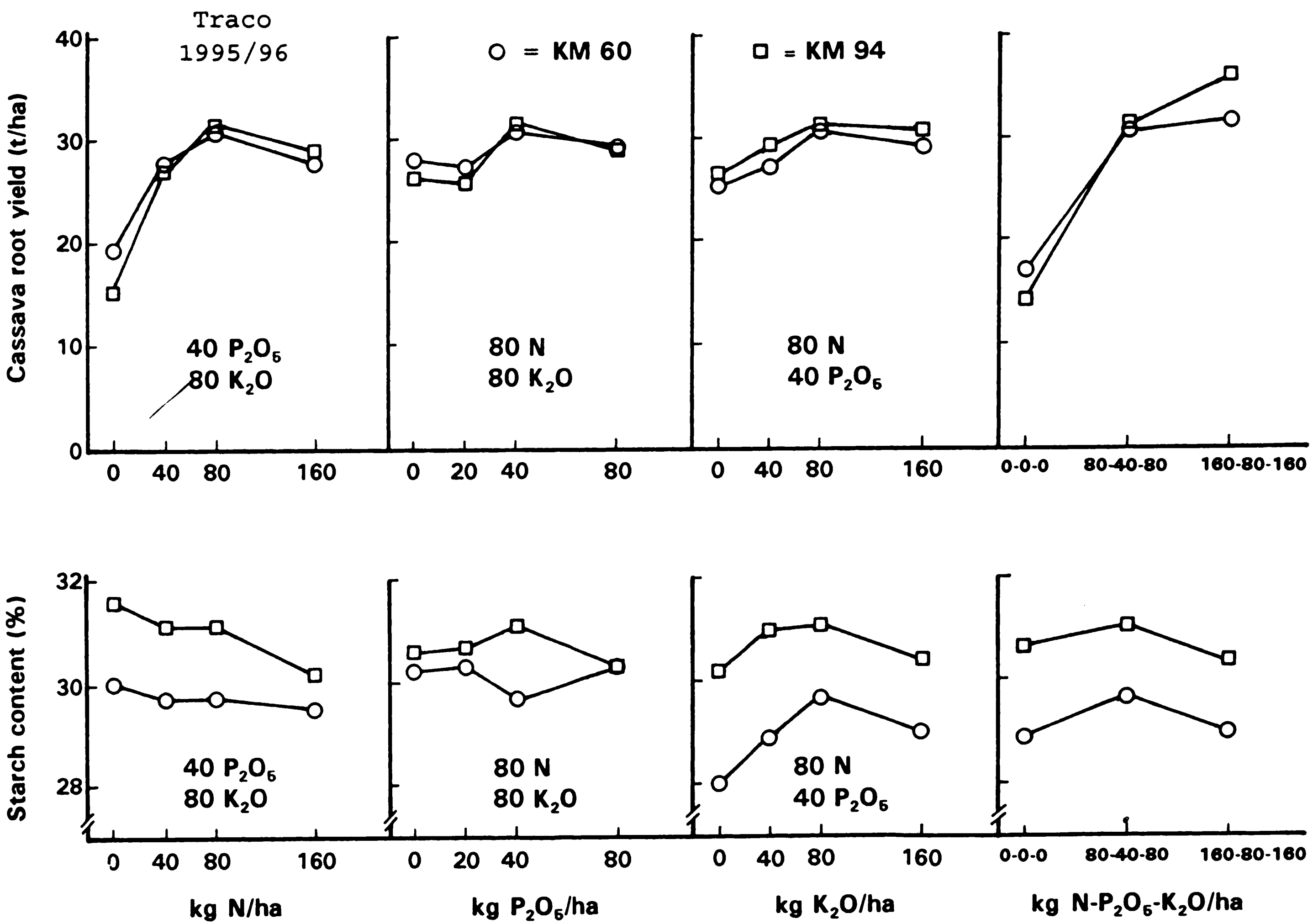


Figure 12. Effect of various levels of application of N, P and K on the root yield and starch content of two cassava cultivars planted in sandy soils in Traco village, Thong Nhat, Dong Nai province of South Vietnam in 1995.

Table 6. Effect of balanced fertilizer application on the yield and economic returns of planting cassava, KM-60, on red Latosol soils at Xuan Thanh, Dong Nai, Vietnam in 1994.

Fertilizer treatments ratio (%)	Root yield (t/ha)	Top yield (t/ha)	Gross income[1] ('000d/ha)	Total costs[2] ('000d/ha)	Net income ('000d/ha)	Profit/cost ('000d/ha)
0 N+0P_2O_5+0 K_2O	17.7a	24.2	4,425	1,750	1,675	95
30 N+ 30 N+P_2O_5+0 K_2O	19.4a	20.5	4,850	1,936	2,914	150
60 N+60P_2O_5+0 K_2O	23.8b	22.7	5,950	2,290	3,660	160
60 N+60P_2O_5+120 K_2O	28.1c	25.5	7,025	2,607	4,418	169
60 N+60P_2O_5+120 K_2O+ 500 kg lime+40 kg $MgSO_4$	31.1d	26.9	7,775	?	?	?
CV (%)	5.5					

[1] 1 kg fresh roots = 250 d
[2] 1 kg urea = 2,790 d
1 kg SSP (18%P_2O_5) = 500 d
1 kg KCl = 1,585 d

Source: *Vo Van Tuan, Hoang Kim and Cong Don Sat, 1994*

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CASSAVA SOILS AND NUTRIENT MANAGEMENT IN SOUTH VIETNAM[1]

Cong Doan Sat[2] and *Pol Deturck*[3]

INTRODUCTION

In South Vietnam, cassava is grown both in the highlands and in the delta, on different soil groups, such as the yellowish red soils, grey degraded soils, alluvial soils and acid sulfate soils. These soils are located mostly in the Central Highlands, the Coastal Region and the Eastern Region of South Vietnam, where perrenial crops such as coffee, tea and rubber are also grown. Cassava is often grown on unfertile soils. As a result, the soil becomes poorer and poorer leading to a decline in soil productivity.

Sloping lands under cassava cultivation are quickly eroded after deforestation. Besides, the soil organic matter content also decreases due to forest burning and leveling and as a result of the direct impact of sunshine and rain drops. The soil will be chemically and physically degraded. Similarly, the soil microbial activity also declines.

To obtain a high and sustainable yield of cassava, it is necessary to use some investment for cassava cultivation. But most cassava farmers are too poor to invest in fertilizers, so the soils quickly lose their productivity. Therefore, better nutrient management is required to maintain sustainable cropping systems, by reducing erosion and preventing a decline in soil fertility.

CHARACTERISTICS OF CASSAVA SOILS IN SOUTH VIETNAM

In South Vietnam, the soils used for cassava cultivation include the three major groups: Acrisols, Arenosols and Ferralsols (Pham Quang Khanh, 1997). They have the following characteristics (**Table 1**):

Topography, soil depth

Most of the land used for cassava cultivation has an undulating topography and the slope is usually less than 25%, which is convenient for transportation and mechanization. The soil depth is generally greater than 100 cm, which enhances good root development.

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[1] Paper presented at the Workshop on Cassava in Vietnam, Ho Chi Minh city, 5-7 March, 1997.

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Table 1. Area and some characteristics of major soil groups used for growing cassava in South Vietnam.

Soil group	Total area in South Vietnam		pH (KCl)	CEC (me/100g)		Base sat. (%)	OM (%)	Total N (%)	Total P (%)	Total K (%)	Texture
	ha	%		Clay	Soil						
Acrisols (Ultisols)	2,296,840	22.6	4.5-5.5	12-14	6-10	25-35	0.8-1.5	0.08-0.10	0.013-0.022	0.25-0.33	light
Ferralsols (Oxisols)	6,907,984	68.1	4.5-5.5	8-12	5-6	30-40	2-4	0.15-0.20	0.026-0.065	0.21-0.37	heavy
Luvisols (Alfisols)	211,958	2.1	5.0-6.5	25-40	15-20	60-80	3-6	0.15-0.25	0.065-0.109	0.42-0.58	medium
Lixisols	34,734	0.3	7.0-8.5	14-20	5-9	80-90	1-2	0.07-0.01	0.022-0.030	0.83-1.67	medium

Source: *Pham Quang Khanh, 1997.*

Soil physical properties

Soil texture varies from light (sand, sandy loam) to moderately heavy (clay loam,clay); the latter are found in the yellowish red soils derived from basalt or schist. Soils with light texture are well-drained and very suitable for cassava root formation; the light texture also facilitates the harvest. However, heavy soils of South Vietnam have good aggregation due to a high Fe content. The soils are porous and well-drained. But most cassava soils have been poorly managed, without much surface cover. This has resulted in the destruction of soil structure, leading to compaction which makes harvesting more difficult.

Soil chemical properties

Cassava is a relatively undemanding crop. Root yields of about 10 t/ha can be obtained on soils which can not be utilized for growing other crops. Due to this characteristic, farmers often exploit as much as possible the nutrient resources in the soil to produce their products.

The degradation of cassava soils can be seen through their chemical and physical properties:

-low pH: 4.5-5.0
-high level of exchangeable Al, and high Al saturation
-low base saturation; low levels of exchangable Ca, Mg and K
-low level of available P and high P fixing capacity
-low CEC
-low organic matter content
-low microbial activity
-low soil permeability

To study the sustainability of different cropping systems in the Eastern Region of South Vietnam, areas were identified in Thay Ninh, Song Be and Dong Nai provinces where forest, rubber, sugarcane, cashew and cassava had been grown continuously for many years, in close proximity to each other, in similar landscapes, on similar grey podzolic soils (Haplic Acrisols) with similar profile characteristics. For each cropping system at least seven soil pits were dug and samplès were taken in the different profile horizons. Both the soil physical and chemical characteristics were determined and the data were averaged over the seven or more profiles. **Figures 1** through **5** and **Table 2** show the results of these analyses. Compared with other cropping systems, cassava soils had the lowest clay content (**Figure 1**) and lowest aggregate stability (**Figure 2**), the second lowest infiltration rate (**Figure 4**) and third highest bulk density (**Figure 3**). Cassava soils also had the lowest level of volumetric water content at different matric pressure heads, ranging from saturation to wilting point (**Figure 5**). This indicates that during cassava cultivation the soil had differentially lost part of its clay, resulting in a lighter soil texture and lower aggregate stability. Compared with natural forest, cassava soils were also more compacted, resulting in a significantly higher bulk density and lower water infiltration rate. Soils under rubber were even more compacted than those under cassava, and they had a similarly low clay content and aggregate stability.

Table 2 shows that cassava soils generally had significantly lower levels of cation exchange capacity (CEC), organic carbon and total N, and lower levels of exchangeable K and Mg than rubber and sugarcane; they tended to have similar chemical characteristics as soils under cashew, except for P, which was considerably higher under cassava than cashew. Soils under rubber and sugarcane tended to have higher levels of fertility due to the higher rates of fertilization used on those crops. These data indicate that soils used continuously for cassava cultivation, generally without adequate levels of fertilization, will become degraded due to soil (especially clay) loss by erosion, as well as by compaction and nutrient depletion. The cultivation practices currently used for cassava in South Vietnam can not maintain the sustainability of the system.

Table 2. Chemical properties of various horizons of Haplic Acrisols that have been under different land use in southeastern Vietnam.

	Forest	Rubber	Sugarcane	Cashew	Cassava	CV(%)
Organic C (%)	1.032 a	0.839 ab	0.796 ab	0.579 ab	0.496 b	44.7
Total N (%)	0.058 a	0.054 ab	0.040 abc	0.032 bc	0.022 c	36.7
Available P (Bray II)(ppm)						
- 1st horizon	5.21 b	20.90 a	20.68 a	4.85 b	15.33 ab	37.5
- 2nd horizon	2.48 b	7.03 a	7.92 a	3.19 b	5.31 ab	32.6
- 3rd horizon	1.57 b	2.83 ab	3.82 a	1.08 ab	3.82 a	44.6
CEC (me/100g)	3.43 a	2.94 a	3.24 a	2.39 ab	1.53 b	27.1
Exch. K (me/100g)						
- 1st horizon	0.132 a	0.127 a	0.051 b	0.070 ab	0.060 b	66.3
- 2nd horizon	0.073 a	0.046 ab	0.022 b	0.031 ab	0.021 b	75.1
Exch. Mg (me/100g)	0.145 a	0.157 a	0.055 ab	0.046 ab	0.036 b	89.1

Values are average of 6-10 profiles per cropping system. Within rows data followed by the same letter are not significantly different at 5% level by Tukey's Studentized Range Test.

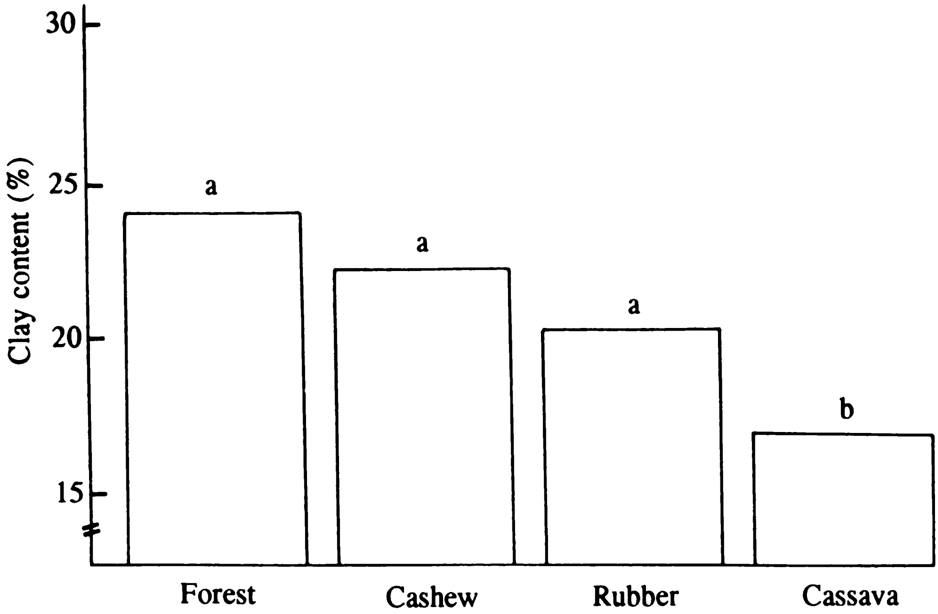

Figure 1. Clay content of Haplic Acrisols under different cropping systems. Values are the average of 7 profiles per cropping system. Bars with common letter are not significantly different at 5% by Duncan's Multiple Range Test.

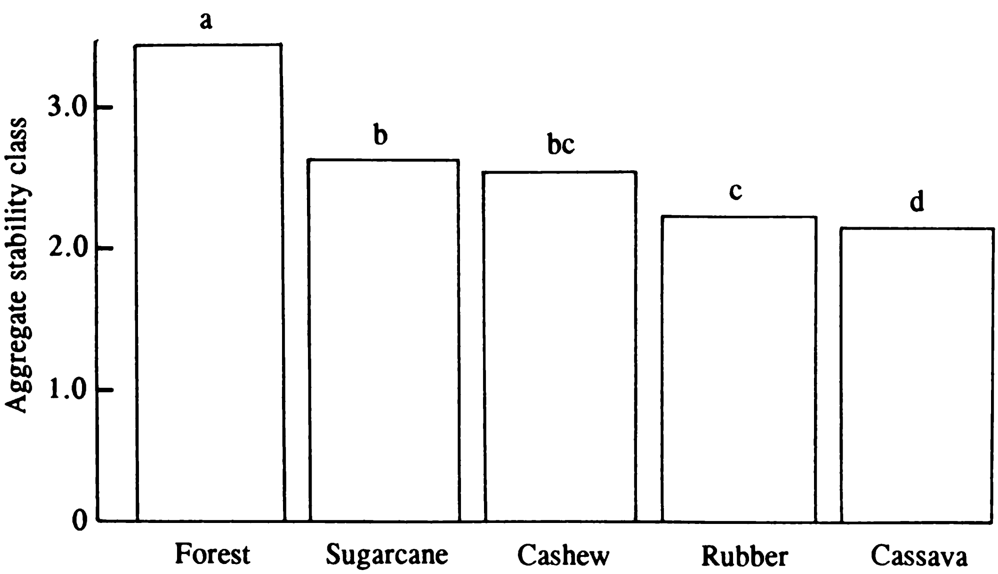

Figure 2. Aggregate stability of Haplic Acrisols under different cropping systems. Values are the average of at least 7 profiles per cropping system and 3 horizons per profile. Bars with common letter are not significantly different at 5% by Tukey's Studentized Range Test.

Note: Aggregate stability class: 1=highly unstable, 2=unstable, 3=relatively stable, 4=stable

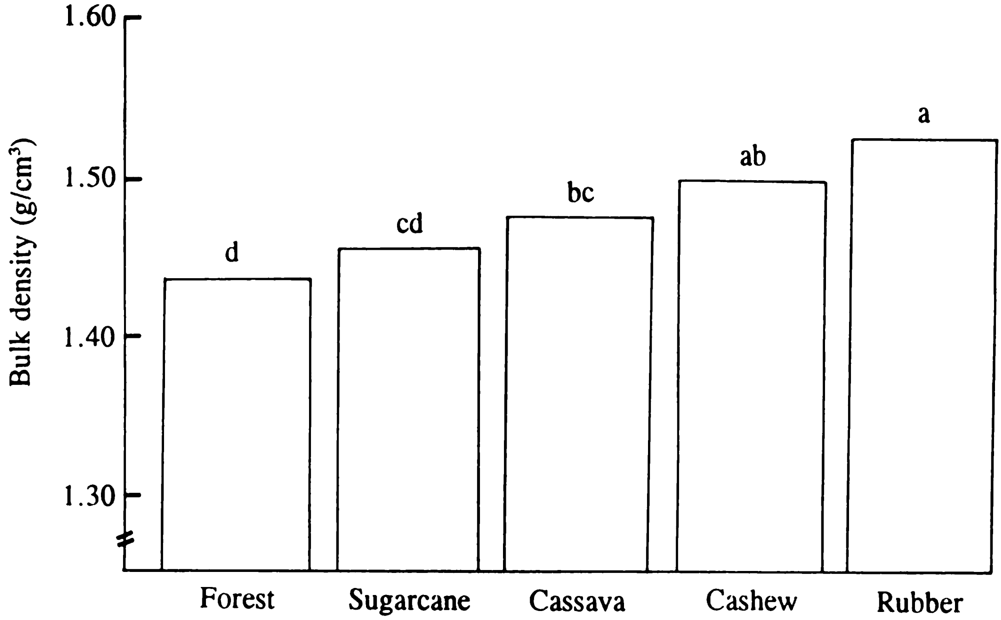

Figure 3. Bulk density of Haplic Acrisols under different cropping systems. Values are average of at least 7 profiles per cropping system and 3 replicates per horizon. Bars with common letter are not significantly different at 5% by Tukey's Studentized Range Test.

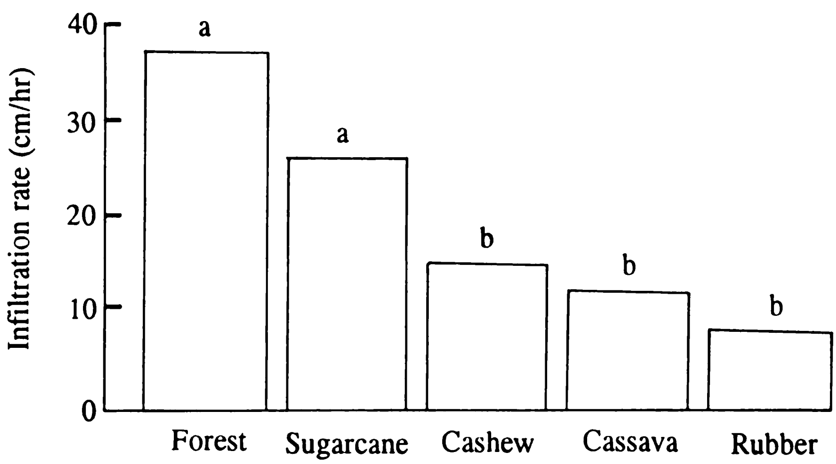

Figure 4. Infiltraton rate of Haplic Acrisols under different cropping systems. Values are average of at least 7 profiles per cropping system and 3 replicates per profile. Bars with common letter are not significantly different at 5% by Tukey's Studentized Range Test.

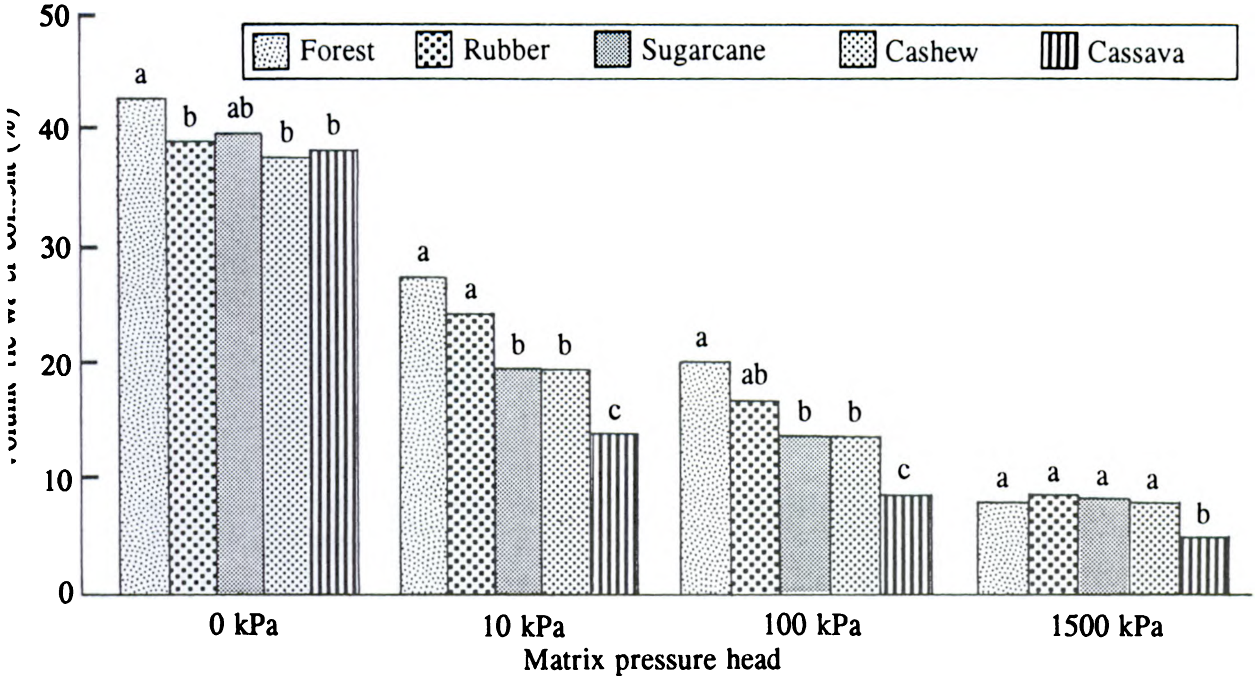

Figure 5, Water retention of the A horizon of Haplic Acrisols under different cropping systems. Values are average of at least 7 profiles per cropping system and 3 samples per horizon. For the same matrix pressure head, bars with common letter are not significantly different at 5% by Tukey's Studentized Range Test.

NUTRIENT MANAGEMENT FOR CASSAVA SOILS

The cassava crop extracts a relatively large amount of nutrients from the soil (**Table 3**). Howeler (1991) showed that cassava removed less N and P in the harvested product (roots) per unit of dry matter produced as compared to other crops; K removal was found to be similar to that of other crops. Like any other crop, continuous cultivation of cassava will deplete the soil's nutrient supply unless fertilizers are added.

Results of experiments conducted from 1989 to 1995 show that mineral fertilizers greatly increased yields when applied at the rate of 80-160 kg N, 40 kg of P_2O_5 and 80-160 kg of K_2O/ha. Intercropping with peanut, mungbean or maize gave high economic efficiency. Highest yields were obtained when cassava was intercropped with *Canavalia* or when contour hedgerows of *Tephrosia candida* were planted (Nguyen Huu Hy *et al.*, 1996).

Table 3. Total nutrient uptake by cassava for various levels of root yield as reported in the literature.

Plant part	Fresh root yield (t/ha)	N	P	K	Ca	Authors
		(kg/ha)				
Total	15	60	17	92	-	Bui Q. Toan, 1990
Total	20	252	41	124	93	Nguyen Tuan Hao, 1994
-stems+leaves		238	32	82	79	
-roots		14	9	42	14	
Total	25	100	31	167	86	Le M. Du, 1995
Total	30	164	31	200	80	Asher, Edwards and Howeler, 1980
-stems+leaves		126	21	124	71	
-roots		38	10	76	9	

The project on the "Development of Sustainable Agriculture for the Uplands of South Vietnam", conducted in collaboration with the Catholic Univ. of Leuven (Belgium), showed that root yields and starch content were highest with the application of 120-120-180 kg/ha of N-P_2O_5-K_2O (**Table 4**). Mulching with straw improved the yield (in one site only), but yields decreased when intercropped with red beans or mung beans, or when cover-cropped with *Calopogonium* (**Tables 5, 6,** and **7**). This may be due to the competition for nutrients or water among crops. Depth of plowing did not result in a significant difference in yield (**Tables 6** and **7**).

Table 4. Average effect of NPK-fertilizers on the yields of fresh cassava roots grown on two Haplic Acrisols in Tay Ninh and Dong Nai provinces of South Vietnam in 1994/95 and 1995/96.

Fertilizers applied (kg N-P_2O_5-K_2O/ha)	Tay Ninh root yield (t/ha)	Dong Nai Root yield (t/ha)	Dong Nai Starch content (%)
0-0-0	12.31 c	15.04 c	22.54 b
30-30-45	18.75 b	22.14 b	22.51 b
60-60-90	19.49 b	23.44 b	22.63 b
120-120-180	26.35 a	28.00 a	23.73 a

Experimental results show that the response of cassava to fertilizers varies from place to place. There is still not enough knowledge to recommend a suitable formula for each soil group. Increasing the dose of mineral fertilizers did not always increase crop yields. As an example, in Thong Nhat district, Dong Nai province, when fertilizer applications were doubled from 30-30-45 to 60-60-90, yields did not significantly improve. However, in the same experiment, application of cassava peel compost plus 20 kg/ha N and 60 kg/ha K_2O produced as high a yield as with application of 120-120-180 kg N-P_2O_5-K_2O/ha. Therefore, organic materials can play an important role as a soil conditioner to maintain adequate soil moisture and a high porosity for root development, or as an additional source of major and minor nutrients.

Table 5. Average effect of mulching and inorganic fertilizer application on the fresh root yield of cassava grown on a Haplic Acrisol in Traco village, Thong Nhat district in Dong Nai province of South Vietnam in 1994/95 and 1995/96.

Treatment[1)]	Fresh root yield (t/ha)		
	M_0	M_1	Average
F_0	17.84 d	18.68 d	18.26
F_1	21.39 c	22.23 bc	21.81
F_2	22.04 c	22.88 bc	22.46
F_3	<u>24.32</u> ab	<u>25.16</u> a	24.74
Average	21.40	22.23	

[1)] F_0: 0-0-0 kg N-P_2O_5-K_2O/ha
F_1: 30-30-45 kg N-P_2O_5-K_2O/ha
F_2: 60-60-90 kg N-P_2O_5-K_2O/ha
F_3: 120-120-180 kg N-P_2O_5-K_2O/ha

M_0: without mulch
M_1: with mulch (3 t/ha of rice straw)

Table 6. Average effect of different management practices on the fresh root yield of cassava grown on a Haplic Acrisol in Tan Phu village, Hoa Thanh district in Tay Ninh province of South Vietnam in 1995/96.

Treatment	Root yield (t/ha)
Intercropping system	
cassava monocropping	23.43 a
cassava+straw mulching	20.96 ab
cassava+peanut intercrop	19.17 b
cassava+cover crop (*Calopogonium*)	13.35 c
Land preparation	
normal plowing	19.88 a
deep plowing	19.57 a

Table 7. Average effect of different management practices on the fresh root yield of cassava grown on a Haplic Acrisol in Traco village, Thong Nhat district in Dong Nai province of South Vietnam in 1994/95 and 1995/96.

Treatment	Root yield (t/ha)
Intercropping	
cassava monocropping	23.16 a
cassava-beans (red bean or mungbean)	17.90 b
Mulching	
without mulch	20.63 b
with mulch of rice straw (3 t/ha)	22.32 a
Dolomite	
without lime	20.74 b
with lime (1 t/ha)	22.22 a
Plowing	
normal (to 20 cm depth)	22.05 a
deep (to 30 cm depth)	21.03 a

In order to maintain a sustainable level of production of cassava in South Vietnam, it is necessary to improve the nutrient management. The problems that need to be studied are:

-the best areas for cassava production

-intercropping and rotational cropping for protection against soil erosion and for maintenance of soil fertility

-suitable combinations of organic and inorganic fertilizers, particularly by-products of cassava processing (stem, peel, fermented products, etc...) to further enhance cassava productivity in the future

-develop a model for improved nutrient management for typical cassava growing regions

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NUTRIENT MANAGEMENT FOR CASSAVA-BASED CROPPING SYSTEMS IN NORTHERN VIETNAM

Thai Phien[1] *and Nguyen Cong Vinh*[1]

ABSTRACT

Five soil types on which cassava is being planted were investigated. Almost all these soils are degraded in terms of soil properties, especially with respect to soil fertility. Cassava is traditionally planted without fertilizer application and soil conservation measures, resulting in a negative nutrient balance.

In experiments on the application of mineral fertilizers, cassava yields increased by 20-112% compared to the control treatment. The combination of organic manures, mineral fertilizers and contour hedgerows to reduce erosion, increased cassava and intercropped peanut yields on average 43-46% compared to the application of organic fertilizers only. The nutrient balance in these areas was positive, with high income and low soil erosion.

INTRODUCTION

Cassava is an annual crop, which is popularly cultivated on sloping lands in the northern mountainous provinces, as well as in other parts of Vietnam. Traditionally, farmers in these regions have adopted a no-input or low-input method of cultivating cassava.

Soil erosion and a decline in soil nutrient content, resulting in land degradation, have been evident from many research results, and farmers are well aware of this. As such, some soil conservationists and policy makers have recommended to replace cassava with other crops, but in fact, thousands of hectares of cassava continue to be cultivated every year on steep sloping lands with little or no input. Annually, cassava removes large amount of nutrients from the soils, while under present crop management systems the nutrient return to the soil is very small.

PROPERTIES OF SOME CASSAVA SOILS

In Vietnam cassava is planted on all soil types, but mainly on sloping lands. The main characteristics of some of these soils are presented in **Table 1**. This shows that the soil physical properties are different for soil types derived from different parent materials. We can see that the clay fraction in the soil texture varied from 10 to 62%, and the coarse sandy fraction from 4 to 60%. Basaltic soils have the highest content of clay, followed by those derived from shale. The sandy and old alluvial soils have a coarse texture. Soil bulk densities varied from 1.08 g/cm^3 in basaltic soil to 1.50 g/cm^3 in old alluvial soil. The rate of infiltration is very low in soils with high bulk density. Run-off and erosion on these soils further lead to soil degradation.

Field capacity also varies between soil types, being 15.0% on old alluvial soil, 29.3% on soil derived on shale, and 43.8% on basaltic soil.

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Comparing the physical properties of soils under forest with those planted to perennial crops, indicate that soils that have been cultivated with cassava for a long time have become degraded. For example, under secondary forest the bulk density of basaltic soils was found to be 0.78 to 0:90 g/cm³, and the clay content 65-71%, while the field capacity was about 48-49%. On soil derived from shale, the bulk density was 1.15-1.25, the clay content 38-41% and the field capacity 30-32%.

Table 1. Characteristics of some cassava soils in Vietnam.

	Soil type				
Parameters	Old alluvial soil	Shale derived soil	Liparit derived soil	Sandstone derived soil	Basalt derived soil
Physical properties					
-Clay (<0.002mm)	12.0	34.8	26.8	10.0	62.0
-Coarse sand (2-0.2mm)	60.0	17.8	34.5	62.0	3.5
-Buld density (g/cm³)	1.50	1.45	1.63	1.60	1.08
-Field capacity (%)	15.0	29.3	19.9	16.0	43.8
-Wilting point (%)	5.0	15.4	8.0	5.2	23.9
-Effective moisture (%)	10.0	13.9	11.9	10.8	19.9
Chemical properties					
-pH_{KCl}	3.7	3.5	4.5	3.9	3.8
-C(%)	1.10	2.20	0.56	1.18	2.57
-Total N(%)	0.08	0.09	0.05	0.09	0.14
-Total P (%)	0.02	0.09	0.01	0.01	0.10
-Total K (%)	0.04	0.12	0.03	0.10	-
-Avail. P (mg/kg)	6.3	18.3	14.5	-	36.5
-Ca (me/100g)	0.20	0.60	0.24	0.98	0.18
-Mg (me/100g)	0.15	0.45	0.17	0.77	0.06
-CEC (me/100g)	4.50	8.50	14.70	4.30	18.0

***Source:** Thai Phien et al., 1995.*

Results of chemical analysis shown in **Table 1** indicate that almost all cassava soils have low pH (in KCl) of 3.5-4.5 depending on the soil's parent material and cassava cultivation practices. The soil pH is below the threshold of that suitable for cassava growing. The soil organic matter and nutrient contents are also very low, with organic C of 1.10-2.57%, total N 0.08-0.14%, total P 0.02-0.10%, and total K 0.04-0.12%. Especially the available nutrient contents are low or very low and can not meet the requirement for normal cassava growth. In terms of suitability for cassava production with respect to nutrient content these soils can be arranged as follows: Soils derived from basaltic rock>Soils derived from shale>Soils derived from liparit rock>Soils derived from sand stone > Old alluvial soils.

This research indicate that almost all cassava cultivated soils on sloping lands are poor to very poor in terms of nutrient content and availability. Therefore, for profitable and sustainable cassava cultivation on these soils, reasonable inputs are needed, together with measures to minimize soil erosion.

SOIL CHANGES UNDER CASSAVA CULTIVATION

1. Soil Degradation as a Result of Cassava Cultivation

The amount of soil eroded by rainfall in sloping areas depends on many factors, but among these the percent crop cover in the rainy season is very important. **Table 2** presents data of soil erosion as affected by crop cover. The secondary forest had a vegetation cover of 80-90%, which resulted in the lowest amount of soil erosion. The highest amount of soil erosion occurred in the soil under cassava.

Soil and nutrient losses by erosion are presented in **Table 3**. Under bush fallow, the amount of soil and nutrient loss was the lowest in comparison with that under tea and cassava. Contour cultivation in tea resulted in soil erosion washing away a depth of top soil of about 2.6 mm/year and a nutrient loss of about 23 kg N, 7 P and 6 K/ha, while the cultivation of cassava resulted in soil and nutrient losses that were 4-10 times higher compared to tea cultivation and bush fallow.

So, it is clear that cassava monocropping on sloping lands may cause serious soil degradation by soil erosion. It is therefore necessary to use reasonable fertilizer inputs and erosion control measures.

The changes in soil organic matter content under cassava monocropping are presented in **Table 4**. After continuous cassava monocropping the soil organic matter content decreased due to soil erosion and organic matter decomposition. After six years the soil organic matter content decreased to about half, and after ten years to only one third of that present in the first year.

Data in **Table 5** show that after 1-2 years of cassava cultivation the soil nutrient content decreased if no fertilizers were applied and no erosion control measures were used. The pH decreased 0.1-0.4 units in comparison with the same soil under forest. Organic matter was about 59-72% compared to the soil under forest. The contents of all nutrients also decreased after cassava cultivation.

2. Improved Management of Soil Nutrients in Cassava-based Cropping Systems

To minimize soil degradation resulting from cassava cultivation, soil conservation measures should be applied. Some research results on the effects of fertilizer application to conserve soil fertility and increase crop yields are presented and discussed.

Effect of application of mineral fertilizers on cassava yield

The experiments were conducted for three years on soil derived from shale.

Figure 1 shows that during three years of continuous cassava cultivation with no fertilization, the yield of cassava decreased from 12.3 to 8.6 t/ha; thus, the productivity of soil decreased to about 70% of that in the first year.

Table 2. Vegetation cover and amount of soil erosion under different crops in soil derived on shale in Thai Nguyen province.

Vegetation/crop	Crop cover (%)	Soil erosion (t/ha)
Secondary forest	80-90	12.4
Maize	30-50	14.7
Upland rice	10-15	95.1
Cassava	10-15	98.6

***Source:** Nguyen Tu Siem and Thai Phien, 1993.*

Table 3. Soil erosion and nutrient losses in eroded soil due to the cultivation of cassava and tea in comparison with bush fallow in Than Hoa district of Vinh Phu province.

Crops	Depth of soil loss (mm/year)	Dry weight soil loss (t/ha/year)	Nutrient loss (kg/ha)		
			N	P	K
Cassava	12.3	145	145	48	26
Tea	2.6	33	23	7	6
Bush fallow	1.0	12	10	2	3

***Source:** Thai Phien and Nguyen Tu Siem, 1993.*

Table 4. Change in organic matter (OM) content and composition due to continuous cassava cultivation for various years at Phu Quy in 1994.

Soil	Total OM (%)	Humic acid (%)	Fulvic acid (%)	Humic/Fulvic acid ratio
Cassava 1 year	1.72	0.48	0.64	0.75
Cassava 6 years	0.80	0.21	0.33	0.64
Cassava 10 years	0.55	0.09	0.36	0.25

***Source:** Nguyen Tu Siem and Thai Phien, 1993.*

Table 5. Chemical characteristics of basaltic rock derived soil under forest and cassava cultivation at Phu Quy in 1994.

	Soil depth (cm)	pH_{KCl}	Total (%)			Exchangeable (me/100 g soil)	
			OM	N	P	Ca	Mg
Forest	0-10	4.2	5.80	0.26	0.11	2.00	0.80
	20-40	4.1	3.30	0.11	0.04	1.18	0.40
	40-60	4.4	3.01	0.10	0.04	1.60	0.76
Cassava (1 year)	0-20	3.8	4.18	0.08	0.05	1.46	1.20
	20-40	4.1	2.19	0.11	0.09	1.40	0.40
	40-60	4.3	1.08	0.10	0.05	1.20	1.60
Cassava (2 years)	0-20	3.8	3.40	0.14	0.10	0.12	0.04
	20-40	3.8	2.08	0.06	0.09	0.04	0.04

***Source:** Nguyen Tu Siem and Thai Phien, 1993.*

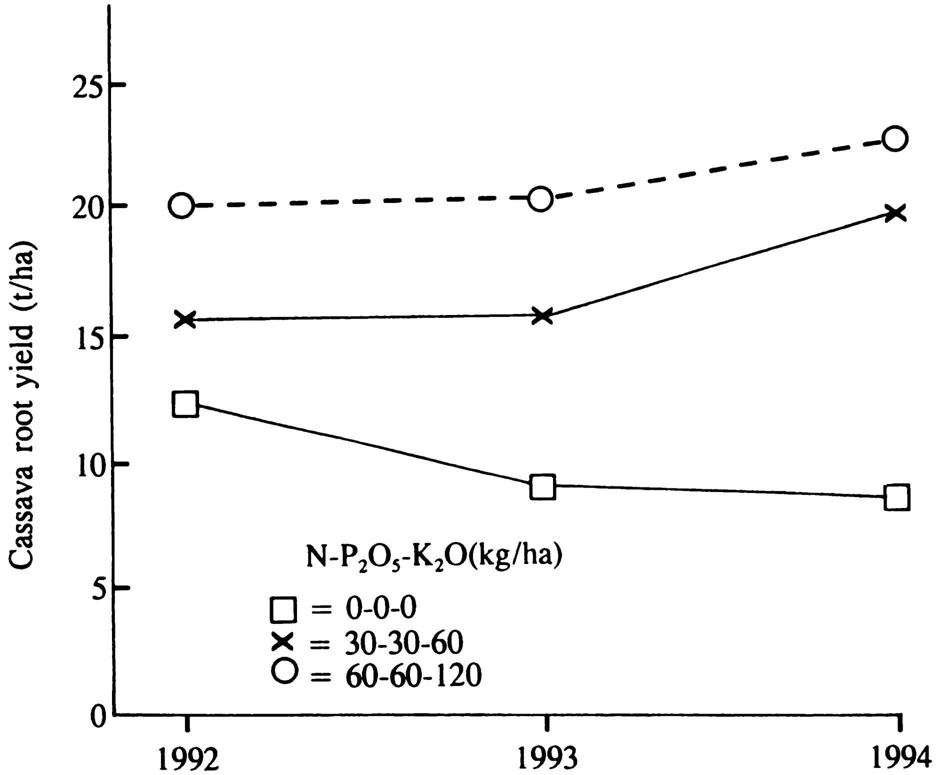

Figure 1. ***Effect of fertilizer application on cassava yield during three years of continuous cropping on a soil derived from shale in north Vietnam.***

Application of NPK fertilizers increased the yield 71-112% in comparison with the control. The effects of N, P and K are presented in Table 6. Application of 30 and 60 kg N/ha increased cassava yields from 16.9 to 17.1 and 17.7 t/ha, respectively. Application of 30 and 60 kg P_2O_5/ha increased cassava yields from 15.6 to 17.1 and 19.6 t/ha, respectively, 10-24% higher than the control. Application of 60 and 120 kg K_2O/ha increased cassava yields 31 and 41%, respectively, compared to the control. The response of cassava to nutrient application in this soil can be ranked as K>P>N.

Table 6. Effect of annual application of N, P and K fertilizers on cassava yields. Data are average values for three years.

Fertilizer applied	Treatments[1)]	Cassava fresh root yield (t/ha)	Relative to control (%)
NPK	$N_0P_0K_0$	10.0	100
	$N_1P_1K_1$	17.1	171
	$N_2P_2K_2$	21.2	212
N	$N_0P_1K_1$	16.9	169
	$N_1P_1K_1$	17.1	171
	$N_2P_1K_1$	17.7	177
P	$N_1P_0K_1$	15.6	156
	$N_1P_1K_1$	17.1	171
	$N_1P_2K_1$	19.6	196
K	$N_1P_1K_0$	13.1	131
	$N_1P_1K_1$	17.1	171
	$N_1P_1K_2$	19.5	195

[1)] $N_0=0$ $P_0=0$ $K_0=0$
$N_1=30$ kg N/ha $P_1=30$ kg P_2O_5/ha $K_1=60$ kg K_2O/ha
$N_2=60$ kg N/ha $P_2=60$ kg P_2O_5/ha $K_2=120$ kg K_2O/ha

Effect of farm-yard manure, inorganic fertilizers and lime in a cassava-grain legume intercropping system

Soil fertility improvement can also be achieved by intercropping cassava with grain legumes in addition to fertilization. **Table 7** shows that application of NPK fertilizers combined with lime (T2, T4) increased the yield of crops, and that these yields were higher than in the treatment with only farm yard manure (FYM). The combination of NPK and FYM (T3, T5) produced higher yields than that of NPK and lime. This indicates that in these hilly soils application of FYM was more effective than that of lime. The combination of NPK with lime and FYM resulted in the highest yield. It shows that the high level of NPK together with FYM and lime promoted the growth and yield of crops. Cassava-legume intercropping systems can achieve yields of 11-19 t/ha of cassava and 78-160 kg/ha of black bean or 550-800 kg/ha of peanut; they tend to be more economical than monocropping of cassava.

Table 7. Effect of three years of annual fertilizer application on crop yields in a cassava-grain legume intercropping system at Hoa Son in 1995.

Treatment[1/]	Cassava yield (t/ha) Mean (1992-1994)	Intercrop yields (kg/ha)	
		Black bean (1992)	Peanut (1993-1994)
1. FYM	11.5	78	546
2. low NPK+lime	14.4	96	730
3. low NPK+FYM	16.8	129	836
4. high NPK+lime	14.8	104	731
5. high NPK+FYM	16.5	143	788
6. high NPK+lime+FYM	18.8	162	870

[1/] FYM = 3 t pig manure/ha.
low NPK = 25 kg N, 50 P_2O_5, 50 K_2O/ha.
high NPK = 50 kg N, 100 P_2O_5, 100 K_2O/ha.

Source: Thai Phien, Nguyen Tu Siem and Nguyen Cong Vinh, 1995.

Soil nutrient balance as affected by fertilization

Every year a considerable amount of nutrients are removed by run-off and soil erosion, as well as by crop removal (**Table 8**). In the case of monocropping of cassava, the annual amount of nutrients removed by cassava was 62-153 kg N, 83-181 kg P_2O_5 and 67-147 kg K_2O/ha. Soil fertility will decline unless nutrients are returned to the soil in the form of fertilizers or manures, or the crop is combined with leguminous crops like black bean, peanut etc. between cassava rows, and the residues of these intercrops are returned to the soil. Even with fertilization of 30-60 kg N, 30-60 P_2O_5 and 60-120 K_2O/ha, the nutrient imbalance that occured varied from 62-120 kg N, 25-59 kg P and up to 72 kg K/ha (**Table 8**). On the other hand, nutrients can be returned by intercropping and mulching with crop residues. Crop residues can provide organic matter and nutrients to the soil (**Table 9**) and improve the soil's physical properties. The nutrient loss in the crop harvest of cassava and beans in a cassava-bean intercropping system was found to be 99-153 kg N, 25-49 P, 31-40 K, 36-58 Ca and 11-19 Mg/ha. Valuable nutrient resources would be taken out of the soil if no crop residues were returned to the soil. The return of crop residues, especially intercropped leguminous residues, can return to the soil about 49-80 kg N, 15-25 P, 10-15 K, 17-28 Ca, and 5-9 Mg/ha. Those are equal to about 110-180 kg urea, 300-500 kg fused magnesium phosphate and 20-30 kg KCl/ha.

The effect of hedgerow farming and intercropping on soil fertility

In Vietnam, cassava is mostly planted on steep lands without or with very low inputs, and without soil erosion control measures. One effective way to minimize soil erosion is the planting of hedgerows of certain plant species along contour lines.

The effect of crop management on soil erosion is presented in **Table 10.** Intercropping with grain legumes and contour hedgerows in combination with fertilizer application reduced soil erosion. On bare land soil loss and run-off were highest. Run-off under monocropped cassava (T2) was reduced by 13% compared to bare land. In cassava intercropped with beans (T3), run-off was only 84% of that of bare land (T3), while intercropped black bean/peanut and contour hedgerows further reduced run-off and erosion.

Fertilizer application also had a marked effect on soil erosion: in the treatments of hedgerow farming with high inputs of fertilizers, soil loss was only 2.8-3.7 t/ha, while with the low input treatment soil loss was 4.8 t/ha.

A large amount of nutrients can be washed out in the eroded soil. It depends on the cultivation method and fertilizer application. These are presented in **Table 11.** In an experiment conducted on an exhausted soil derived from Liparit in Tam Dao, Phu Tho province, 7.8 kg N, 3.9 kg P and 7.2 kg K/ha were washed out as part of the eroded soil from bare land. In monocropped cassava (T2) nutrients are not only lost by soil erosion, but also by removal of the crop products and residues. By intercropping cassava with peanut and planting contour hedgerows, some nutrients are returned by mulching with crop residues (T3, T4, T5, T6). Nutrient losses were lower in treatments with high inputs than in those with low inputs. With high inputs and intercropping, more nutrients were returned than lost. When peanut/black bean were intercropped with cassava, the positive nutrient balance varied from 47 to 63 kg N, 0.3 to 2.0 kg P and 19 to 27 kg K/ha/year.

Table 8. Effect of fertilization on the nutrient balance in soil after cassava monocropping at Hoa Son, 1995.

Treatment	kg N/ha			kg P_2O_5/ha			kg K_2O/ha		
	F[1)]	R[1)]	F-R	F	R	F-R	F	R	F-R
T1	0	62	-62	0	36	36	0	56	56
T2	30	108	-78	0	54	54	42	85	43
T3	30	76	-46	13	49	36	0	72	72
T4	30	135	-105	13	38	25	84	73	11
T5	30	125	-95	13	63	50	42	97	55
T6	0	120	-120	13	61	48	42	94	52
T7	60	134	-74	13	72	59	42	111	69
T8	30	138	-108	26	69	43	42	108	66
T9	60	153	-93	26	79	53	84	122	63

[1)] F = applied in fertilizers; R = removed in crop

Table 9. Biomass and nutrients removed or returned (kg/ha) to the soil in a cassava-bean intercropping system at Hoa Son, 1995.

Treatments		Biomass returned	N	P	K	Ca	Mg
T1	L[1)]		99	24.9	31.2	35.7	11.4
	R[1)]	3910	49	14.7	10.1	17.1	5.4
T2	L		118	36.9	36.3	45.7	14.5
	R	4050	60	18.5	12.1	20.7	6.6
T3	L		121	39.3	39.3	45.0	15.7
	R	4220	64	19.7	13.1	22.9	7.2
T4	L		135	43.1	41.3	50.7	16.9
	R	4450	76	22.2	14.1	25.7	8.4
T5	L		136	43.1	45.4	54.3	17.5
	R	4910	79	24.6	15.2	27.1	9.0
T6	L		153	49.2	46.4	57.8	19.3
	R	507	80	24.8	15.2	27.9	9.0

[1)] L = Lost in crop harvest; R = Returned in crop residues

Source: Thai Phien, Nguyen Tu Siem and Nguyen Cong Vinh, 1995.

Table 10. Soil loss and run-off from degraded soil derived from Liparit (slope: 9-12%) at Tam Dao, Vinh Phu in 1994.

Treatment	Cultivation measures	Run-off m^3/ha/year	Dry soil loss t/ha/year
T1	Bare land (control)	14,539	6.9
T2	Cassava monocrop	12,678	6.9
T3	Cassava+black bean or peanut with low input	12,233	6.1
T4	Cassava+bean or peanut+hedgerow+low input	12,031	4.8
T5	Cassava+bean or peanut+hedgerow+high input	11,473	2.8
T6	Cassava+bean or peanut+mixed hedgerow+ high input	10,674	3.7

Source: Huynh Duc Nhan et al., 1995.

Table 11. Nutrient loss in eroded soil and return in crop residues (kg/ha/year) at Tam Dao, Vinh Phu in 1994.

	N			P			K		
Treatment[1]	L[2]	R[2]	D	L	R	D	L	R	D
T1	7.8	0	-7.8	3.9	0	-3.9	7.2	0	-7.2
T2	7.6	0	-7.6	5.7	0	-5.7	6.2	0	-6.2
T3	6.7	66.2	+59.5	5.6	5.9	+0.3	7.3	30.4	+23.1
T4	8.1	55.3	+47.2	4.8	5.3	+0.5	7.6	26.6	+19.0
T5	4.5	67.2	+62.7	4.4	6.3	+1.9	5.9	33.4	+27.5
T6	6.7	60.3	+53.6	4.3	6.3	+2.0	6.7	31.8	+25.1

[1] Treatments as in Table 10
[2] L=Loss; R=return with crop residues, D=R-L.

Source: *Huynh Duc Nhan et al., 1995.*

The effect of fertilization and biological technology on crop yield

The effect of fertilization and intercropping with grain legumes on crop yields is shown in **Table 12**. Fertilization and contour hedgerows increased the total gross income obtained in a cassava-peanut intercropping system. Monocropping of cassava produced a yield of 10.8 t/ha, while the intercropping system produced 7-9 t/ha of cassava and 450-500 kg/ha of peanut per year, resulting in a gross income of 5.5-6.6 million dong/ha, compared with 4.9 million dong/ha for monocropping.

Table 12. Effect of soil and crop management practices on the yields of cassava and intercrops, as well as on total gross income in Tan Dao, Vinh Phu in 1994.

Treatments[1]	Yield of cassava (t/ha)	Yield of peanut (kg/ha)	Gross income[2] ('000d/ha)
T2	10.8	0	4860
T3	9.1	498	6585
T4	7.6	450	5670
T5	7.9	466	5885
T6	6.9	479	5500

[1] Treatments as in Table 10
[2] Prices: cassava d 450 /kg fresh roots.
peanut 5000 /kg dry pods.

Source: *Huynh Duc Nhan et al., 1995.*

CONCLUSIONS

1. In nearly all soils used for cassava cultivation adequate soil erosion control measures have not been used; as a result, they have become degraded in terms of soil physical properties and nutrient contents.
2. Application of mineral fertilizers to cassava markedly increased cassava root yields, the increase ranging from 20 to 112% compared with the control treatment without fertilization.
3. The combined application of organic and mineral fertilizers increased cassava yields 43-46% compared to the application of organic manures alone. Highest cassava yields were obtained when combining organic and mineral fertilizers with lime.
4. Intercropping grain legumes (bean, peanut) between cassava rows reduced the amount of soil loss by 22-59% compared to cassava monocropping, and contributed to a positive nutrient balance, improved soil fertility and increased income.

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PROGRESS IN AGRONOMY RESEARCH IN INDIA

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ABSTRACT

Nutritional studies of cassava have shown that in high-P acid laterite soils, there was no response to P application during four years of consecutive cropping. In low-P soil, even though cassava initially responded to 100 kg P_2O_5/ha, the response gradually declined. The optimum economic dose of P for cassava in acid laterite soil is about 45 kg P_2O_5/ha. Studies on the NPK requirement of a short duration variety of cassava in a rice-based cropping system, showed that there was a response to the application of 100 kg each of N and K_2O/ha, but no significant response to P.

In upland rice fields the sequential cropping of vegetable cowpea and cassava can eliminate the need for FYM application by incorporating the crop residue of vegetable cowpea before planting cassava.

Application of N and K had a significant effect on root yield of short-duration (7 months) lines of cassava, CI-649 and CI-731, up to 75 kg N/ha and 100 kg K_2O/ha. Studies conducted by Kerala Agric. Univ. have shown that up to 50% of the KCl requirement of cassava can be substituted by sodium chloride (NaCl) without any deleterious effect on crop yield. Another study revealed that under partial shade of adult coconut palms (76% PAR), rainfed cassava (cv Sree Visakham) yielded 77% of that grown in the open.

Transplanting of rooted cassava cuttings, inoculated with the VA-mycorrhizal fungus (VAMF) *Glomus microcarpum* var. microcarpum, was found to enhance the total dry matter and root yield, besides increasing the concentration of micronutrients like Cu and Zn in the leaves. Mass inoculation with VAMF in farmers' fields by planting rooted infected cuttings showed that 70% of the farmers were convinced that they could obtain a higher yield of roots using this practice.

The present practice of planting cassava is to plant stakes directly in the field with the onset of pre-monsoon rains. In this practice, the uncertainty of rainfall may cause poor establishment. In order to overcome this, cassava stakes are first planted in a nursery at a very close spacing of 4.5 x 4.5 cm so as to accommodate about 500 stakes/m^2. Uprooting is easiest when a saw dust media is used in the nursery. Root yield was not affected by the time of uprooting and transplanting in the field between 15 and 25 days, but beyond that age there was a significant reduction in root yield. This technique can be effectively used when short duration varieties are grown under rainfed conditions in areas where rainfall is limited to 4 to 5 months per year. The plants are first raised in a nursery for 25 days and then transplanted in the field with the onset of rains.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz), locally known as tapioca, was introduced in Kerala state of India by the Portuguese in the 17th century. Of the different tropical root and tuber crops grown in India, cassava is of significant importance since it can produce more calories per unit of land area. Its importance in tropical agriculture is due to its

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[2] Kerala Agricultural University, Thiruvananthapuram, Kerala, 695017, India.

drought tolerance/drought avoidance, wide adaptability to diverse soil, nutrient and management conditions, including the time of harvest. The drought tolerance is mainly due to the in-built mechanism to shed/drop the leaves under low soil moisture conditions to facilitate a slow down of all the vital activities of the plant. When soil moisture increases it again puts forth fresh growth and starts accumulating starch in the storage roots. Being a photo-insensitive crop, cassava can be profitably cultivated throughout the year with irrigation.

About 70% of the cassava production in India is used as food, either directly or in processed forms. The most popular and traditional mode of consumption is in the form of cooked and mashed roots. After removing the outer rind and inner thread-like fibrous center core, fresh roots are cut into pieces, cooked in boiling water, decanted and eaten with fish or coconut gratings. Other methods of consumption are as chips fried in oil, or sun-dried chips, which are made into flour and used for preparations similar to those of rice or wheat flours. "Sago" is an important food product derived from cassava starch. It is consumed as a convalescence food in many parts of India.

In India the cultivation of cassava is mainly confined to the southern states, i.e. Kerala, Tamil Nadu, Andhra Pradesh and Karnataka, and parts of the north-eastern regions (**Table 1**). In Kerala where the annual mean rainfall is about 3000 mm, distributed over a period of 7-8 months from April-November, cassava is grown under rainfed conditions. Meteorological data of the major cassava growing states in India are presented in **Figures 1** and **2**. In Tamil Nadu where the annual rainfall is only about 1000 mm, distributed over a period of 4-5 months, the crop is grown mainly under irrigation and with high-input management practices.

Cassava Soils and their Characteristics

In Kerala, cassava is mainly grown on laterite soils (Ultisols), followed by forest soils (Mollisols) and red soils (Alfisols). In Tamil Nadu, the major soil groups under cassava are red soils (Alfisols) and black soils (Vertisols). In Andhra Pradesh the cultivation is mainly confined to the alluvial (Entisols) and red soils (Alfisols). The main characteristics of these soils are shown in **Table 2**.

Micronutrient status of cassava soils

A critical appraisal of the availability of micronutrients in the major cassava growing states revealed that in most cases the soil have micronutrient contents that are well above the critical limits (**Table 3**). Inspite of that, there are locations where there is a response to the application of zinc (Zn). It was noted that Zn availability in laterite soils did not follow any relationship with the physio-chemical properties of the soil.

Table 1. Area, production and yield of cassava in the main cassava producing states of India.

State	Area ('000ha)				Production ('000t)				Yield (t/ha)			
	1970/71	80/81	90/91	93/94	70/71	80/81	90/91	93/94	70/71	80/81	90/91	93/94
Kerala	293.6	243.3	147.2		4,617.2	4,097.5	2,798.9		15.7	16.8	19.0	
Tamil Nadu	38.6	53.3	71.6		466.6	1,539.3	2,107.9		12.1	28.8	29.4	
Andhra Pradesh	3.0	13.0	15.0		21.7	171.0	146.1		7.2	13.2	9.7	
Assam	0.5	1.3	2.3		2.1	5.9	9.8		4.2	4.5	4.3	
Karnataka	0.8	1.3	0.9		9.5	12.8	8.3		11.8	9.8	8.7	
Others	10.6	18.6	5.7		26.5	141.1	40.9		2.6	6.1	7.8	
All India	**337.1**	**320.8**	**243.1**	**235.0**	**5,123.6**	**5,867.9**	**5,111.9**	**5,340.0**	**15.2**	**18.3**	**21.0**	**22.72**

Source: *FAO Production Year Book 1994; Agricultural Situation in India (various issues).*

Table 2. Physio-chemical characteristics of the main cassava growing soils in three states of India.

State	Soil type	pH	Organic carbon (%)	CEC (me/100g)	Clay content (%)
Kerala	Laterite (Ultisols)	4.7-6.2	0.3-2.7	1.4-3.1	11.8-27.8
	Red (Alfisols)	4.8-7.0	0.5-1.1	2.0-7.0	12.9-22.4
	Forest (Mollisols)	4.5-6.0	0.3-14.7	1.5-19.0	10.6-24.9
Tamil Nadu	Red (Alfisols)	8.1-8.7	0.1-1.4	0.5-26.0	11.2-21.8
	Black Vertisols)	7.8-8.9	0.3-1.8	2.7-30.0	12.4-21.3
Andhra Pradesh	Red (Alfisols)	5.1-7.4	0.1-0.8	2.3-7.0	11.3-15.3
	Alluvial (Entisols)	7.2-8.7	0.2-0.8	3.7-4.0	17.8-37.3

Source: Sheeja, 1994.

Table 3. Content of available micronutrients in the main cassava growing soils in three states of India.

State	Soil type	Cu	Zn	Fe	Mn	B
		(mg/kg)				
Kerala	Laterite	1.2	0.8	19.3	19.9	0.3
	Red	0.6	1.2	12.4	15.1	0.2
	Forest	1.2	0.9	43.2	15.7	0.2
Tamil Nadu	Red	1.5	1.0	21.4	12.7	0.2
	Black	3.2	0.9	6.5	5.7	1.1
Andhra Pradesh	Red	1.7	1.1	19.1	20.3	0.2
	Alluvial	4.4	0.7	9.5	13.6	0.4
Critical limit (mg/kg)		0.2	0.6	4.5	1.0	0.2

Source: Sheeja, 1994.

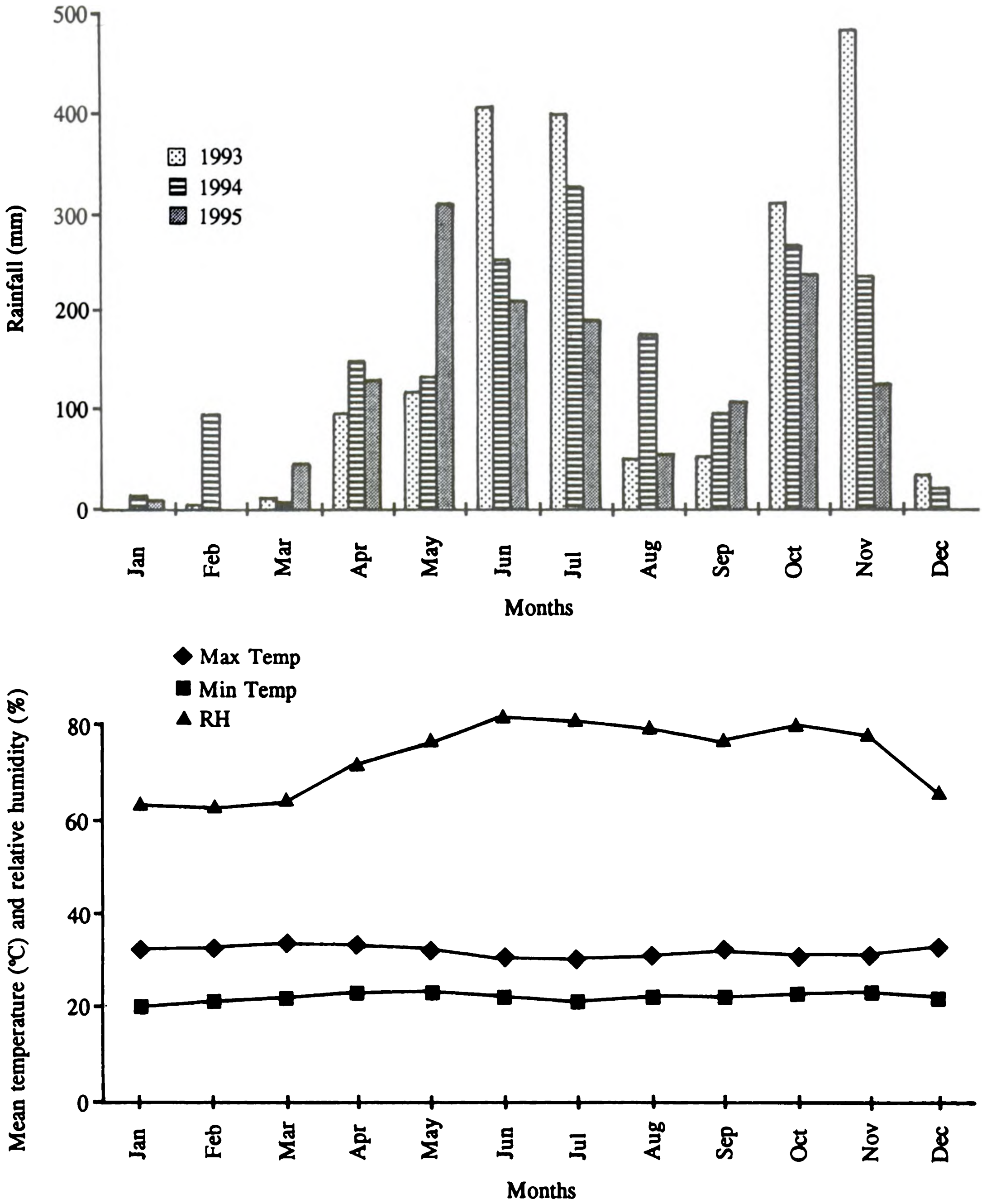

Figure 1. Rainfall (top) and temperature (bottom) at CTCRI in southern Kerala, India, during 1993 to 1995.

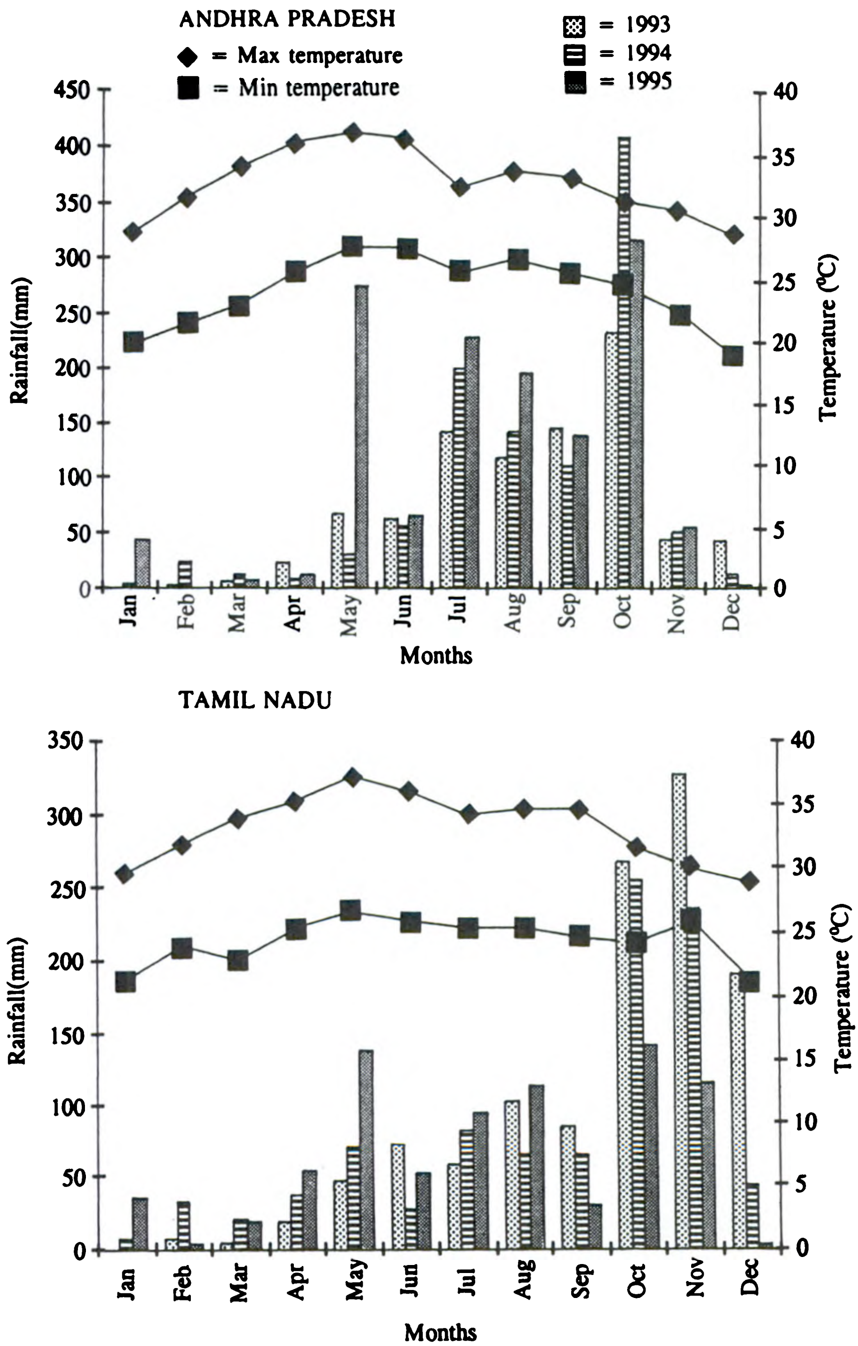

Figure 2. Rainfall and maximum and minimum temperature in Andhra Pradesh (top) and Tamil Nadu (bottom), during 1993 to 1995.

In about 47% of the surveyed area of black soils of Tamil Nadu, the available Zn content was below the critical limit and foliar yellowing and low productivity were noticed. Both red and black soils of Tamil Nadu have a high pH (7.4 and 8.5, respectively) and Zn availability in these soils was negatively correlated with pH. The red soils of Andhra Pradesh had comparatively higher levels of available Zn.

Regarding the availability of iron (Fe) all soils had available Fe contents above the critical limit. In Tamil Nadu red soils had a high level of Fe. The black soils recorded the lowest content of Fe. Iron deficiency in some parts of these black soils are due to the calcarious parent material of these soils and, consecuently, a high soil pH (8.4). Lime-induced Fe chlorosis was observed in black soils of Tamil Nadu. In Andhra Pradesh red soils had high Fe availability.

With respect to the availability of manganese (Mn), all soils are considered sufficient in Mn availability. Manganese availability was negatively correlated with pH. The availability of copper (Cu) in the major cassava growing soils of Kerala, Tamil Nadu and Andhra Pradesh is also considered adequate as all soils had available Cu contents above the critical limit.

Nearly all cassava soils in Kerala are low in available boron (B), while red soils in Tamil Nadu and Andhra Pradesh also have very low levels of B. Nevertheless, significant responses of cassava to B application have seldom been reported.

RESEARCH RESULTS

A. Cultural Practices for Cassava

1. Standardization of nursery techniques for cassava

The present practice of cassava planting in traditional areas is to plant the stakes directly in the field after the receipt of pre-monsoon showers. But in non-traditional areas, where the rainfall is limited to 4 or 5 months, it is recommended to plant stakes first in nursery beds at a very close spacing of 4.5x4.5 cm under irrigation during three weeks before the onset of regular rains. The settlings thus raised in the nursery are transplanted in the main field with the onset of monsoon rains.

1.1 Effect of nursery medium and time of transplanting

Research results (**Table 4**) indicate that time of transplanting had significant effects on root yield. Maximum root yields were obtained when 20 day old settlings were transplanted in the main field. The type of rooting media had no significant effect on root yields.

The main advantages of the nursery technique are:

1. Settlings expressing symptoms of cassava mosaic disease can be discarded in the nursery itself, thereby greatly reducing the incidence of mosaic in the main field.
2. As the settlings are raised prior to the rainy season and transplanted to the main field

with the onset of the monsoon rains, the crop can more effectively utilize the short rainy season for growth and yield. This is especially advantageous in areas having a very short rainfall period.

3. In areas where the crop is raised under irrigation, this technique can reduce the number and quantity of irrigation to the crop.
4. When stakes are planted directly to the main field about 10% of the stakes may fail to germinate. This technique will reduce the percentage of failure in the main field.
5. Transplanting of healthy and uniform-sized settlings generally results in a more uniform crop stand in the main field.

1.2 Effect of stem portion and stake treatment

A study was conducted to determine the effect of stem portion and treatment of nursery-grown stakes on the root yield of cassava. Stakes collected from the bottom 1/3, middle 1/3 and top 1/3 portion of the stem were treated with either VA-mycorrhizal fungi (VAMF), plant protection chemicals, 2% zincsulfate solution or 50 ppm IBA. Water-treated stakes were used as control. The stakes thus treated were planted in the nursery and 25 day old settlings were transplanted in the main field.

The results (Table 5) indicate that there was no significant difference in yield due to stake treatment. Regarding the stem portion, cuttings derived from the bottom and middle portion of the stem were significantly superior to those obtained from the top portion. From this study, it is concluded that while selecting planting material, stakes derived from the bottom and middle portion (lower 2/3 length of the stem) are superior to those from the top part.

1.3 Field trial of rooted infected cuttings

The production of rooted infected cuttings using different media like sawdust, sand and polypack with garden mixture were assessed. The sawdust was found to be the best medium. Among dates of transplanting, the 25th day seemed to be good compared to the 20th day of transplanting.

2. Sequential cropping with vegetable cowpea

The recommended dose of farm-yard manure (FYM) to be applied to cassava is 12 t/ha. In order to substitute for this high dosage of FYM a short-duration leguminous crop of vegetable cowpea was grown preceding cassava, both under lowland and upland conditions.

Under lowland conditions, vegetable cowpea followed by cassava was found to be a feasible alternative to the use of FYM. The yield reduction under such conditions was only 12% when compared to the control, where there was no preceding crop of vegetable cowpea (Table 6). The vegetative matter produced by the seasonal crop was sufficient to provide enough organic matter to cassava; however, under upland conditions, the cassava crop that followed vegetable cowpea suffered from a root yield reduction of 30%. The significant reduction in yield was due to moisture deficiency as a result of late planting and subsequent drought affecting the crop at the root bulking stage. When cassava was planted in May, up to the harvest of the crop in December, there was no serious moisture stress, as the crop was receiving the monsoon rains both for growth and yield.

3. Influence of photosynthetically active radiation (PAR) in intercropped cassava

A trial was conducted at the Kerala Agricultural University to study the influence of PAR on the root yield of cassava grown as an intercrop under coconut trees during 1992/93 and 1993/94. Cassava was grown as an intercrop under the partial shade of about 40 year old coconut palms planted at a spacing of 7.5x7.5 m. The planting patterns of the cropping systems used are shown in **Figure 3**. PAR incidence on the cassava canopy was measured at monthly intervals with the help of a line quantum sensor. PAR received on the canopy of the intercropped cassava was less (76%) compared to cassava grown under full sunlight (**Figure 4**). During the rainy months not much variation was noticed between the quantum of PAR under shaded and open conditions, whereas in the dry months the PAR received in the open was considerably higher than that in the shaded area.

The root yield of cassava grown under the partial shade of coconut palms was less (68%) compared to cassava grown in the open (**Table 7**). As the shade was more or less uniform in the coconut garden, no significant differences in cassava root yield were observed due to the various crop combinations.

B. Soil Fertility Management

1. Long-term effect of manures and fertilizers in acid cassava growing soils

Table 8 shows that increased cassava yields were obtained with an increase in the level of fertilizer application. Among different nutrient levels, the highest yield was obtained with 125:50:125 kg/ha of N, P_2O_5 and K_2O, in addition to 12 t/ha of FYM. This treatment was not significantly different from 100:50:100 + FYM. Application of FYM had a significant effect on yield. Application of the recommended dose of N, P_2O_5 and K_2O, i.e 100:50:100 kg/ha but without the recommended dose of 12 t FYM/ha, resulted in significantly lower yields. Sources of P, i.e. triple superphosphate or Mussorie phosphate, had no significant effect on yield. Application of Zn with the recommended rate of NPK gave a significantly higher yield.

Table 4. Effect of nursery media and time of transplanting of settlings in the main field on cassava root yield (t/ha) at CTCRI, Trivandrum, Kerala, India.

Rooting media	Time of transplanting of settlings in the main field (days)					
	10	15	20	25	30	Mean
Sawdust	25.5	26.7	26.1	24.0	22.6	25.0
Sand	27.8	26.6	27.1	24.5	21.9	25.6
Pot mix	25.2	26.5	28.3	24.5	20.3	25.0
Direct planting	25.0	25.5	26.7	23.2	18.6	23.8
Mean	25.9	26.3	27.1	24.0	20.8	-

CD(5%): media NS; time 2.588

Source: Mohankumar, 1993.

Table 5. Effect of stem portion and various treatments of nursery-planted stakes on cassava root yield (t/ha) in the field at CTCRI, Trivandrum, Kerala, India.

	Stem portion			
Stakc treatments	Top	Middle	Bottom	Mean
VA-mycorrhizal fungi	27.1	30.2	30.1	29.1
PPC (Plant protection chemicals)	27.4	29.3	30.0	28.9
Zinc sulfate (2% solution)	28.3	30.1	30.5	29.6
IBA (50 ppm)	27.9	29.4	30.3	29.2
Control (water)	28.1	30.3	30.1	29.5
Mean	27.8	29.9	30.2	-

CD(5%): stake treatment NS; stem portion 0.466

Source: Mohankumar and Potty, 1994.

Table 6. Biomass production of vegetable cowpea and root yield (t/ha) of subsequently grown cassava as compared to the root yield of cassava grown without cowpea under upland and lowland conditions at CTCRI, Trivandrum, Kerala, India.

Crop (date of planting-harvest)	Lowland	Upland
Vegetable cowpea-cassava		
Biomass of vegetable cowpea (May-July)	20.5	9.1
Root yield of cassava (July-Febr)	51.1	23.5
Root yield of cassava alone (May-Dec)	58.0	33.1

Source: Mohankumar and Nair, 1996.

Table 7. Root yields of cassava grown in various intercropping systems in a coconut garden, as compared with that of monoculture cassava grown in full sunlight at Kerala Agric. Univ., Trivandrum, Kerala, India

Cropping systems[1]	Cassava root yield(t/ha)		
	1992/93	1993/94	Average
1. Co+Ca	25.01	19.43	22.22
2. Co+Ca+Vcp	19.75	20.11	19.93
3. Co+Ca+EFY	29.79	31.56	30.67
4. Co+Ca+Ba	27.32	22.26	24.79
5. Co+Ca+Vcp+EFY+Ba	30.20	29.21	29.70
Mean	26.41	24.51	25.46
CD(5%)	NS	NS	
SEM+	2.642	3.247	
6. Cassava monoculture (full sunlight)	35.38	30.23	32.80

[1]Co = Coconut, Ca = Cassava, Vcp = Vegetable cowpea,
EFY = elephant foot yam; Ba = banana
Source: Ravindran, 1996.

Table 8. Effect of annual applications of manures and fertilizers on the root yield of the sixth successive crop of cassava grown in an acid Ultisol at CTCRI, Trivandrum, Kerala, India.

Treatments[1)]	Root yield (t/ha)
50:25(S):50+FYM	21.7
75:37.5(S):75+FYM	24.4
100:50(S):100+FYM	29.4
125:50(S):125+FYM	30.4
50:25(M):50+FYM	19.1
75:37.5(M):75+FYM	20.4
100:50(M):100+FYM	25.1
125:50(M):125+FYM	31.8
100:50:100 (noFYM)	18.3
100:50:100+1/2FYM	23.3
100:50:100+crop residue incorporated (no FYM)	25.9
100:50:100+Zn (12.5kg.Zn_2 SO_4) (no FYM)	31.1
Ash+FYM	15.5
Ash+crop residue incorporated (no FYM)	10.2
CD(5%):5.65	

[1)](S)=Triple superphosphate; (M)=Mussorie rock phosphate; FYM=12 t/ha of farm yard manure
Source: Kabeerathumma and Ravindran, 1996.

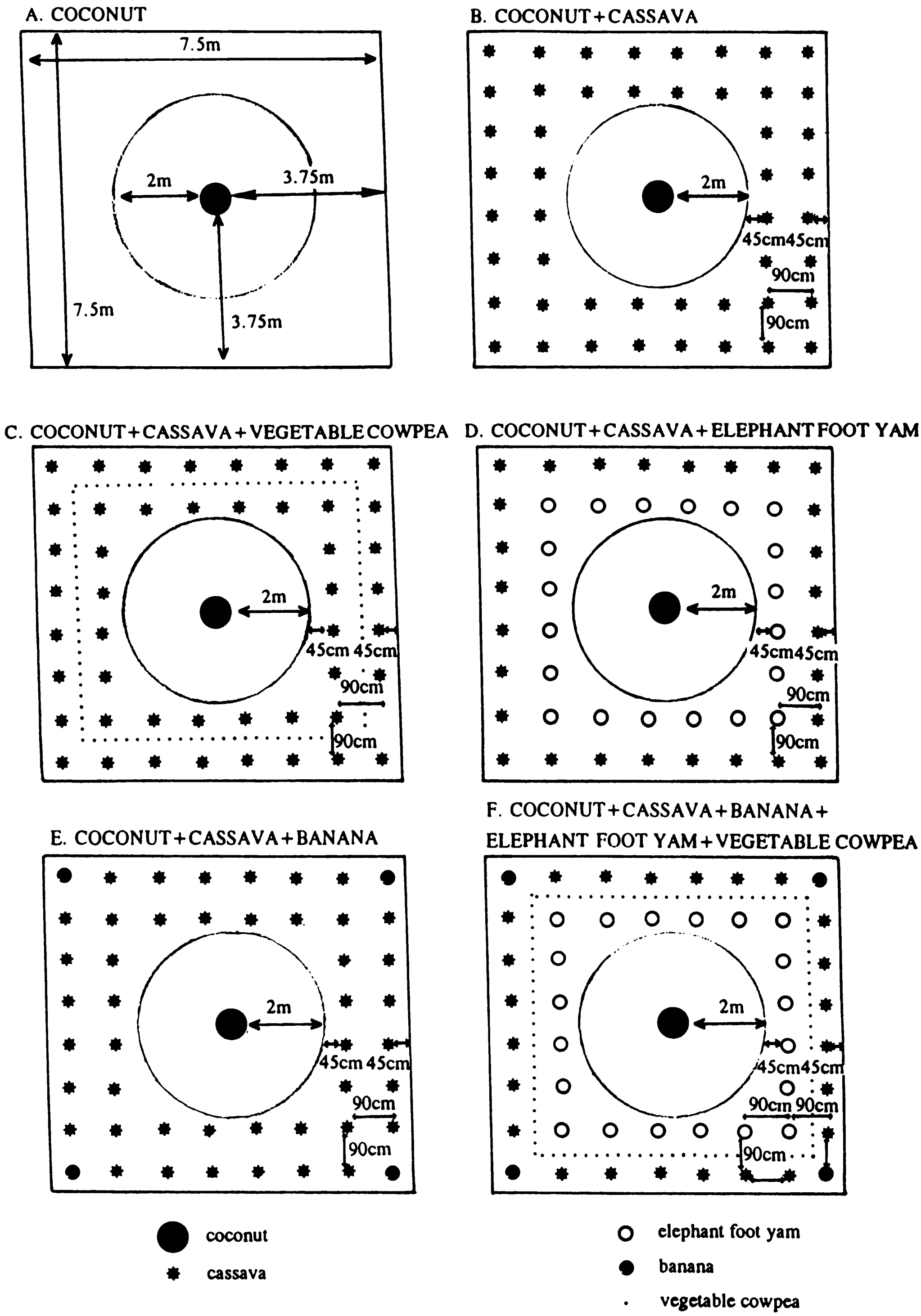

Figure 3. Planting patterns of component crops in various coconut-based intercropping systems.

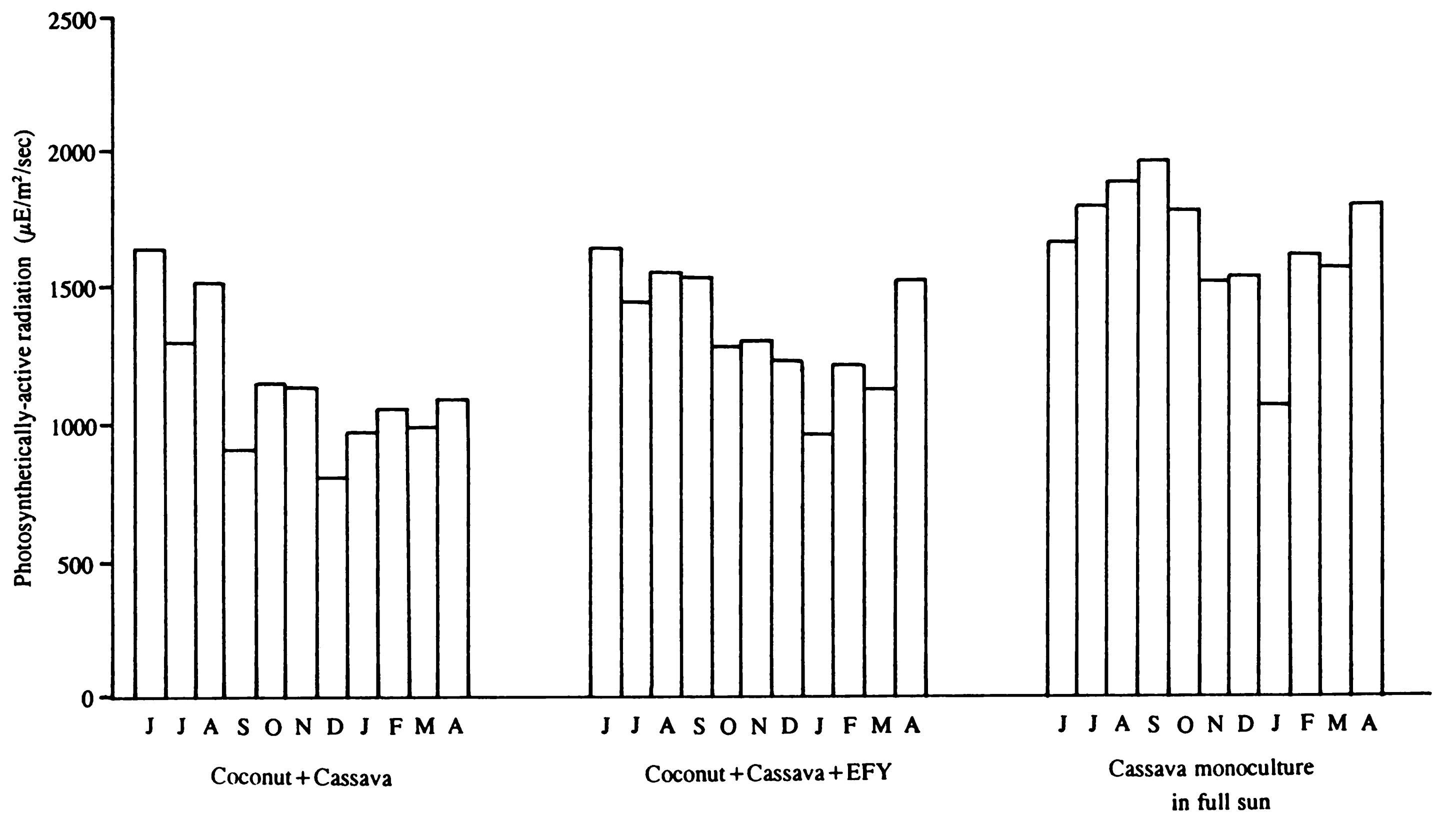

Figure 4. Incidence of photosynthetically active radiation (PAR) on the crop canopy of cassava during the cropping cycle of three cropping systems (see Table 6) at CTCRI in Kerala, India.

2. Phosphorus requirement under upland conditions

Under upland conditions of acid lateritic soils of high-P status, skipping of P application for the first four years had no significant effect on cassava yield. In low-P soils, even though cassava responded initially to 100 kg P_2O_5/ha, the response gradually declined. The optimum economic dose of P for cassava in acid lateritic soils was determined to be about 45 kg P_2O_5/ha (Nair *et al.*, 1988).

3. Fertilization of short-duration varieties of cassava in a rice-based cropping system

3.1 NPK requirements

The common cropping system in a single crop rice field under upland conditions in Kerala is to grow a single crop of dry-sown paddy during the wet season (June-Sept); afterwards the land is left fallow or rice is followed by a pulse crop. Farmers are forced to adopt this system due to a lack of irrigation facilities to raise a second crop of rice.

Cropping system studies conducted at CTCRI have shown that a short-duration (early-maturing) variety of cassava, "Sree Prakash", with seven month duration can be grown successfully in a rice-based cropping system. In order to standardize the NPK requirement of Sree Prakash grown under this system, a study was carried out with three levels of nitrogen (50, 100, 150 kg/ha), three levels of P_2O_5 (25, 50, 75 kg/ha) and three levels of K_2O (50, 100, 150 kg/ha) after the harvest of wet season rice.

Table 9 shows that application of 100 kg N/ha increased the yield significantly over 50 kg/ha. A further increase in N did not show any further positive response. There was no significant response of cassava to P application in this rice-based cropping system. Application of K at 100 kg K_2O/ha showed a significant improvement in yield over 50 kg/ha, but this yield was not significantly different from that at 150 kg/ha. The combined effect of N and K was also significant. However, additional increases in the level of N and K beyond 100 kg/ha did not produce any significant effect on yield.

From the study it could be concluded that the variety "Sree Prakash" responded to a fertilizer dose of 100 kg N, 25 P_2O_5 and 100 K_2O/ha in this rice-based cropping system.

3.2 N and K requirements

Two promising pre-released accessions of cassava, i.e. CI-649 and CI-731 of seven months duration were tested for standardizing the N and K requirements in a rice-based cropping system.

The first rainy season crop was rice followed by short-duration cassava. A short-duration rice was grown during the wet season. "Sree Prakash", a released short-duration cassava variety was used as a control with a fertilizer dose of 75:50:75 kg of N, P_2O_5 and K_2O/ha. Two short duration accessions of cassava, CI-649 and CI-731, were tested under three levels of N and K.

Table 9. Effect of levels of N, P and K application on the root yield (t/ha) of cassava, cv Sree Prakash, grown after rice under lowland conditions at CTCRI, Kerala, India.

	P_{25}	P_{50}	P_{75}	K_{50}	K_{100}	K_{150}	Mean
N_{50}	34.0	32.8	33.4	31.1	33.8	35.2	33.4
N_{100}	36.8	40.2	38.3	34.5	40.7	40.1	38.4
N_{150}	37.5	39.0	38.2	36.2	38.5	40.2	38.3
Mean	36.1	37.3	36.6	33.9	37.7	38.5	

CD (5%) N = 1.385; K = 1.385; P not significant

***Source:** Mohankumar et al., 1996.*

The cassava variety CI-649 recorded a mean yield of 30.53 t/ha, which was significantly superior to that of CI-731 or the released variety Sree Prakash.

Tables 10 and **11** show that the application of N had a significant effect on root production. The highest yield was recorded at 75 kg N/ha, which was significantly superior to that at 50 kg N/ha, but not significantly different from that at 100 kg N/ha.

Tables 10 and **12** show that application of K had a significant effect on root yield. The highest yield was obtained with the application of 100 kg K_2O/ha, which was significantly superior to that at 50 or 75 kg K_2O/ha. Highest root yields of both varieties were obtained with 75 kg N and 100 K_2O/ha.

4. Effect of fertilization on the yield of triploid cassava

4.1 Effect of NPK

Some of the triploid cassava varieties developed have given higher yields and had higher dry matter contents than diploids. In order to suggest a suitable fertilizer schedule, the triploids were grown under three levels of fertilization. The results are presented in **Table 13**.

The triploid variety 2/14 recorded the highest yield of 25.58 t/ha, which was significantly superior to that of 9/76, but not significantly different from that of 237/84. Regarding levels of fertilizer, the dose of 75:50:75 resulted in a significantly higher yield than that of 50:25:50, but was not significantly different from 100:50:100 kg/ha of N, P_2O_5 and K_2O.

Table 10. Effect of various rates of N and K application on the root yield (t/ha) of two short-duration lines and a released variety of cassava grown in lowland soils at CTCRI, Trivandrum, Kerala, India.

Fertilizer levels(kg/ha) $N:K_2O$.[1]	Variety		
	CI-649	CI-731	Sree Prakash (control)
50:50	27.8	27.7	-
50:75	29.3	27.0	-
50:100	31.7	27.6	-
75:50	30.7	28.8	-
75:75	29.7	28.2	27.2
75:100	33.5	31.0	-
100:50	30.5	28.8	-
100:75	29.8	29.1	-
100:100	31.7	29.4	-
Mean	30.5	28.6	

CD (5%):variety 0.77; CD: Control vs treatment 2.33

[1]P was constant at 50 kg P_2O_5/ha

Source: *Mohankumar, 1996.*

Table 11. Average effect of various rates of N on the root yield (t/ha) of two short-duration cassava lines grown in lowland soils at CTCRI, Trivandrum, Kerala, India.

Cassava lines	Levels of N (kg/ha)			Mean
	50	75	100	
CI-649	29.6[1]	31.3	30.7	30.5
CI-731	27.4	29.3	29.1	28.6
Mean	28.5	30.3	29.9	-

CD(5%):0.95

[1]Date are average values for three levels of K; P was constant at 50 kg P_2O_5/ha

Source: Mohankumar, 1996.

Table 12. Average effect of various rates of K on the root yield (t/ha) of two short-duration cassava lines grown in lowland soils at CTCRI, Trivandrum, Kerala, India.

Cassava lines	Levels of K_2O (kg/ha) 50	75	100	Mean
CI-649	29.6[1)]	29.6	32.3	30.5
CI-731	28.4	28.1	29.3	28.6
Mean	29.0	28.9	30.8	-
CD(5%):0.95				

[1)]Data are average values for three levels of N; P was constant at 50 kg P_2O_2/ha
***Source:** Mohankumnar, 1996.*

Table 13. Effect of fertilizer rates on the yield (t/ha) of three triploid cassava varieties grown at CTCRI, Trivandrum, Kerala, India.

Triploid cassava varieties	Fertilizer rate ($N:P_2O_5:K_2O$ in kg/ha) 50:25:50	75:50:75	100:50:100	Mean
9/76	22.78	23.25	24.64	23.56
2/14	23.61	25.95	27.18	25.58
237/84	24.50	25.61	25.48	25.20
Mean	23.63	24.94	25.77	-
CD(5%):0.953				

***Source:** Mohankumar and Nair, 1993.*

4.2 Effect of lime application

Since some triploids showed foliar symptoms of Ca deficiency, an experiment was conducted on the potential need for lime application.

The results showed that application of lime had a significant effect on the yield of all varieties (**Table 14**). No symptoms of calcium deficiency were noticed, however, in any of the varieties. The round-shaped leaf lobe of 9/76 was a varietal character and was observed both in limed and unlimed plots.

Table 14. Effect of lime application on the yield (t/ha) of three triploid cassava varieties as compared to that of a standand diploid variety grown at CTCRI, Trivandrum, Kerala, India.

Triploid cassava varieties	Levels of lime applied (kg/ha)		
	0	600	Mean
9/76	22.53	24.61	23.57
2/14	25.08	26.08	25.58
237/84	24.00	26.38	25.19
Mean	23.87	25.69	-
CD(5%): 0.78			
H-1687 (control)	19.62	21.87	20.75

Source: *Mohankumar and Nair, 1993.*

5. Substitution of KCl with sodium chloride (NaCl)

5.1 Effect on cassava yield

Studies conducted at Kerala Agricultural University have shown that up to 50% of the K requirement of cassava can be substituted by that of Na by the application of sodium chloride (NaCl) without any deleterious effect on crop yield (**Table 15**).

5.2 Effect on nutrient uptake

The uptake of N at different growth stages and with different levels of substitution of K by Na is shown in **Table 16**. Up to six months after planting (MAP), in all the treatments the uptake of N showed an increasing trend and thereafter a decline. The decline in N-uptake was more conspicuous at 50% substitution of K by Na than in other treatments. At 2 MAP and 6 MAP, this treatment with 50% substitution recorded the highest uptake of N. But at harvest time K applied at full dose resulted in the highest uptake of N.

Table 15. Effect of partial substitution of K by Na application on the root yield of cassava grown at Kerala Agric. Univ., Trivandrum, Kerala India.

Treatments	Root yield (t/ha)		
	1992/93	1993/94	Mean
100% KCl	21.91	16.70	19.30
75% KCl+25% NaCl	19.05	20.30	19.70
50% KCl+50% NaCl	26.04	24.50	25.30
25% KCl+75% NaCl	18.42	17.90	18.20
100% NaCl	11.43	15.30	13.40
50% wood ash+50% NaCl	13.81	18.30	16.10
50% $KHCO_3$+50% $NaHCO_3$	16.19	17.80	17.00
CD(5%)	7.87	6.55	3.44

***Source:** Sudharmai Devi, 1995*

Table 16. Nitrogen uptake at different growth stages as affected by partial substitution of K by Na in cassava at Kerala Agric. Univ., Trivandrum, Kerala India.

Treatments	Nitrogen uptake (kg/ha)				
	2 MAP	4 MAP	6 MAP	8 MAP	Harvest[1)]
100% KCl	17.08	33.90	70.36	59.73	60.94
75% KCl+25% NaCl	11.13	48.89	58.81	54.60	45.74
50% KCl+50% NaCl	18.85	42.30	102.42	49.65	37.01
25% KCl+75% NaCl	14.95	37.39	69.25	50.53	34.93
100% NaCl	10.20	43.32	66.48	53.58	23.97
50% wood ash+50% NaCl	8.86	57.10	89.36	54.04	30.50
50% $KHCO_3$+50% $NaHCO_3$	11.20	33.18	77.25	49.54	36.93
CD(5%)	4.16	NS	22.39	NS	28.40

[1)] At 10 months after planting (MAP).

***Source**: Sudharmai Devi, 1995.*

The uptake of P also increased up to 6 MAP and thereafter declined (**Table 17**). Treatment differences were significant only at 2 MAP. During most of the growth stages the highest uptake of P was observed when 50% of the K requirement was substituted by NaCl.

Table 17. Phosphorus uptake at different growth stages as affected by partial substitution of K by Na in cassava grown at Kerala Agric. Univ., Trivandrum, Kerala India.

	Phosphorus uptake (kg/ha)				
Treatments	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
100% KCl	1.92	4.36	8.87	8.65	6.27
75% KCl+25% NaCl	0.61	5.47	7.29	6.32	6.61
50% KCl+50% NaCl	1.82	5.19	11.14	9.55	7.02
25% KCl+75% NaCl	1.11	4.65	8.70	7.77	5.00
100% NaCl	0.65	4.84	6.60	7.53	3.09
50% wood ash+50% NaCl	0.71	5.80	10.40	6.62	4.03
50% $KHCO_3$+50% $NaHCO_3$	0.92	3.75	8.14	7.15	4.36
CD(5%)	0.36	NS	NS	NS	NS

Source: *Sudharmai Devi, 1995.*

At all stages of growth the highest uptake of K was observed in the 50% substitution treatment (**Table 18**). At later stages of growth, Na substitution above 50% or substitution with other alternate sources decreased K uptake.

The Na uptake followed the same pattern as that of K (**Table 19**). The uptake increased up to 6 MAP, and thereafter there was a slight decline.

6. Response of cassava to mycorrhizal inoculation

Studies on the effect of inoculation with VA mycorrizal fungi (VAMF) to nursery-grown stakes clearly showed that plants inoculated with *Glomus microcarpum* var. microcarpum and *Glomus fasciculatum* enhanced total dry matter and root yields, besides increasing the concentration of micronutrients like Zn and Cu in the leaves (**Figure 5** and **Tables 20** and **21**).

About 70% of the farmers who participated in the program on field inoculation of VAMF infected cuttings were convinced of the benefit of mycorrhizal inoculation in improving the growth and yield of cassava.

C. Present Recommendations for Cassava Production

Table 22 shows a summary of the present varieties and recommended practices for cassava production in Kerala.

Table 18. Potassium uptake at different stages of growth as affected by partial substitution of K by Na in cassava grown at Kerala Agric. Univ., Trivandrum, Kerala India.

	Potassium uptake (kg/ha)				
Treatments	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
100% KCl	12.44	11.03	46.66	35.35	28.45
75% KCl+25% NaCl	4.40	18.25	38.00	35.77	38.53
50% KCl+50% NaCl	12.14	16.49	48.36	37.54	38.76
25% KCl+75% NaCl	6.44	10.05	29.76	24.33	14.13
100% NaCl	4.06	11.88	18.58	21.96	14.57
50% wood ash+50% NaCl	3.84	23.34	46.56	31.49	15.95
50% $KHCO_3$+50% $NaHCO_3$	2.79	10.54	30.56	29.82	14.37
CD(5%)	2.43	NS	NS	10.19	17.50

Source: Sudharmai Devi, 1995.

Table 19. Sodium uptake at different stages of growth as affected by partial substitution of K by Na in cassava grown at Kerala Agric. Univ., Trivandrum, Kerala India.

	Sodium uptake (kg/ha)				
Treatments	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
100% KCl	0.48	2.17	2.76	2.70	1.45
75% KCl+25% NaCl	0.24	2.47	1.96	1.81	1.42
50% KCl+50% NaCl	1.00	1.68	2.75	2.38	1.65
25% KCl+75% NaCl	0.63	1.49	3.87	2.92	1.14
100% NaCl	0.62	2.11	2.56	2.40	1.00
50% wood ash+50% NaCl	0.45	1.94	3.69	2.03	0.98
50% $KHCO_3$+50% $NaHCO_3$	0.34	1.75	2.82	1.99	1.04
CD(5%)	0.29	NS	NS	NS	NS

Source: Sudharmai Devi, 1995.

Table 20. Effect of VA-mycorrhizal inoculation and P application on the P concentration of various cassava tissues.

Treatments[1]	Concentration of P in various cassava tissues (%)		
	Root	Stem	Leaf
M_0P_0	0.13	0.10	0.20
M_1P_0	0.19	0.15	0.50
M_0P_1	0.21	0.25	0.65
M_1P_1	0.19	0.30	0.75

[1] M_0=no mycorrhizal inoculation; M_1= mycorrhizal inoculation
P_0=no P added; P_1= half the recommended dose of P
Source: Potty, 1993.

Table 21. Effect of VA-mycorrhizal inoculation and P application on the Cu and Zn concentration of upper leaves of cassava.

Treatments[1]	Months after inoculation				
	2nd	4th	6th	8th	10th
A. Zn concentration (mg/kg)					
M_0P_0	145	150	125	100	75
M_1P_1	120	140	100	110	70
M_0P_1	150	125	100	90	80
M_1P_1	150	145	100	90	80
B. Cu concentration (mg/kg)					
M_0P_0	11	12	13	13	14
M_1P_1	11	12	13	14	15
M_0P_1	9	10	12	13	16
M_1P_1	9	11	13	13	17

[1] Mo=no mycorrhizal inoculation; M_1=mycorrhizal inoculation
Po=no P added; P_1=half the recommended dose of P
Source: Potty, 1993.

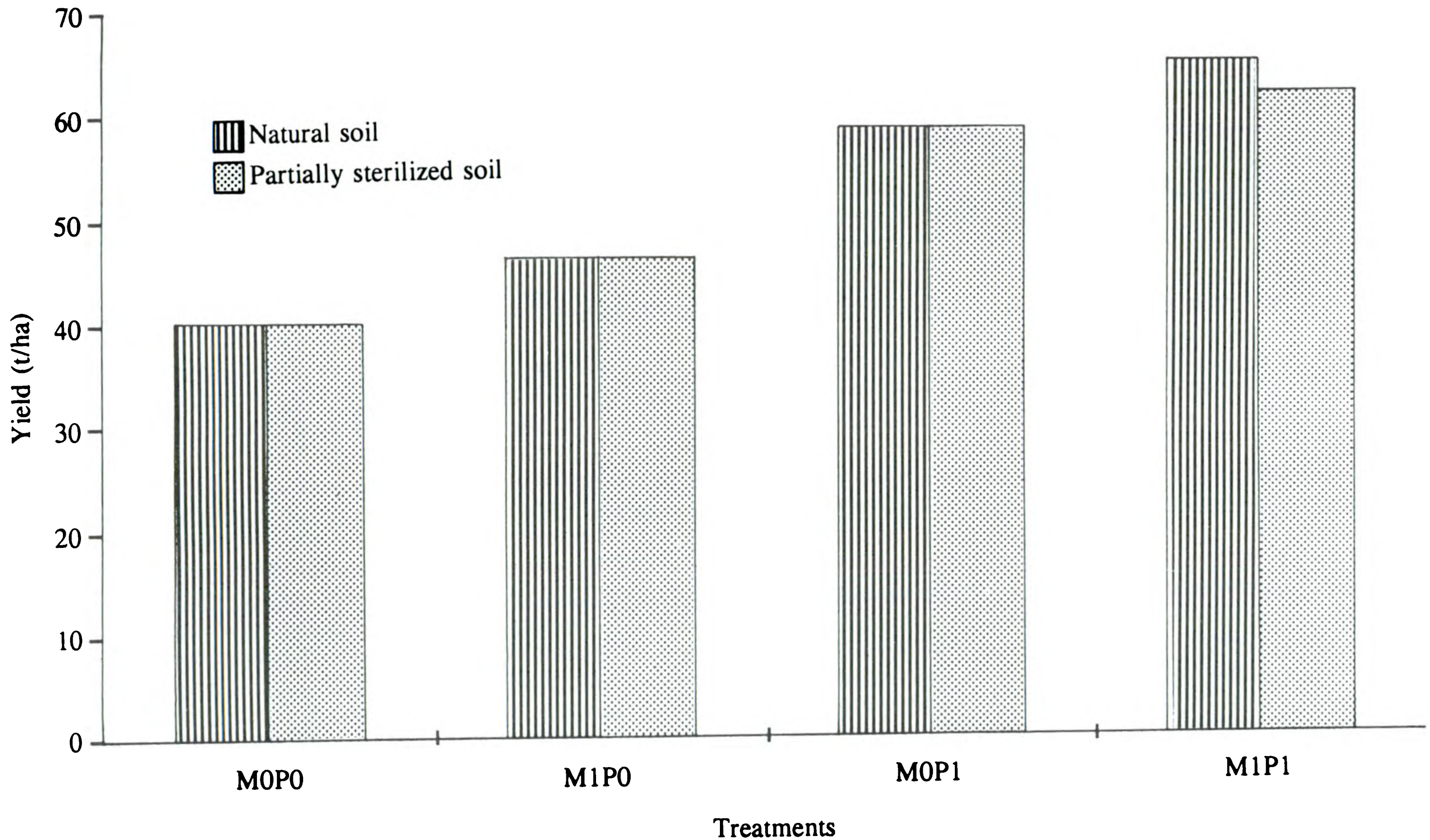

Figure 5. Influence of inoculation with VA-mycorrhizal fungi (M_1) and application of P (P_1) to nursery-grown stakes on the yield of cassava in the field.

Table 22. Recommended cultural practices for cassava production in Kerala, India in 1996.

Varieties:		M-4	: excellent eating quality
		H-97	: high starch, good cooking quality, 10 months duration
		H-165	: early(7 months) variety, desease and pest resistent
		H-226	: good cooking quality
	Sree Visakham	(H-1687)	: good cooking quality, high yield
	Sree Sahya	(H-2304)	: high yield, drought resistent, high starch content
	Sree Prakash	(S-856)	: early harvestable (6-7months)
Planting time:		April-May or Sept-Oct	
Land preparation:		mounds of 25-30cm high, or contour ridges of 25-30cm high	
Planting material:		select plants free of CMV, cut mature stems, 15-20cm stakes	
Planting method:		vertical, 5 cm deep; replant missing hills at soon as possible	
Plant spacing:		90x90 cm for branching varieties; 75x75 cm for non-branching types	
Fertilization:		10-15t/ha of FYM, incorporated; 100 kg N, 45 P_2O_5. 100 K_2O/ha; P all at planting, N and K split at 0 and 45-60 days; only 25 P_2O_5 if soil is high in P; under lowland conditions FYM can be eliminated if vegetable cowpea is grown before cassava and its residues are incorporated into the soil	
Sprout removal:		retain only two shoots, removing excess sprouts at 30-45 days.	
Weeding and earthing up:		at 45-60 days and 1-2 months later	
Intercrop:		peanut, french bean, cowpea	
Harvest:		at 7-10 months, depending on variety (see above)	

FUTURE DIRECTIONS AND THRUST AREAS

1. Standardization of agro-techniques for cassava grown in rice-based cropping systems

   It has been observed that in rice fields where no water logging is experienced, cassava would be a better crop compared to rice. In the present condition of high labor costs, farmers are eagerly looking for a less labor-intensive crop like cassava. It is therefore necessary to standardize the agro-techniques for cassava in a rice-based cropping system.

2. Cassava as an intercrop with perennials trees

   Early bulking, short-duration varieties can be tested under different plant density/geometry, so as to determine the best planting arrangement when intercropped under perennial trees.

3. Cassava leaves as a source of animal feed

   The high-yielding varieties with high rates of leaf production may be tested under varying levels of inputs to identify varieties suitable for the animal feed industry. Prunning of tops may be intensified to monthly intervals starting from the 7th month to the 15th month to determine whether a regular supply of biomass for cattle feed can be obtained.

4. Rapid multiplication of disease-free planting material

   It was found that a rapid propagation method of growing mini-setts in the nursery, and transplanting to the main field, was very effective as compared to the cumbersome method of tissue culture. The technique needs to be popularized among farmers also for the elimination of virus diseas

5. Identification of short-duration high yielding varieties of cassava.

   Short-duration varieties of cassava are in high demand among farmers to fit in a rice-based cropping system, especially in areas where the 2nd crop of paddy is not remunerative due to lack of an assured source of water for irrigation.

6. Studies on the effect of cassava intercropping in reforested areas on soil nutrients, surface runoff and soil loss

   Wherever reforestation is initiated, cassava may be introduced as a companion crop in the first 2 or 3 years, which will give additional income to the government. No detailed studies have been carried out on the impact of interplanting of cassava with forest species. A detailed study is required to find out the changes that are taking place in the flora and fauna of the ecosystem, the soil nutrients, surface runoff and soil erosion loss as the land is of varying topography.

7. Integrated nutrient management for sustainable crop production by complementing chemical fertilizers with green manures and biofertilizers

8. Identification of varieties for non-traditional areas

   At present, the area under cassava in non-traditional areas is increasing as the cassava roots constitute the raw material for various industrial products, such as starch, sago etc. So, suitable agro-techniques have to be developed for popularizing cassava cultivation in non-traditional areas. Wherever irrigation facilities are available, irrigation experiments have to be initiated to determine the water requirement.

9. Regional trials

   Location-specific trials have to be undertaken in different agro-climatic zones, so as to identify varieties better suited to various agro-ecological conditions.

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RECENT PROGRESS IN CASSAVA AGRONOMY RESEARCH IN INDONESIA

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ABSTRACT

Annual growth of cassava production in the main cassava production areas during the last five years seems to have kept pace with the increase in population, while the harvested area of cassava increased only 0.6% annually. Of the total cassava produced, about 54% is used for human food, 28% for industrial purposes, 2% for feed and 16% for export. Therefore, the development of this crop should be in line with the development of other food crops and agro-industry, as well as with that of dried casssava for export.

Of the total cassava area planted in the country, more than 60% is harvested during June to October. Delaying the planting of both cassava and the intercrops tends to give a similar gross return compared to that of planting in the early rainy season. Therefore, most farmers in Sumatra are now planting cassava from the early rainy season to the early dry season. Thus, the cassava harvest is more spread out and cassava becomes a more dependable crop for both the starch and pellet industries, as well as a food security crop in rural areas. Most farmers do not fertilize cassava due to lack of capital; therefore, a closer cooperation between the farmers and starch and pellet factories should be considered to solve this problem.

Cassava agronomy research is mainly conducted by the Bogor and Malang Research Institutes for Food Crops, by Brawijaya University in Malang and by the Umas Jaya cassava plantation in Lampung.

The yield of both cassava and intercrops grown on an ultisol in Lampung decreased more than 60% during the third consecutive cropping without any fertilizer application. Interplanted crops like maize, rice and peanut grow faster than cassava and the amounts of nutrients absorbed by these crops during the first two months are higher than for cassava under these intercropping systems. But, there is an indication that cassava absorbs residual fertilizer applied to these interplanted crops. Crop productivity could be maintained by the application of adequate amounts of fertilizer and by the incorporation of cassava stems and leaves into the soil. A balanced fertilizer rate of 75-100 kg N, 25-100 kg P_2O_5 and 60-100 kg K_2O/ha for monoculture cassava and 100-150 kg N, 50-100 kg P_2O_5 and 100-150 kg K_2O/ha increased net income by 70 and 370% and reduced erosion by 11 and 35%, respectively.

Soil loss due to erosion in monoculture cassava during 10 months in Malang, E. Java, was more than 50 t/ha of dry soil. Fertilizer application, ridging, elephant grass strips and intercropping decreased the amount of eroded soil significantly, compared to monoculture cassava without fertilization. Cassava clones with wide leaves and no branching are considered suitable for intercropping systems.

INTRODUCTION

Indonesia has the fifth highest cassava production in the world. Annual production is quite variable, fluctuating from 15.8 million tons in 1990, 17.3 million tons in 1993 and 15.7 million tons in 1994 (**Table 1**). This fluctiation is caused by fluctiations in prices for cassava products both in Indonesia and in other cassava

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producing countries. Higher prices of pellets and chips, both inside and outside the European Union countries, as well as in the Indonesian market, stimulate cassava production in the following season. Then, the increase in cassava production always brings about a decrease in price. This low price discourages farmers from growing cassava in the next season. These price fluctuations should be minimized through the development of more rural agro-industry and food processing as well as through greater diversification of end markets.

Table 1. Cassava area, yield, production and export in Indonesia, as well as prices of pellets and chips in the EEC and outside the EEC Market from 1990 to 1994.

Year	Harvested area('000ha)	Yield (t/ha)	Production ('000t)	Total exported ('000t)	Prices($/ton)			
					In EEC		Outside EEC	
					Chips	Pellets	Chips	Pellets
1990	1,311	12.07	15,830	1,009	118	124	61	98
1991	1,319	12.10	15,955	956	132	138	58	144
1992	1,351	12.23	16,516	932	127	132	72	143
1993	1,402	12.33	17,285	1,150	109	115	52	51
1994	1,357	11.59	15,729	776	93	100	72	50

Source: BINUS, 1995

Of the total cassava produced in Indonesia about 54% is used for human food (0.83 kg fresh root/day/person), 28% for industrial purposes, 2% for feed and 16% for export (BINUS, 1995).

Crop and land productivity are the determining factors in the farmers' income. In Indonesia cassava is mostly grown on marginal upland soils and the average cassava yield of about 12.2 t/ha is much below the potential yield obtained in experiments, which ranges from 20-40 t/ha. Therefore, there is still a potential to improve production technologies in order to increase yields and farmers' income, while at the same time conserving the soil and water resources.

The main cassava producing areas in Indonesia are located in relatively dry regions and on marginal soils of Java and Nussa Tenggara, where the crop is grown mainly by small-scale farmers which have limitations of land, capital and labor. Consequently, the cassava planting time tends to coincide with the beginning of the rainy season and cassava is usually intercropped with other food crops. In transmigration areas of Sumatra and Kalimantan cassava yields and harvested area vary due to limited availability of labor and capital to grow cassava as well as other food crops. For cassava to be a dependable crop, both as a staple food and as a cash crop, farmers will grow cassava depending on the availability of capital and labor in the family, usually from the early to the end of the rainy season.

Cassava plants absorb large amounts of nutrients from the soil. Therefore, fertilization is often the only way to maintain soil fertility and land productivity. As the goverment plans to stop subsidizing fertilizers, it means that the price of fertilizers will increase and farmers will reduce fertilizer applications to cassava.

In Indonesia most cassava plant parts are utilized and removed from the field. Thus, organic matter additions are also needed to maintain soil fertility in the long-term. Intercropping cassava with upland food crops not only improves the land use efficiency, farmers' income and the distribution of this income through the year, but it also adds more organic matter to the soil than planting cassava in monoculture.

Cassava growth during the first three months is relatively slow. Erosion during this period is relatively high as the soil surface is not adequately covered by the cassava plant canopy. Cropping systems and cultural practices that cover the soil more quickly must be identified to reduce erosion.

During the past ten years, the Bogor and Malang Research Institute for Food Crops, the Agricultural Faculty of Brawijaya University in Malang, and the Umas Jaya cassava plantation in Lampung have been conducting cassava agronomy research with emphasis on solving the above-mentioned problems.

Production Areas and their Agro-ecological Characters

Recent trends in cassava area, production, yield and cassava product prices, as well as the total amount of cassava exported are presented in **Table 1**. Annual growth rates of cassava production and harvested area from 1990 to 1993 were 3.0 and 2.2%, respectively. The decrease in harvested area (7.5%) and production (9.0%) in 1994 was mainly due to drought. Cassava yields were also affected by drought conditions.

Plant productivity is determined by NAR (net assimilation rate), where NAR depends on soil conditions and water availability (Hozyo *et al.*, 1984). Cassava root yields decreased significantly when 2-4 months before the harvest the top soil became hard due to drought (Wargiono, 1993). During the 1993/94 cropping season, rainfall during the 3rd to 5th month after planting was substantially lower than during the same period in the 1992/93 season. This resulted in considerably lower yields in 1994 in all production zones except in Kalimantan (**Figure 1**).

Limited availability of capital is one of the constraints for the farmer to fertilize his cassava crop and to maintain land productivity. Since cassava absorbs large amounts of nutrients from the soil, the application of farm yard manure (FYM) or fertilizers have to be considered. Limited labor in the family is another production constraint and farmers may need to rent a tractor for land preparation and use herbicides to control weeds.

More than 60% of cassava production is located in Java and the remaining 40% mainly in Sumatra, Nussa Tenggara and in the Sulawesi islands. Most cassava in Java is planted in the early rainy season due to limited arable land, whereas in Sumatra land holdings are larger, generally more than one ha, so cassava is planted from the beginning to the end of the rainy season. The wider spread of cassava planting time is one alternative to reduce temporary over-production (Wargiono, 1993). Since the delay in cassava planting time is possible in Sumatre due to a longer wet season, cassava production in Lampung is better distributed throughout the year compared to that in Java (Wargiono *et al.*, 1995).

Cassava in Indonesia is grown on a variety of soils, such as Alfisols, Ultisols, Entisols, Inceptisols, Vertisols and various soil complexes (Wargiono, 1988). These soils are usually infertile and are often 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.

RECENT CASSAVA AGRONOMY RESEARCH

Cassava agronomy research in Indonesia has as its main objective to increase cassava yields and farmer income while maintaining or improving soil fertility and land productivity. The research, therefore, includes the identification of cassava production constraints, the evaluation of new cassava clones under intercropping systems, the control of erosion, and the improvement of cultural practices and fertilizer use efficiency.

1. Case Study to Determine Cassava Production Constraints

A study was conducted in Nov 1995 in transmigration areas of northern Lampung. The sub-districts studied were Manggala, Tulangbawang Udik, Tulangbawang Tengah and Mesuji.

Cassava in this area is a staple food, consumed as steamed cassava/rice pellets (tiwul) during 3 to 9 months of the year. Tiwul is made from cassava flour mixed with rice in a ratio of 2-4: 1. Based on an average cassava flour consumption of 0.33 kg/day/person, the cassava consumed as tiwul is about 25 kg fresh roots/month/person. **Table 2** shows supply and demand of cassava in the sub-districts studied, where utilization for human food and industrial purposes were only 9.3% and 32.3%, respectively. **Table 3** shows cassava yield and production during 1990-1994 in the sub-districts studied. In some cases production increased in spite of a decrease in yield; this is due to a marked extension of planted area. This production was affected by demand by the industries and by availability of infrastructure. Good infrastructure reduces transportation costs and facilitates the sale of cassava. Therefore, the farmgate cassava price of these areas is higher compared to those in areas with poor infrastructure.

The cropping system used in this area is affected by the availability of labor and capital. Average available labor is two persons per family. The capability of these two laborers to prepare land and grow food crops was 0.25-0.5 ha/month. Therefore, farmers have to delay land preparation and the planting of food crops when they want to grow crops on more than 0.5 ha.

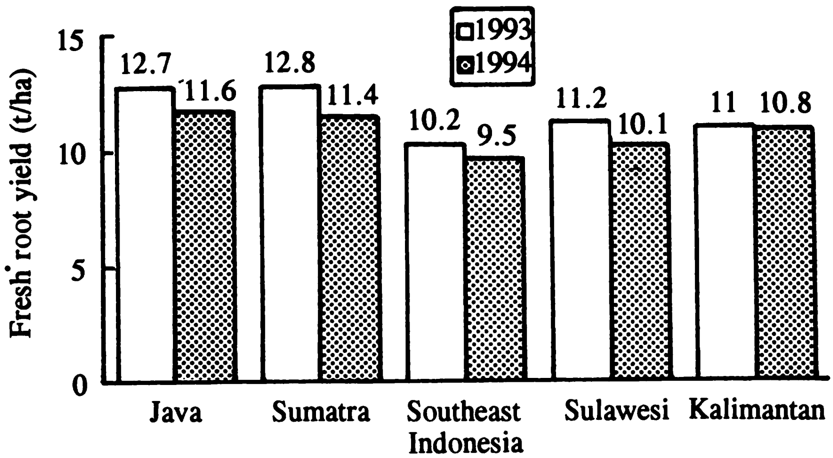

Figure 1. Cassava yields by region in 1993 and 1994.
Source: CBS, 1995.

The Ultisol soils of the areas studied are mostly infertile; thus fertilization and good crop management (controlling weeds and pests/deseases) are essential for obtaining good yields. Since cassava grows better than other food crops on infertile land and with low inputs, more and more cassava is grown by those farmers that have limited capital. **Table 3** shows that cassava yields decreased dramatically over time in all four sub-districts. In 1990 the land was newly opened from the bush and high yields could be obtained without any fertilization. However, cassava extracts large amounts of nutrients from the soil and soil fertility decreased, resulting in a decrease in cassava yield as no fertilizers were applied by the farmers in each growing season. With adequate fertilization high yields of cassava could probably have been maintained (see below). But most cassava farmers have no money to buy fertilizers; thus, the subsidizing of fertilizers may still be needed. As fertilizer subsidies from the government will be stopped, fertilizer subsidies from private companies through a cooperative system with farmers' groups may have to be considered. A Cooperative Model (**Figure 2**) with clearly defined relations between farmers' groups and a tapioca factory, might be recommended.

2. Cropping Systems

Cassava is planted in monoculture only around urban areas, in starch factory plantations and on non-productive land, which cannot be planted to 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's physical

Table 2. Supply and demand of cassava in various subdistricts studied in northern Lampung in 1995.

Sub-district	Production ('000t)	Demand(%) Food	Demand(%) Industrial purpose	Surplus ('000t)
Manggala	483.6	5.9	32.7	297.2
T.B. Tengah	137.2	16.4	49.6	46.7
T.B. Udik	111.4	8.5	0	102.0
Mesuji	111.9	16.0	41.8	47.3

Source: Ditpertan, North Lampung 1995

Table 3. Cassava yield and production in four subdistricts of northern Lampung from 1990 to 1994.

Year	Manggala		T.B.Tengah		T.B.Udik		Mesuji	
	Yield (t/ha)	Production ('000t)	Yield (t/ha)	Production ('000t)	Yield (t/ha)	Production ('000t)	Yield (t/ha)	Production ('000t)
1990	27.0	326.0	26.3	138.8	23.9	72.9	22.4	222.9
1991	24.7	436.1	23.1	128.2	19.7	162.9	20.2	133.3
1992	21.3	269.7	20.0	80.2	19.5	153.7	20.0	83.1
1993	13.9	503.7	14.2	271.9	13.9	84.5	13.8	89.8
1994	11.9	882.3	12.4	66.8	11.1	83.2	13.4	30.6

Source: Ditpertan, North Lampung, 1995.

condition and reduce erosion, as compared with planting in monoculture (Guritno, 1989; Wargiono *et al.*, 1992).

Table 4 and **5** show that growing food crops, either in monoculture or in an intercropping system, without any fertilization is generally not recommended because of the low yields obtained. Intercropping cassava+maize+upland rice-peanut may be recommended because higher total crop values can be obtained compared with monoculture upland rice, maize and peanut, followed by cassava. In the latter cropping systems, the low yield of cassava (**Table 3**) is due to drought during the last four months and the harvesting of cassava at only 6 months. The higher crop value of the peanut-cassava system compared to that of upland rice-cassava or maize-cassava is due to the higher crop value of dry pods of peanut than dry grain of either maize or rice. The cropping system of peanut-cassava produced a high crop value as well as an effective control of erosion (**Figures 3** and **4**). More research of this system is needed before it can be recommended.

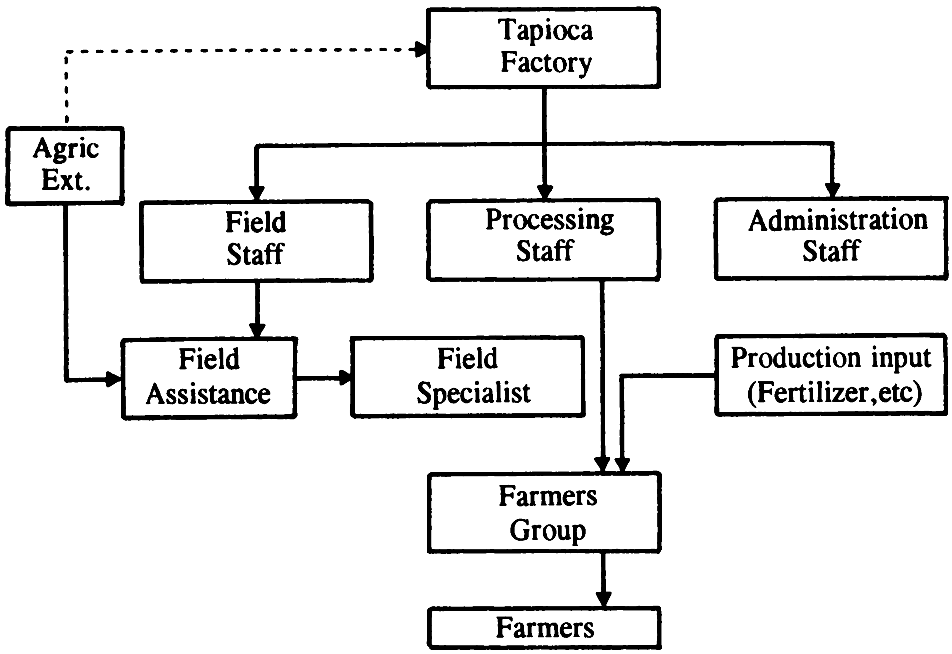

Figure 2. Diagram of Cooperative Model of farmers' group with tapioca factory at Lampung, Indonesia.

Table 5 shows that the intercropping of cassava+maize+upland rice-soybean increased net income 17% compared to that of monoculture cassava, while the LER of this intercropping system was 1.44. Monoculture plantings of upland rice-soybean, maize-maize, peanut-peanut or soybean-soybean usually yielded a higher net income than the intercropping system of cassava+maize+upland rice-soybean. For farmers having land that is very susceptible to erosion, intercropping systems are still recommended since these systems tend to control erosion more effectively.

Table 6 shows the performance of various cassava clones and the corresponding interplanted crops. Some characteristics of Adira 1 are the lack of branching short maturity and narrow canopy diameter, which favor high yield of interplanted crops due to the low competition from cassava. The average land holding of most farmers in Java is relatively small; thus, high yields of both cassava and interplanted crops are expected to enhance food diversity and increase farmers' income. UB1-2 is another cassava clone well suited for intercropping systems.

3. Erosion Control by Cultural Practices

In Indonesia cassava production areas are mainly located in mountainous areas of Java and in regions of undulating topography outside of Java. In Java land holdings are relatively small and erosion could be reduced substantially by terracing; however, this is still very expensive. Land holdings outside of Java tend to be larger, so reducing erosion by terracing is too expensive and this method is seldom practiced by the farmers. Soil erosion, which is the main cause of soil degradation (Suwardjo and Sinukaban, 1986), can also be reduced effectively by cultural practices, such as contour ridging, contour barriers/hedgerows, mulching and minimum tillage (Evangelio *et al.*, 1993; Sittibusaya *et al.*, 1993; and Wargiono, 1993).

Table 7 shows that soil erosion varied markedly from year to year but was consistently higher in unfertilized than in fertilized plots. Erosion losses could also be reduced by contour ridging, by intercropping with peanut or the planting of a covercrop of *Mimosa envisa*; however, the latter markedly reduced cassava yields, which is probably unacceptible to farmers. Most effective in reducing erosion, while also increasing cassava (and sometimes maize) yields, was the establishment of contour hedgerows of *Gliricidia sepium* or *Flemingia congesta*. When the pruned leaves and branches of these leguminous trees were mulched between cassava plants, they obviously supplied additional N to the crop, resulting in greener and more vigorous cassava plants. The beneficial effect of these hedgerows increased over time. Contour barriers of elephant grass were also quite effective in reducing erosion and increasing yields as long as the elephant grass was adequately fertilized. This system also provides a regular supply of feed for the farmer's animals. A similar trial conducted on a farmer's field with 10% slope in Tarokan village of Kediri district (**Table 8**) also shows that intercropping cassava with peanut and planting contour barriers of elephant grass was the most effective way to increase cassava yields and reduce erosion. This system is easier and cheaper to implement than the terracing system.

Fertilizer application to cassava grown in monoculture or intercropped in an Ultisol in Lampung not only increased crop value by 56% and 23%, respectively, but also reduced erosion (Wargiono *et al.*, 1995).

Table 4. Effect of various cropping systems and cultural practices on the yields of cassava and intercropped maize, rice and peanut, as well as gross and net returns and the total soil loss at four months after planting in Tamanbogo, Lampung, Indonesia in 1993/94.

Cropping system[1]	Yield(t/ha)				Total crop value ('000Rp/ha)	Net return[1] ('000Rp/ha)	Dry soil loss ('000p/ha)
	Cassava	Maize	Rice	Peanut			
1.Cassava monoculture; 100x100 cm, no fertilizers	11.21 ab	-	-	-	616	616	17.98ab
2.C+R+M-R; 200x50 cm, no fertilizers	6.50 bc	0.20	0.14	0.34	699	699	19.27a
3.C+R+M-P; 273x60x60 cm, no fertilizers	7.87 bc	0.17	0.09	0.47	861	861	18.68ab
4.Cassava monoculture; 100x100 cm, with fertilizers	12.04 ab	-	-	-	662	552	21.92a
5.C+R+M-P; 200x50 cm, with fertilizers	15.90 a	1.21	0.65	0.44	1601	1358	18.44ab
6.C+R+M-P; 273x60x60 cm, with fertilizers	14.28 a	1.07	0.45	0.74	1677	1435	18.04ab
7.R-C, 100x100 cm, with fertilizers	2.55 c	-	0.74	-	352	157	18.94ab
8.M-C, 100x100 cm, with fertilizers	3.36 c	3.72	-	-	836	641	22.78a
9.P-C, 100x100 cm, with fertilizers	3.39 c	-	-	1.52	1402	1244	14.09b

[1] C=cassava, R=upland rice, M=maize, P=peanut

[2] Net return= Total crop value minus fertilizer costs.

Table 5. Effect of various crops and cropping systems on the yields of cassava, maize, rice, peanut and soybean, the gross and net income as well as the total soil loss during an 8-month cropping cycle in Tamanbogo, Lampung, Indonesia in 1994/95.

Treatments[1]		Yield(t/ha)					Gross income[3]	Fertilizer cost[3]	Net income	Dry soil loss
		Cassava	Maize[2]	Rice	Peanut[2]	Soybean[2]	<------------	('000Rp/ha)	----------->	(t/ha)
Cassava	monocult., no fertilizer	6.80	-	-	-	-	408.0	0	408.0	54.80
R-S	monocult., no fertilizer	-	-	0.33	-	0.65	684.0	0	684.0	33.10
M-M	monocult., no fertilizer	-	0.74;0.53	-	-	-	317.5	0	317.5	35.38
Cassava	monocult., with fertilizer	19.65	-	-	-	-	1,179.0	148.9	1,030.1	35.57
R-S	monocult., with fertilizer	-	-	0.81	-	1.53	1,620.0	260.9	1,359.1	29.32
M-M	monocult., with fertilizer	-	2.37;3.62	-	-	-	1,497.5	297.8	1,199.7	28.54
P-P	monocult., with fertilizer	-	-	-	1.45;1.49	-	2,352.0	224.0	2,128.0	19.27
S-S	monocult., with fertilizer	-	-	-	-	1.15;1.36	2,259.0	224.0	2,035.0	37.00
C+M+R-S intercrop, with fertilizer		8.86	0.34	1.62	-	0.57	1,615.6	409.8	1,205.8	25.75

[1]C=cassava, R=upland rice, M=maize, P=peanut, S=soybean.
[2]two numbers correspond to the yields of the first and second season crops.
[3]Prices:

cassava fresh roots	=Rp	60/kg.	urea	=Rp	245/kg.
rice dry grain	=	300/kg.	TSP	=	340/kg.
maize dry grain	=	250/kg.	KCl	=	340/kg.
peanut dry shell	=	800/kg.			
soybean dry grain	=	900/kg.			

Table 6. Yields of seven cassava varieties as well as those of intercropped maize, upland rice and mungbean planted in a C+M+R-Mu system in Playen district of Yogyakarta, Indonesia in 1994/95.

Cassava Variety	Cassava (t/ha)	Maize (t/ha)	Rice (t/ha)	Mungbean (t/ha)	Total crop value ('000Rp/ha)[1)]
Adira 1	17.23	2.75	1.01	0.69	2661
Malang 1	21.75	1.71	0.99	0.44	2345
UB 1-2	22.97	2.46	0.98	0.58	2744
UB 1-2/15	23.27	2.14	0.81	0.41	2433
UB 15-10	22.49	2.75	0.76	0.47	2595
UB 881-5	21.39	1.71	1.07	0.56	2465
UB 477-2	22.90	1.86	1.02	0.51	2528

[1)]Prices:

	cassava fresh roots	:	Rp 50/kg.
	rice dry grain	:	350/kg.
	maize dry grain	:	250/kg.
	mungbean dry grain	:	1,100/kg.

Fertilization usually increases both plant height and canopy diameter. The greater the canopy diameter of both cassava and interplanted crops the more soil is protected from the direct impact of falling rain drops and the lower the erosion. **Figure 3** shows that fertilization to monoculture cassava, to upland rice-soybean and to maize-maize reduced erosion by 35, 11 and 19%, respectively. Eroded soil loss in monoculture soybean-soybean was as high as in monoculture cassava. Therefore, growing soybean in areas that are susceptible to erosion have to be reconsidered. On the other hand, monoculture peanut-peanut controlled erosion very effectively. Similar results were obtained in a previous trial at the same location, in which only one crop of peanut, upland rice or maize were grown per year in comparison with monoculture or intercropped cassava (**Figure 4**). Based on these results, the development of both monoculture and intercropping systems with peanut in upland areas which are susceptible to erosion is recommended.

The effect of agronomic practices on soil losses and crop value, as shown in **Table 4**, indicate that the intercropping system of cassava+upland rice+maize-peanut and the monoculture system of peanut-cassava have a similar crop value and controlled erosion effectively. Therefore, these conservation cultural practices are also applicable for farmers having marginal soils in cassava production areas.

4. Fertilization

The efficiency of fertilizer application, or the crop's ability to absorb nutrients, is affected by the type of soil and the fertilizer applied, the responsiveness of the crop or variety, the crop's general condition, the cropping pattern and the availability of other nutrients (Wargiono, 1991; Widjaya *et al.*, 1990).

In Thailand and Indonesia, among the nutrients applied, the effect of N application on cassava yield was most pronounced, and the response to N increased with each consecutive cropping cycle, whereas the effect of P and K was only significant in some locations (Sittibusaya *et al.*, 1993; and Wargiono *et al.*, 1995). Continuous cropping of

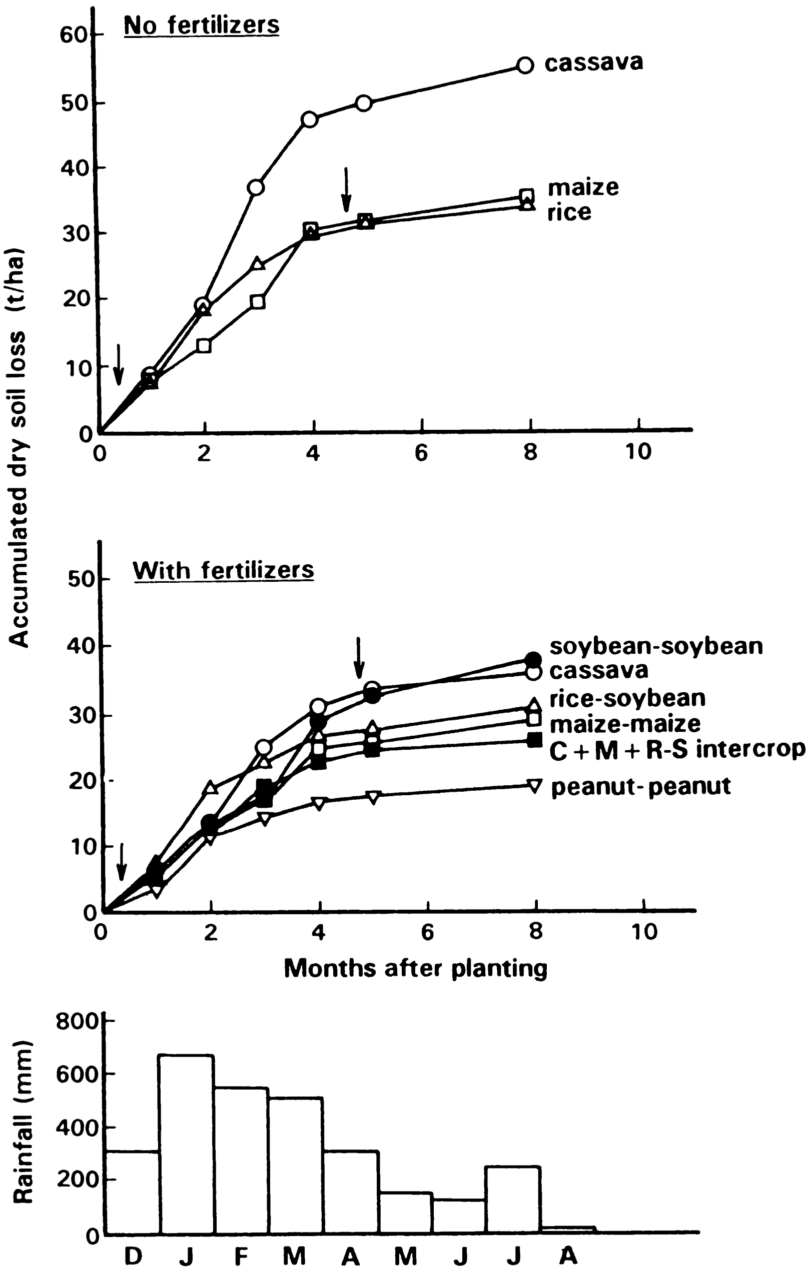

Figure 3. Accumulated dry soil loss due to erosion in various crops grown in monoculture or intercropped, with or without fertilizers, on 5% slope in Tamanbogo, Lampung, Indonesia in 1994/95. The rainfall distribution during the cropping cycle is shown below. Arrows indicate time of planting first and second crops.

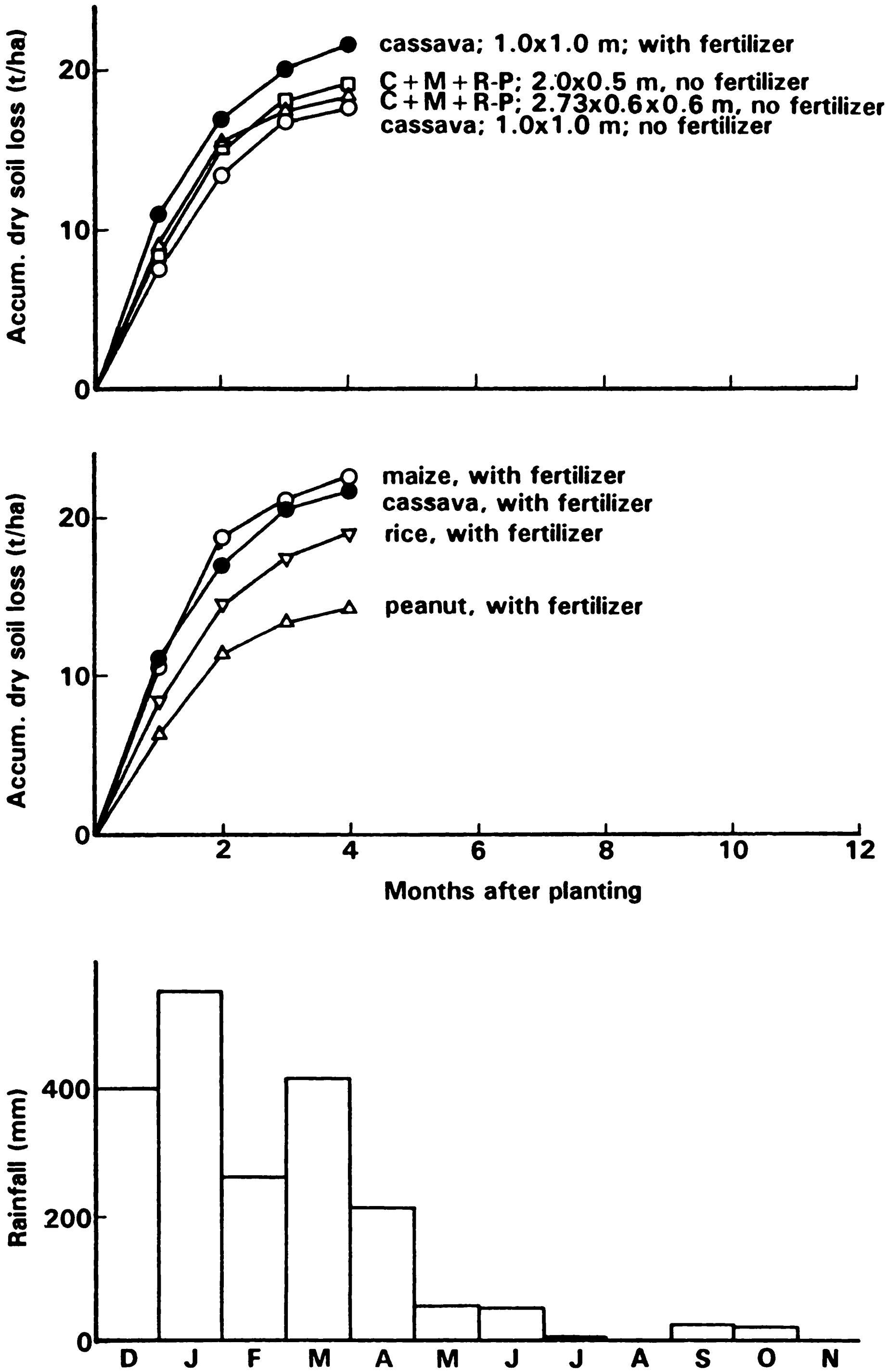

Figure 4. Effect of various crops, cropping systems and agronomic practices on the accumulative dry soil loss due to erosion on 5% slope in Tamanbogo, Lampung, Indonesia in 1993/94. The rainfall distribution during the cropping cycle is shown below.

cassava with application of only chemical fertilizers was able to sustain high cassava yields in India, but the application of chemical fertilizers with FYM could also maintain the organic matter as well as the Ca, Mg, Cu and Zn contents of the soil (Nayar *et al.*, 1995).

Tables 4 and **5** show the fertilization effect on both monoculture and intercropping systems. Fertilizer application to monoculture cassava, upland rice-soybean and maize-maize increased gross income by 189, 137 and 371%, respectively, compared to that of the unfertilized crops. Fertilization of the intercropping system of cassava+maize+upland rice-peanut increased gross return by 94 to 129% compared to that of the same unfertilized intercrops. Since fertilization of either monoculture or intercropping systems increased net income, often by more than 150%, this is an effective way to increase farmers' income.

The long-term effect of annual application of N, P and K on cassava yields and nutrient levels in the soil during eight consecutive cropping cycles in Umas Jaya farm in Lampung province of Sumatra, is shown in **Figure 5**. Independent of fertilizer applications, cassava yields increased during the first two-three years, subsequently declined, but increased again from the 6th to the 8th year. There was no statistically significant response to application of any of the nutrients since both P and K levels in the soil remained near or above the critical levels. Only after four consecutive crops did the P and K levels decrease slightly below the critical levels and a minor response to these nutrients was observed in subsequent years. The lack of response to fertilizers in a soil that is generally considered as an "infertile" Ultisol is attributed mainly to the fact that after each harvest, plant tops were reincorporated into the soil, while only the nutrients in the roots were removed from the field. In this way, excessive nutrient extraction was prevented and soil fertility maintained at a reasonable level. However, with annual application of intermediate levels of NPK (50-57-60 kg N-P_2O_5-K_2O/ha), high yields of 25-30 t/ha as well as a reasonable level of soil fertility could be maintained for at least eight years.

Figures 6 and **7** show the results of a similar long-term fertility trial conducted on an Andosol (Inceptisol) in Jatikerto Experiment Station in Malang in eastern Java.

Table 7. Effect of various crop/soil management practices on soil loss due to erosion and on cassava and maize yields during four consecutive cropping cycles on 5% slope in Jatikerto Experiment Station, Malang, Indonesia.

	Dry soil loss(t/ha)				Cassava yield(t/ha)				Maize yield(t/ha)		
	91/92	92/93	93/94	94/95	91/92	92/93	93/94	94/95	91/92	92/93	93/94
1.C+M[1], no fertilizers, no ridges.	58.3	49.3	55.7	8.5	16.3	15.8	5.1	6.6	-	-	0
2.C+M[1], no fertilizers, contour ridges.	43.0	36.9	36.7	2.8	25.4	23.2	5.1	13.3	-	-	0
3.C+M, with fertilizers, contour ridges.	39.2	24.8	28.1	3.8	20.4	20.5	17.8	16.7	1.98	2.27	2.88
4.C+M, with fertilizers, ridges, *Gliricidia* hedgerows	43.2	22.3	20.9	2.2	16.3	18.0	16.1	20.7	1.16	1.28	2.80
5.C+M, with fertilizers, ridges, elephant grass barriers	36.9	19.8	20.8	2.4	18.4	17.4	11.8	19.3	1.36	1.42	1.96
6.C+M, with fertilizers, ridges, *Flemingia* hedgerows	41.3	17.7	17.3	1.9	17.2	18.1	14.2	21.6	1.26	1.46	3.20
7.C+M, with fertilizers, ridges, *Mimosa* covercrop	38.4	18.3	24.7	2.4	17.1	18.2	12.2	9.9	1.44	1.63	3.36
8.C+M[1], with fertiltzers, ridges, peanut intercrop	36.4	21.7	26.3	4.5	23.7	23.7	19.9	25.3	-	-	2.10

[1]During the first two years there was no intercropped maize in treatments 1, 2 and 8

Table 8. Effect of various cropping systems on dry soil loss due to erosion and on the fresh root yield of cassava (cv Adira 4) planted on 10% slope in Tarokan village of Kediri district in E. Java, Indonesia in 1993/94

Treatments	Dry soil loss (t/ha)	Fresh root yield (t/ha)
1.Cassava[1)] monoculture	31.90	16.75 bc
2.C+maize	27.54	14.38 a
3.C+peanut	16.60	20.13 d
4.C+2 rows of elephant grass	23.81	18.25 c
5.C+*Crotalaria juncea* intercrop	19.18	15.13 ab
6.C+maize+1 row of elephant grass	21.24	15.38 ab
7.C+peanut+1 row of elephant grass	13.99	23.38 e
8.No crop (bare fallow)	38.09	-

[1)]cassava planted at 1.0x1.0 m, maize 1.0x0.5 m, peanut 0.25x0.25 m, *Crotalaria juncea* 1.0x1.25 m.

***Source:** Soemarjo Poespodarsono and Nur Basuki, 1994.*

In this case, cassava was intercropped with maize and all plant tops were removed after harvest. There was a highly significant response to NPK application already in the first year. The response to N increased over time, while the response to P and K varied over the years, but was usually not significant. Although this soil has an intermediate level of OM (1.2-1.8%), the main cassava response was to N application, which was probably accentuated by the strong competition from the intercropped maize. Without N, cassava yields dropped to less than 4 t/ha in the 7th crop cycle. While the soil P level was slightly below and the exchangeable K was far above the critical level, there was no response to P but a significant response to K during the 7th consecutive cycle (**Figure 7**). The annual application of intermediate and high levels of NPK increased yields from 2 to 23 and 30 t/ha, respectively.

Figure 8 shows the effect of NPK fertilizers on the yield of intercropped cassava, maize, upland rice and mungbean during the 4th cropping cycle in an Alfisol in Yogyakarta. A fertilizer application of 90 kg N + 50 P_2O_5 + 90 K_2O/ha tended to maintain low but stable yields of cassava and high yields of interplanted crops during four years of cropping. The growth of mungbean as a second intercrop (planted after the harvest of upland rice) was affected by light competition from cassava. Fertilization stimulated the cassava growth, resulting in an increase in cassava yield but a decrease in mungbean yield. Fertilization of 90 kg N + 50 P_2O_5 +90 K_2O/ha seemed to be a good fertilization rate as it maintained both high yields of crops and net income.

Figure 9 shows the effect of NPK fertilization on cassava intercropped with

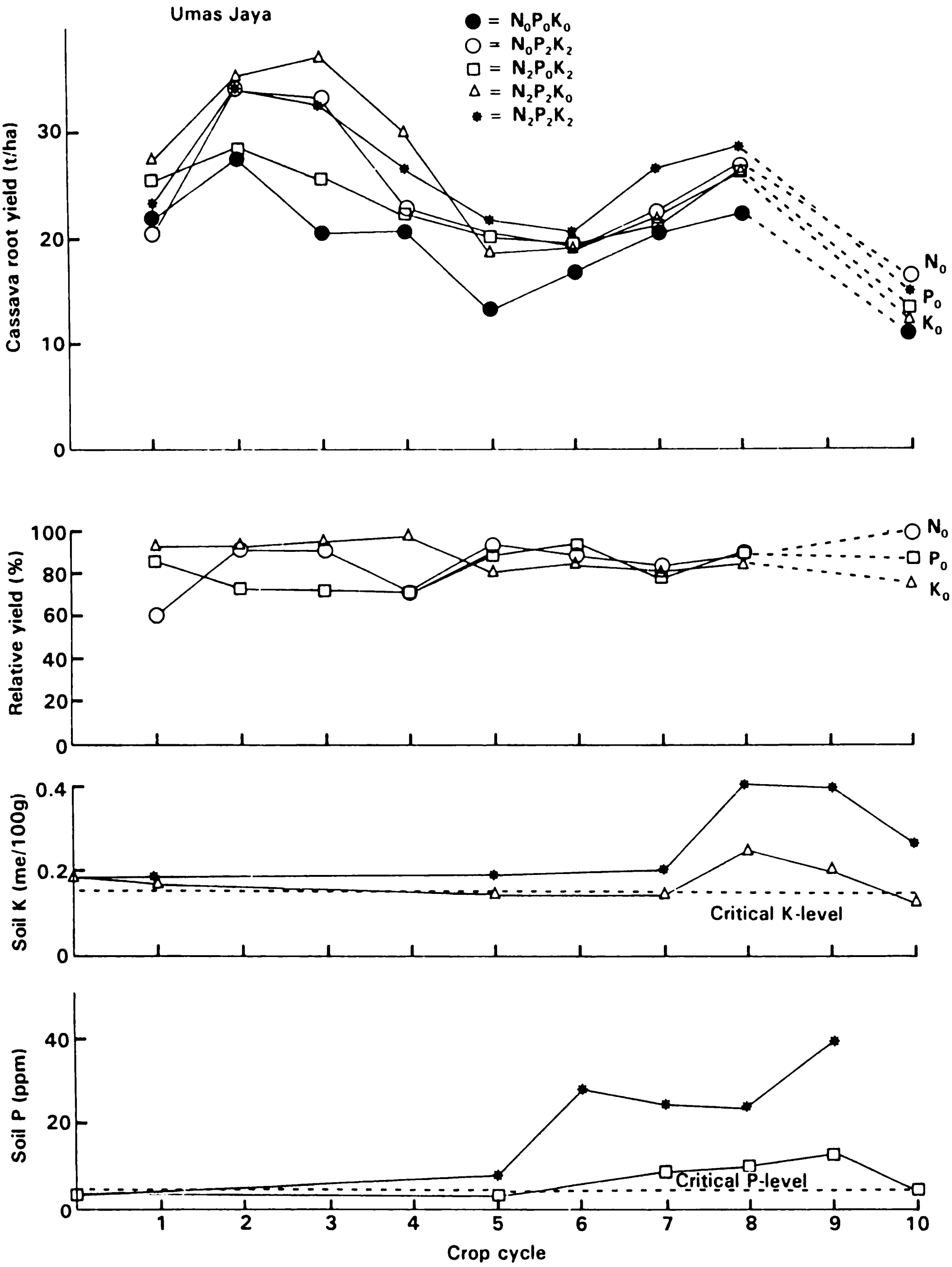

Figure 5. Effect of annual application of N, P and K on cassava root yield, relative yield (yield without the nutrient over the highest yield with the nutrient) and exchangeable K and available P (Bray 2) content of the soil during ten years of continuous cropping in Umas Jaya, Lampung, Indonesia.

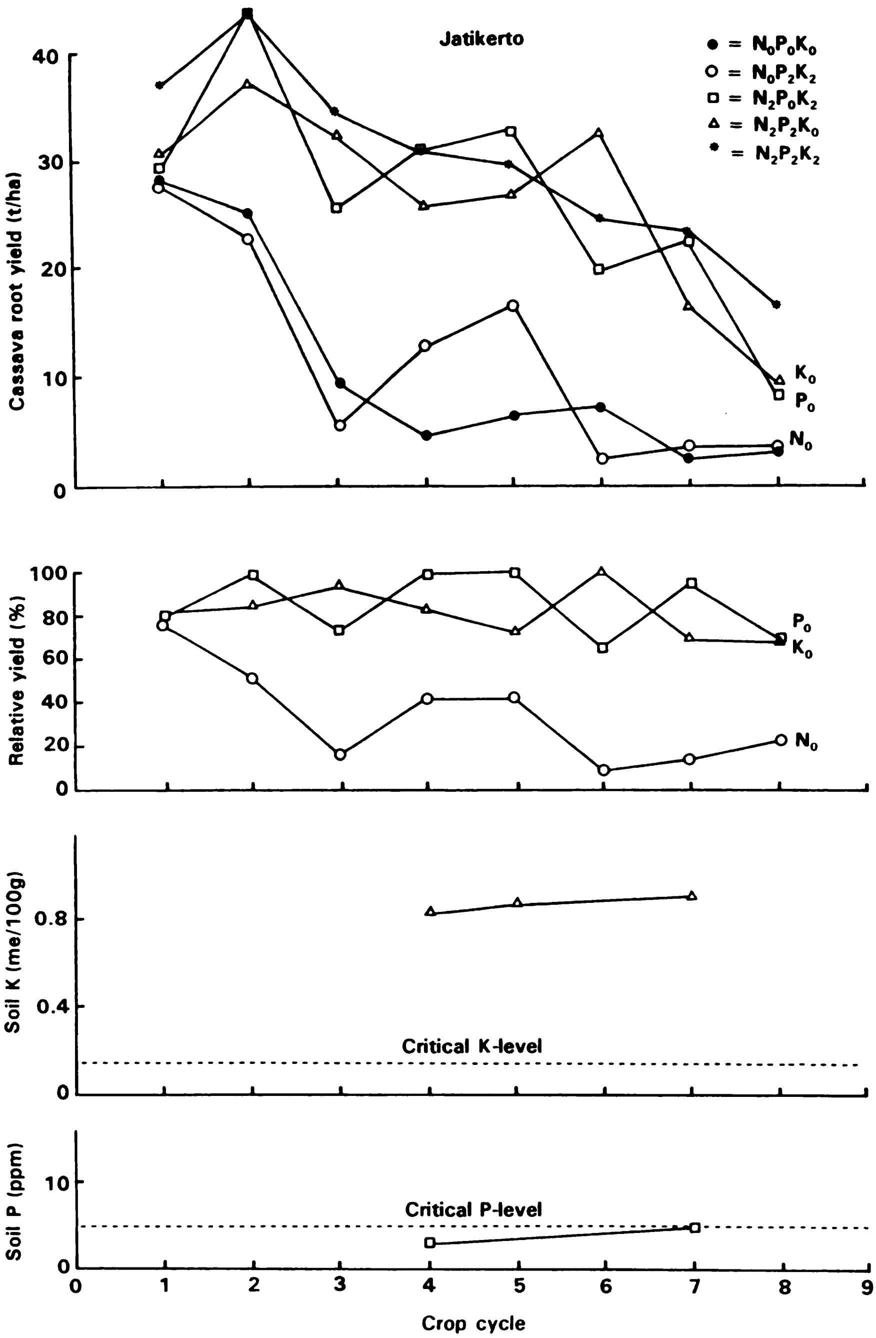

Figure 6. Effect of annual application of N, P and K on cassava root yield, relative yield (yield without the nutrient over the highest yield with the nutrient) and exchangeable K and available P (Bray 2) content of the soil during eight years of continuous cropping in Jatikerto Experiment Station in Malang, E. Java, Indonesia.

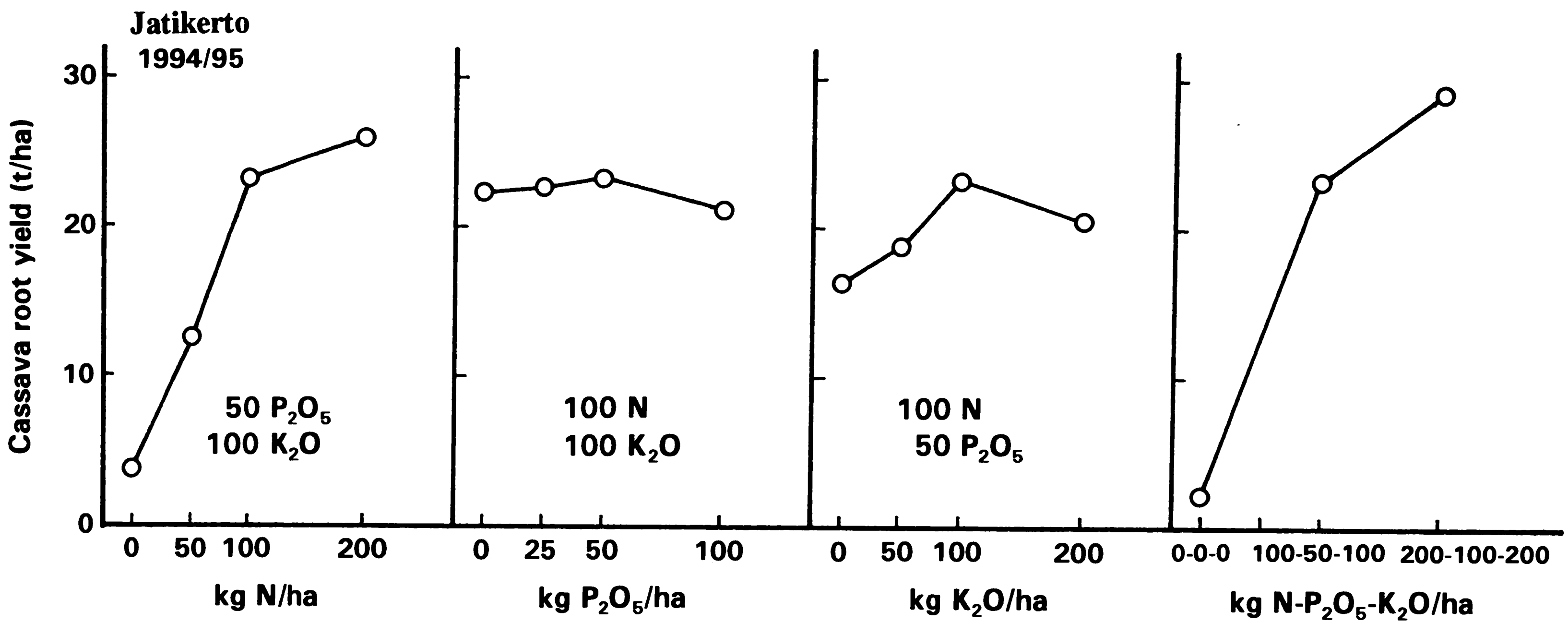

Figure 7. Response of cassava, cv Faroka, to the annual application of various levels of N, P and K during the 7th cycle in Jatikerto, East Java, Indonesia in 1994/95.

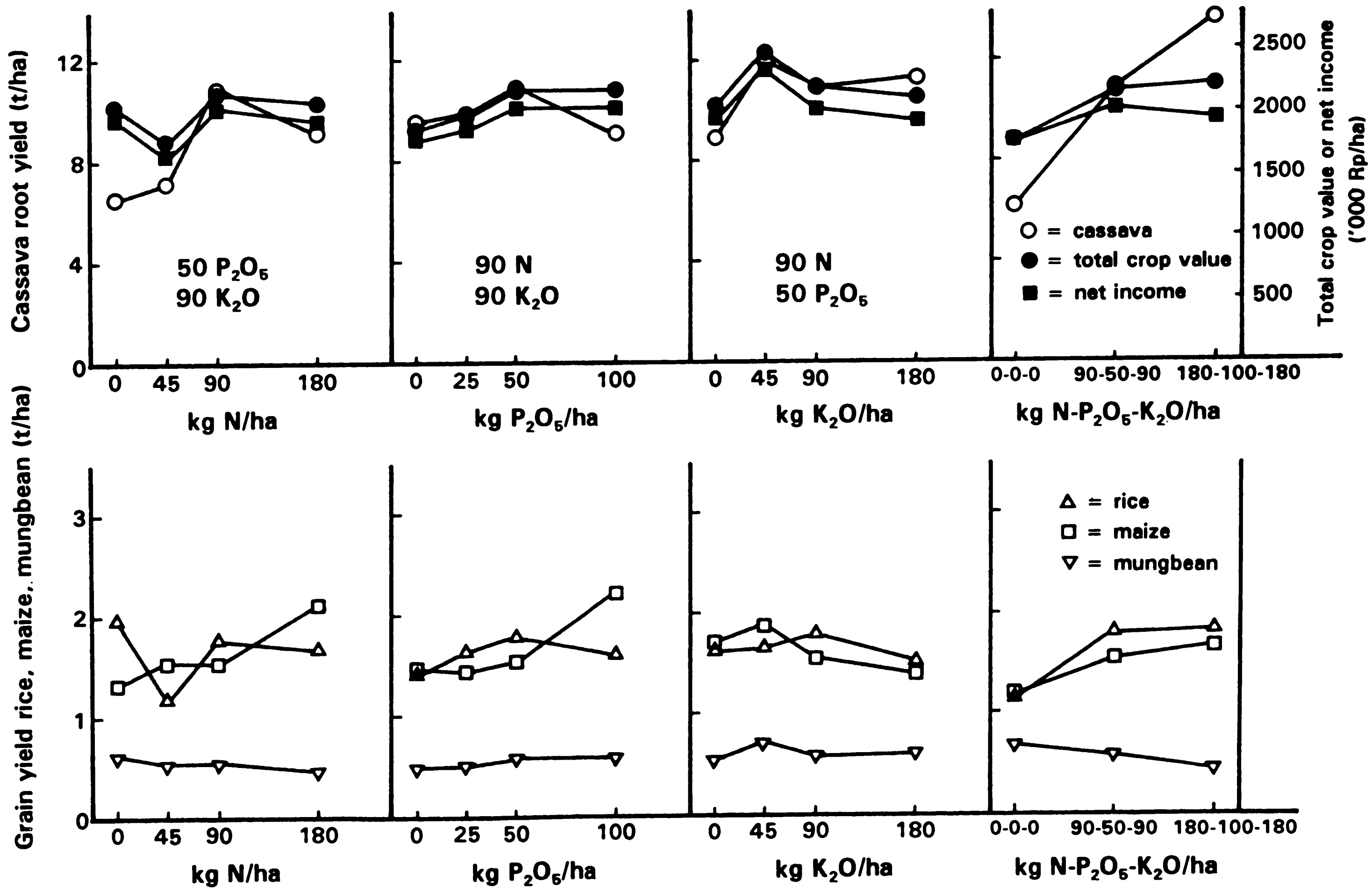

Figure 8. Effect of the application of various levels of N, P and K on the yield of cassava and intercrops, as well as on total crop value and net income, in a cassava+maize+rice+mungbean cropping system in Yogyakarta, Indonesia in 1994/95 (4th year).

upland rice and maize in an Ultisol of Lampung during the 4th cropping cycle. Cassava in this area is an important crop, so cassava is grown in the cropping system with a higher plant population than is used in Java. As such, the yield of cassava is higher but the yield of interplanted crops is lower compared to those in Java. Most Ultisols have relatively low nutrient contents; consequently, crop productivity is low. To obtain a high net income, the rate of fertilizers applied must be relatively high. In Yogyakarta the fertilizer application of 90 kg N + 50 P_2O_5 + 90 K_2O/ha in the intercropping system of cassava+maize+upland rice-mungbean yielded a net income of Rp 1,900,000/ha, whereas in Lampung the higher fertilizer rate of 180 kg N + 100 P_2O_5 + 190 K_2O/ha yielded a net income of only Rp 900,000/ha.

Based on on-farm research in cassava production areas of southern Malang in East Java a balanced rate of fertilization for both cassava and intercropped maize (**Table 9**) increased net income by about 50%. Therefore, a rate of 170-67-60 of N-P_2O_5-K_2O/ha (corresponding to C1-M2 in **Table 9**) can be recommended when farmers have access to sufficient capital.

FUTURE PLANS

Some soil conservation practices, such as contour ridging, fertilizer application, intercropping with peanut and alley cropping with *Gliricidia* or *Flemingia* offer good possibilities to improve farmers' income while reducing soil losses due to erosion. Which practice is the most beneficial to the farmers still needs to be investigated. There is also a need to conduct more research about the efficient management of crop residues, improved fertilizer efficiency and cassava clone performance under specific conditions, since optimum agronomic practices are different in each agro-ecological zone.

CONCLUSIONS

Most cassava is grown on poor soils that are susceptible to erosion, and where farmers have limited availability of capital and labor. Intercropping is recommended due to its capability to reduce erosion, increase LER and net income, and improve food crop's diversification and support the food security program.

The limited availability of labor and capital of most farmers tend to encourage the growing of low-input crops, such as cassava, and to delay cassava planting. Better cooperation with private companies to supply fertilizers and herbicides for their food crop cultivation is a possible solution.

A balanced rate of fertilizer application, such as 75-100 kg N + 25-50 P_2O_5 + 60-100 K_2O/ha for monoculture cassava, and 100-150 kg N + 50-100 P_2O_5 + 100-150 K_2O/ha for the intercropping system of cassava+maize+upland rice-peanut or soybean is able to increase net income by 70 and 370% and to reduce soil erosion by 11 and 35%, respectively, as compared to that of unfertilized crops. Moreover, adequate fertilizer application can maintain soil productivity.

Table 9. Effect of fertilizer application to cassava and/or maize in cassava/maize intercropping systems on yield, crop value and net income. Data are average of three farms in Sempol village, southern Malang, Indonesia in 1991/92.

Treatments[1)] Cassava-Maize	Yield (t/ha)		Fertilizer cost[2)]	Totalcrop value[2)]	Net income
	cassava	maize	<----------	('000Rp/ha)	---------->
C2 - M2	30.73 a	1.20 a	175.50	1716	1541
C1 - M2	29.66 a	1.19 a	136.25	1661	1525
C0 - M2	20.49 c	1.19 a	97.00	1203	1106
C2 - M1	28.23 b	1.03 b	127.00	1566	1439
C1 - M1	22.87 d	0.99 bc	87.75	1292	1204
C0 - M1	17.56 f	0.94 c	48.50	1019	970
C2 - M0	26.01 c	0.61 d	78.50	1392	1313
C1 - M0	21.89 de	0.57 d	39.25	1180	1141
C0 - M0	18.06 f	0.54 d	0	984	984

1) C2 = full recommended dose for cassava = 150 kg urea, 100 kg TSP and 100 kg KCl/ha

C1 and Co are half recommended dose and no fertilizer, respectively, for cassava

M2 = full recommended dose for maize = 300 kg urea, 100 kg TSP and 50 kg KCl/ha

M1 and Mo are half recommended dose and no fertilizer, respectively, for maize

2) Prices: cassava fresh roots :Rp 50 /kg
maize dry grain : 150 /kg
urea : 210 /kg
TSP : 210 /kg
KCl : 260 /kg

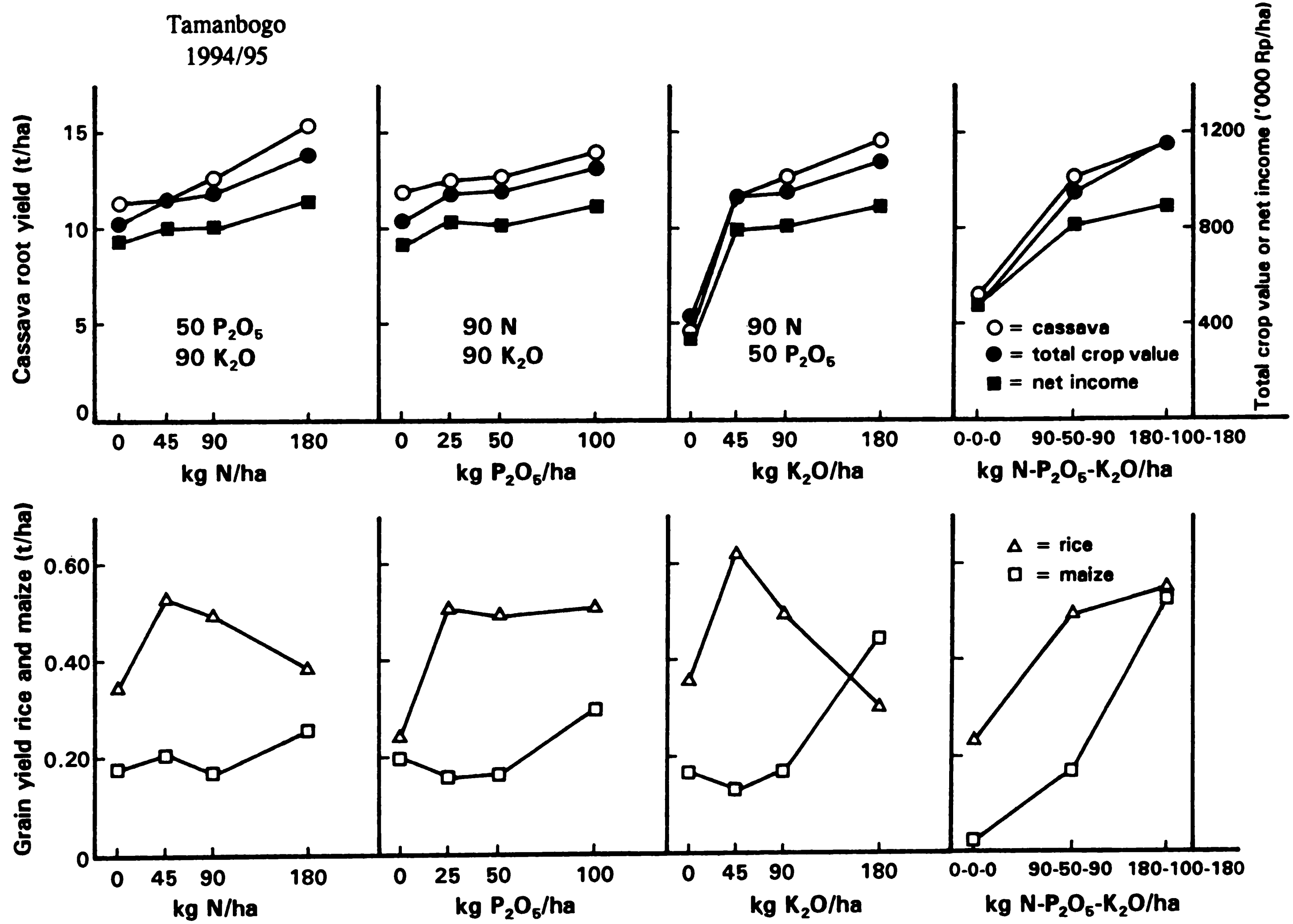

Figure 9. Effect of the application of various levels of N, P and K on the yield of cassava and intercrops, as well as on total crop value and net income in a cassava+maize+rice cropping system in Tamanbogo, Lampung, Indonesia in 1994/95 (4th year).

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RECENT PROGRESS IN CASSAVA AGRONOMY RESEARCH IN THE PHILIPPINES

Fernando A. Evangelio[1] *and Julieta C. Ladera*[2]

ABSTRACT

During the last three years cassava production in the Philippines did not progress markedly, neither in area nor in volume. In terms of area, there was only an increase of 14,424 ha or 6.4%, while in terms of volume the increase was 112,177 metric tons or 5.7%. One of the reasons for this was the unstable price for chips, especially in 1994/95. Up to the present, cassava cultivation is still concentrated in Mindanao where there are greater opportunities for marketing, particularly trading of dry chips by the San Miguel Corporation and animal feed millers, as well as fresh roots for production of starch.

In terms of research, not much data has been generated, since only very few experiments were conducted. Some experiments were terminated, like the one on cropping systems trials in Negros Occidental. In Leyte the fifth cropping cycle of the long-term fertility trial under coconut showed no significant responses to fertilizers, but there were some responses in the sixth year of consecutive cropping. In the erosion control trial, highest soil losses were observed in plots with application of inorganic fertilizers (14-14-14), while the lowest soil losses were observed in plots with vetiver grass barriers or with grass mulch. Root yields were highest with the application of grass mulch or when *Crotalaria juncea* was intercropped and mulched at 2 months; yields were lowest in plots with lemon grass barriers.

The variety x fertilizer trial in Bontoc, southern Leyte, showed a clear varietal response to fertilizers. The variety with a heavier canopy responded more markedly to fertilizer applications.

In an intercropping trial in Bohol, even after three cropping cycles, cassava yields were not significantly affected by interplanting of either soybean, mungbean, cowpea, peanut or pole sitao (yard-long bean). However, row spacing significantly affected the yields of cassava and intercrops. In another trial, marked increases in cassava yields were obtained when the plant densify was increased to 15,000-25,000 plants/ha. On the other hand, no significant differences were observed when the age of pruning cassava was varied.

INTRODUCTION

The cassava industry in the Philippines is now gaining momentum with the existence of various market opportunities. Cassava is grown not only for human food, but also for starch, feed and industrial uses such as alcohol. Aside from the San Miguel Corporation, which currently exports cassava chips to Europe and uses cassava meal as an ingredient in animal feed, other firms, like La Tondena, are also working with cassava as a raw material for production of alcohol. This is due to scarcity of molasses resulting from low sugarcane production. Moreover, various food products from cassava are now developed, further increasing the demand for the crop.

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Cassava Area and Production

During the last three years (1993-1996) cassava production in the Philippines did not increase very much, neither in area nor in volume (**Table 1**). In terms of area, there was only an increase of 14,430 ha from 211,420 to 225,850 ha, which is an increase of 6.8%. In terms of volume, the increase was 112,177 metric tons or 5.7%. One of the reasons for the slow growth of cassava production was the unstable price for chips, especially in the 1994/95 season. Up to the present, cassava cultivation is still concentrated in Mindanao because of the greater market opportunities, particularly the presence of chips traders like the San Miguel Corporation, feed millers and starch processors.

Table 1. Cassava area, production and yield by region in the Philippines during the last five years (1991-1995).

Region	1991	1992	1993	1994	1995
			Cassava area (ha)		
Philippines	**211,036**	**204,313**	**211,420**	**213,090**	**225,852**
Ilocos	1,807	1,805	2,207	2,210	2,218
Cagayan Valley	354	411	384	350	398
C. Luzon	1,240	1,148	1,160	1,230	1207
S. Tagalog	10,264	10,048	10,418	10,460	10,617
Bicol	30,960	31,188	31,048	28,990	28,417
W. Visayas	9,568	9,548	8,993	8,800	8,661
C. Visayas	20,595	19,387	20,751	20,940	20,136
E. Visayas	25,111	24,009	24,033	24,280	26,679
W. Mindanao	22,643	22,512	22,588	22,820	22,650
N. Mindanao	10,949	12,588	15,349	15,460	13,780
S. Mindanao	3,017	3,134	3,278	3,300	2,610
C. Mindanao	1,636	1,589	1,655	1,670	1,570
CAR[1)]	301	294	312	320	319
ARMM[2)]	63,913	58,430	60,742	63,740	79,140
CARAGA[3)]	8,678	8,222	8,502	8,520	7,450

Table 1. (continued)

Region	1991	1992	1993	1994	1995
			Cassava production (t)		
Philippines	**1,815,700**	**1,784,897**	**1,844,377**	**1,891,780**	**1,956,574**
Ilocos	10,656	10,269	11,771	12,134	12,868
Cagayan Valley	1,317	1,321	1,312	1,565	1,832
C. Luzon	7,776	7,972	7,532	7,890	7,744
S. Tagalog	62,800	64,066	63,515	63,751	65,861
Bicol	249,587	254,930	251,362	240,990	236,227
W. Visayas	50,238	47,857	46,822	45,979	45,000
C. Visayas	160,866	148,747	159,896	160,462	162,287
E. Visayas	96,722	92,849	93,975	94,856	92,678
W. Mindanao	218,422	215,652	220,528	227,391	226,634
N. Mindanao	103,041	117,727	156,709	157,086	139,139
S. Mindanao	24,949	25,679	26,547	26,245	23,020
C. Mindanao	10,773	11,066	11,230	12,691	12,864
CAR[1)]	2,836	2,950	2,972	3,008	2,936
ARRM[2)]	783,734	753,886	758,609	806,135	894,815
CARAGA[3)]	31,983	29,926	31,597	31,597	32,669
			Cassava yield (t/ha)		
Philippines	**8.60**	**8.74**	**8.72**	**8.88**	**8.66**
Ilocos	5.90	5.69	5.33	5.49	5.80
Cagayan Valley	3.72	3.21	3.42	4.47	4.60
C. Luzon	6.27	6.94	6.49	6.41	6.42
S. Tagalog	6.12	6.38	6.10	6.09	6.20
Bicol	8.06	8.17	8.10	8.31	8.31
W. Visayas	5.25	5.01	5.21	5.22	5.20
C. Visayas	7.81	7.67	7.70	7.66	8.06
E. Visayas	3.85	3.87	3.91	3.91	3.47
W. Mindanao	9.65	9.58	9.76	9.96	10.01
N. Mindanao	9.41	9.35	10.21	10.16	10.10
S. Mindanao	8.27	8.19	8.10	7.95	8.82
C. Mindanao	6.58	6.96	6.79	7.60	8.19
CAR[1)]	9.42	10.03	9.53	9.40	9.20
ARMM[2)]	12.26	12.90	12.49	12.65	11.31
CARAGA[3)]	3.69	3.64	3.72	3.71	4.39

[1)]CAR = Cordillera Autonomous Region
[2)]ARMM = Autonomous Region of Muslim Mindanao
[3)]CARAGA = Newly created region comprising the provinces of Surigao del Norte, Surigao del Sur, Agusan del Norte and Agusan del Sur

Source: Bureau of Agricultural Statistics

Cropping Systems

The most common cropping system used by farmers is intercropping cassava with maize. This is practiced by farmers in Bukidnon , Mindanao and Camotes Island in the Visayas, where cassava is planted in the furrow right after the hilling up of maize. In this manner, the farmers can save labor and reduce costs in land preparation, cultivation and even fertilizer application. When the maize is harvested, the stover is either cut or pulled down to the ground as dried mulch, thus allowing the full exposure of cassava plants to sunlight. This practice has been proven to be successful and profitable, and is now being adopted by other cassava farmers, especially if their farms are flat and in open fields.

Some farmers also grow cassava in rotation with legumes or maize, or plant casssava under coconut. In large plantations like Matling in Malabang, Lanao, cassava is rotated with sorghum, which is used for livestock feed.

RESEARCH RESULTS

Recent Experiments in Leyte

1. Long-term fertilizer trial under coconut. A long-term fertility trial under mature coconut trees spaced at about 8 x 8m, showed that yield differences due to fertilizer application were not significant in the fifth, but were significant in the sixth cropping cycle (**Table 2**). Highest yields were generally obtained from the treatment with 60 kg N, 90 P_2O_5 and 60 K_2O/ha (F_8), while lowest yields were obtained in treatments without N and K application (F_2 and F_9), suggesting mainly a deficiency of these two nutrients (**Figure 1**). Soil analysis of the NPK check plots in 1996 indicated an intermediate level of 4.09% organic matter, but a very low level of K (0.07 me/100 g) and P (0.35 ppm Bray-II-extractable P). Thus, significant responses to N, P and K applications are in accordance with soil analysis results.

2. Variety x fertilizer trial. A variety x fertilizer trial was conducted in Bontoc, southern Leyte in an area with a slope of 20%, but with double hedgerows of *Gliricidia sepium* and vetiver grass. Results show that different varieties had significantly different responses to fertilizer (**Table 3**). The cassava variety with the heavier canopy (VC-3) responded most markedly to fertilizers. However, there was no significant difference between the levels of fertilizer application.

3. Cultural practices for erosion control. **Table 4** indicates that during the 6th cropping cycle of the erosion control trial in Baybay, Leyte, soil loss was highest at 45.0 t/ha in plots with inorganic fertilizer (14-14-14) and lowest in plots with vetiver grass contour barriers (8.1 t/ha). On the other hand, cassava yields were highest in plots applied with dried grass mulch (14.5 t/ha) and lowest in plots with vetiver or lemon grass as contour barriers.

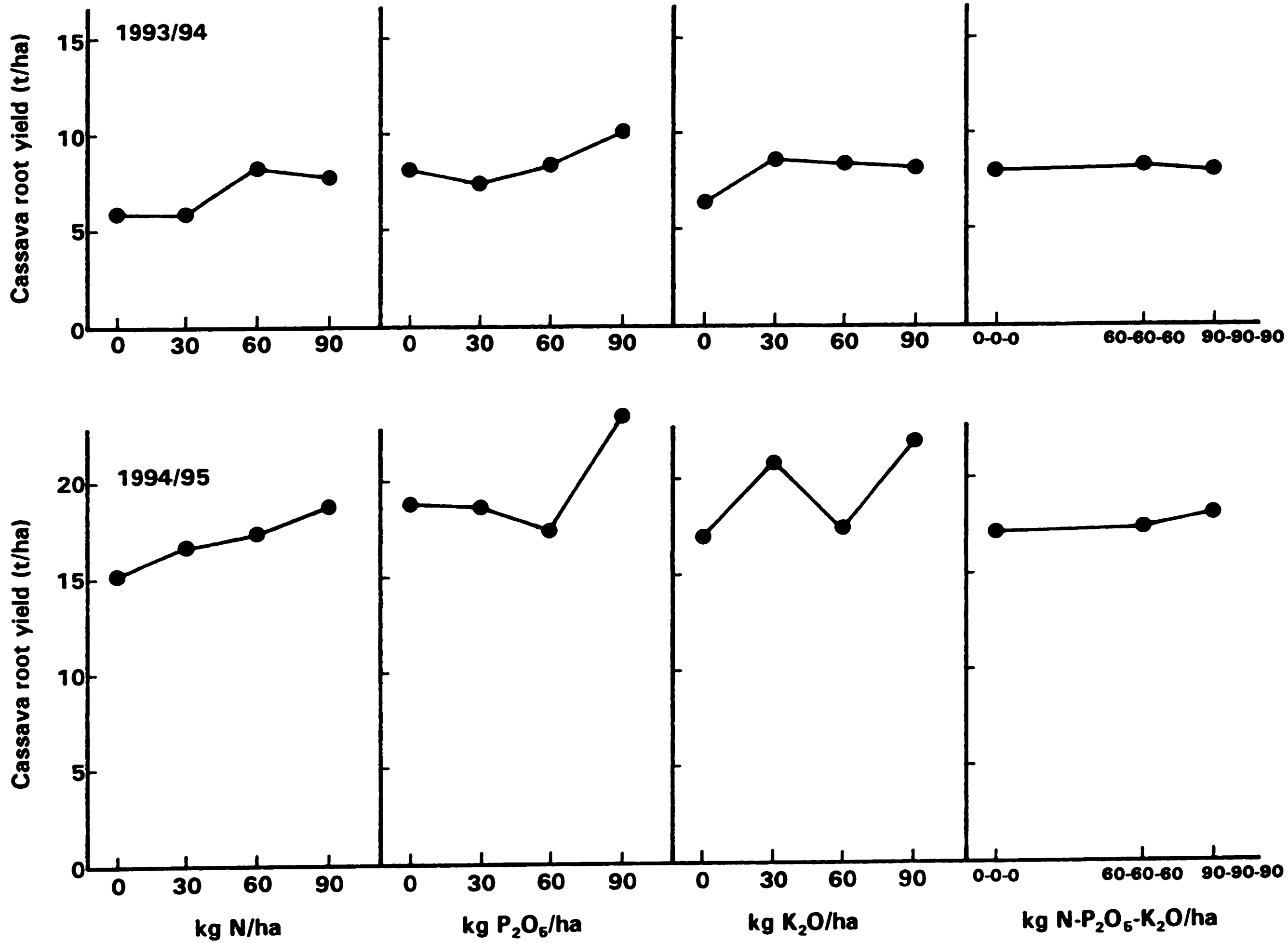

Figure 1. Effect of annual application of various levels of N, P and K on the yield of cassava, cv. Golden Yellow, during the 5th and 6th cropping cycle under coconut trees at ViSCA, Baybay, Leyte, Philippines in 1993/94 and 1994/95.

Table 2. Root yield of cassava, cv. Golden Yellow, grown under coconut trees as affected by different levels of N, P and K fertilizers during the fifth and sixth cropping cycles in ViSCA, Baybay, Leyte, Philippines.

Treatment	N-P_2O_5-K_2O (kg/ha)	Root yield (t/ha) 5th year 1993/94	Root yield (t/ha) 6th year 1994/95
1.	0-0-0	8.15a	17.07bc
2.	0-60-60	5.95a	15.20c
3.	30-60-60	5.87a	16.72bc
4.	60-60-60	8.37a	17.27bc
5.	90-60-60	7.95a	18.92abc
6.	60-0-60	8.17a	18.97abc
7.	60-30-60	7.92a	18.72abc
8.	60-90-60	10.17a	23.35a
9.	60-60-0	6.32a	17.00bc
10.	60-60-30	8.60a	20.90ab
11.	60-60-90	8.15a	21.87ab
12.	90-90-90	8.17a	18.10bc
CV(%)		35.60	28.90
F test:	Global:	NS[1)]	*
	N:	NS	NS
	P:	NS	NS
	K:	NS	NS

[1)]NS = not significant
* = significant ($P<0.05$)
Mean separation: DMRT (0.05)

Table 3. Cassava yield (t/ha) of four varieties grown with and without fertilizers on 20% slope in Bontoc, southern Leyte, Philippines in 1993/94.

Variety	Fertilizer Level 0-0-0	Fertilizer Level 60-60-60	Average
VC-1	52.3a	52.8a	52.5a
VC-2	22.6b	25.6b	24.1c
VC-3	22.6b	32.4a	27.5c
Lakan	29.5b	32.6a	31.0b
Average	31.8b	35.8a	

Table 4. The effect of various cultural practices on cassava yield and soil loss due to erosion during the 6th consecutive cropping cycle on 25% slope in Baybay, Leyte, Philippines. (1993/94: 3,154 mm rainfall)

Treatments[1)]	Root yield (t/ha)	Soil loss (t/ha)[2)]
CT with lemon grass hedgerows	3.5c	17.9c
CT with 60-60-60 fertilizer	8.4bc	45.0a
CT with vetiver grass hedgerows	5.7c	8.1d
CT with dried grass mulch	14.5a	10.7d
CT with *Crotalaria juncea* intercrop	10.7b	28.5b

[1)]CT = check treatment
[2)]Dry soil loss during the cropping cycle.

Recent Experiments in Bohol

1. Intercropping. **Table 5** shows the yields of cassava and intercrops as influenced by cassava planting arrangement during three cropping cycles at Bohol Experiment Station in Ubay, Bohol, Philippines. It was observed that even after three cropping cycles cassava yields were not significantly affected by interplanting of either soybean, mungbean, cowpea, peanut or pole sitao (yard-long bean). However, plant spacing significantly affected the yields of cassava and intercrops. Double-row planting of cassava (0.81 x 0.71 m in the double row, 2.0 m between double rows) generally resulted in the highest cassava yields, but a normal square arrangement (1.0 x 1.0 m) gave the heighest intercrop yields during all three years.

2. Prunning. Cutting of cassava plant tops (pruning) at 30 cm above ground level before or right after a typhoon damages the plantation, may result in improved root yields, depending on the time of pruning. Moreover, planting at closer spacing has also been found to mitigate the damaging effect of typhoons. For that reason, a time of pruning x plant spacing trial was initiated in Bohol in 1995. **Table 6** presents the first year's result. There were no marked differences in the yield of cassava due to time of pruning but pruning did reduce yields on average 13-21%; this yield reduction was greater at wider than at closer spacing. Spacing had a significant effect on cassava yield. Highest yields were obtained in plots with planting distances of 0.80m x 0.80m or 0.60m x 0.60m. This implies that higher population densities can result in higher cassava yields, either with or without pruning.

Table 5. Yields of cassava and intercrops (t/ha) as influenced by cassava planting arrangement during three cropping cycles at Bohol Experiment Station, Ubay, Bohol, Philippines.

Cropping system	Cassava spacing (m)									
	1.0x1.0			1.7x0.59			(2.0+0.81)x0.71			Average
	91/92	92/93	93/94	91/92	92/93	93/94	91/92	92/93	93/94	
Cassava yield (t/ha)										
Cassava	12.75	39.41	9.97	14.47	33.39	7.24	14.58	36.93	8.13	19.65
C+peanut	11.71	32.20	13.70	9.10	32.48	9.53	12.47	37.37	10.62	18.80
C+mungbean	15.92	35.66	6.95	13.68	31.63	6.54	16.37	36.96	6.25	18.88
C+soybean	17.40	34.12	9.20	15.92	33.89	8.53	16.60	38.54	6.19	20.04
C+cowpea	13.83	34.91	11.85	14.86	33.18	10.26	14.91	40.52	8.48	20.31
C+pole sitao	11.86	26.93	9.66	11.13	27.57	7.00	14.74	34.38	8.38	16.85
Average	13.91ab	33.87	10.22	13.19b	32.02	8.18	14.94a	37.45	8.01	
CV(%)	16.72									
F-test: Cropping system NS[1]; Spacing*; System x Spacing NS										
Intercrop yield (t/ha)										
C+peanut	1.34	0.89	1.70	0.88	0.96	1.49	1.14	1.29	1.30	
C+mungbean	0.49	1.12	1.24	0.32	0.83	0.99	0.40	0.98	1.09	
C+soybean	0.47	1.41	2.00	0.29	0.81	1.34	0.17	0.92	1.30	
C+cowpea	0.90	1.96	1.29	0.92	1.39	0.97	0.89	1.88	0.86	
C+pole sitao	0.48	1.48	1.04	0.30	1.09	0.90	0.48	1.18	0.94	
Average	0.74a	1.37	1.45	0.54b	1.02	1.14	0.62ab	1.25	1.10	
F-test: Cropping system**; Spacing*; System x Spacing NS										

[1]NS = not significant
* = significant ($P<0.05$)
** = highly significant ($P<0.01$)

Table 6. Effect of pruning and planting distance on the yield of cassava at Bohol Experiment Station, Ubay, Bohol, Philippines in 1995/96.

Planting distance	Pruning treatments[1]				Average
	1	2	3	4	
1 x 1m	19.92	14.61	14.58	15.63	16.18
0.80 x 0.80m	23.67	17.61	21.36	21.26	20.97
0.60 x 0.60m	23.55	20.64	21.69	21.52	21.85
Average	22.38	17.62	19.21	19.47	19.67

[1] 1=no pruning
2=pruning at 5 months after planting (MAP)
3=pruning at 7 MAP
4=pruning at 9 MAP

CONCLUSIONS

During the past three years there has only been a slight increase in cassava production in the Philippines, both in area and in volume. Cultivation of the crop is still concentrated in Mindanao where there are better market outlets, such as chips traders, feed millers and starch processors.

In Baybay, Leyte, cassava planted under coconut trees responsed more to K and N and less to P after six years of continuous cropping. Contour barriers of vetiver grass and application of dry grass mulch resulted in low levels of soil loss due to erosion, while cassava root yield was high in plots with application of grass mulch or *Crotalaria juncea* as intercrop. A variety with a heavier canopy responded most markedly to fertilizer application in Bontoc, Leyte.

In intercropping trials in Bohol, cassava yields were not affected by any of the legume intercrops, but yields were affected by plant spacing. Pruning did not affect cassava yields, but closer spacing significantly increased yields.

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VARIETAL IMPROVEMENT AND AGRONOMY RESEARCH IN MALAYSIA

S.L. Tan[1]

ABSTRACT

Over the period 1994-1996, seven batches of seeds and two of meristem tissue cultures were evaluated and selected. As important as root yield is the trait starch content (or dry matter content) if a clone is to be accepted as a starch cultivar. At the time of reporting a number of clones have been identified as having yield levels similar to the high-yielding early cultivar MM 92, while showing dry matter contents equivalent to that of the commercial starch cultivar Black Twig. Two of these promising clones have also been evaluated positively for processing into oil-fried crisps, a popular local snack.

Agronomic research included various studies on nutrient inputs and the effects of flooding on cassava performance when the crop is planted on drained peat. With the early cultivar MM 92, fertilizer inputs may be halved and applied once every alternate cropping without affecting root yields. While the effect of Ca application was not clear-cut, there was some indication that Ca applied as a 9% foliar solution of $Ca(NO_3)_2$ or as 1,500 kg/ha of $CaCO_3$ to the soil improved root dry matter content. Solid wastes from starch processing factories may be returned to the soil at the rate of 1.0-1.5 t/ha as a supplement to chemical fertilizer inputs. MM 92, in contrast to 12-month Black Twig (critical stage at 3 1/2 months), showed the greatest yield reduction when flooding occurred at 4-5 months after planting. Four days of continuous flooding resulted in yields declining as much as 45%.

INTRODUCTION

Malaysia and MARDI (the Malaysian Agricultural Research and Development Institute) have reached a major cross-road as far as cassava research is concerned. Labor costs, and indeed availability of agricultural labor, have become a major constraint to small-scale cultivation of cassava. Technology packages for mechanized production have been formulated by MARDI, but require a scale of production of at least 400 ha of cultivated area (Sukra *et al.*, 1992). On the other hand, to keep a starch factory with a minimal daily capacity of processing 150 t fresh roots (Mat Isa, A., Food Technology Research Centre, MARDI, Serdang, *pers. comm.*) well-supplied with roots would require a cultivated area of at least 1,650 ha. This assumes fresh root yields of 25 t/ha, 275 working days in a year, and that the factory operates a single 8-hour shift per day. However, land of less than 14% slope (to allow for mechanization without accompanying risks of soil erosion) of the required area in one contiguous piece is no longer so easily available for cassava cultivation in Peninsular Malaysia, where the demand for starch is strong.

Sustained research on cassava, particularly in the fields of breeding/selection and agronomy, has been going on for more than two decades in MARDI, and many practical and cost-effective technologies have been generated. Adoption of those technologies by the end-user, however, has been less than enthusiastic or satisfactory, largely due to the

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constraint of land availability.

For these reasons, in Malaysia's Seventh Development Plan, covering the period 1996-2000, funding for cassava research has been discontinued. Starch, on the other hand, is anticipated to have a growing demand, especially in the widely varied processed food industries (Tan, 1996). Hence, research emphasis has shifted to sweet potato as a possible alternative starch source.

MARDI is also on the treshold of embracing a corporate image, which brings with it an increasingly important role in income generation for the institute through such activities as consultancy services, contract research, patents and copyrights. Having built up strong expertise in cassava production technology, prospects are sound in attracting consultancy services. There has been encouraging interest from the private sector to invest in cassava production in the east Malaysian states of Sabah and Sarawak, as well as in other Southeast Asian countries where labor availability is still secured. Thus, while active cassava research in MARDI may wind down in the coming years, the promotion of cassava technologies will remain a significant role of the institute.

The cassava breeding and selection program has CIAT to thank for keeping it alive for a few more years through the mechanism of the small contract agreement. These modest funds will ensure that the evaluation and selection of short-listed clones may be completed satisfactorily.

VARIETAL IMPROVEMENT 1994-1996

Anticipating the gradual closure of the cassava research program, only two seed batches were introduced since the last Asian Cassava Research Workshop. In 1994, 1,141 seeds, labeled batch (CIAT 13 (TH), were sent from the CIAT-Thai program, while 1,040 seeds (CIAT 14) came from CIAT Headquarters in Cali. The germination rate was quite different for the two batches: 59% for CIAT 13 (TH) resulting in 673 seedlings, and only 7.8% for CIAT 14, giving 81 seedlings.

Over the period 1994-1996, evaluation and selection following the usual stages of Seedling, Single-row, Preliminary, Advanced and Regional Yield Trials involved materials introduced from 1989-1994 (**Table 1**).

Past experience shows that mere high root yield (as in cv. Perintis), even with an early harvestable characteristic (as in cv. MM 92), is insufficient to attract wide use of the clones by farmers, especially those supplying the starch processors. This is due to the existence of a price discounting system based on a minimal root starch content of 28%. In an effort to ensure greater acceptability of the new clones, intermediate (i.e. as high as the local cultivar Black Twig) to high root starch content has become a significant selection criterion. Latest harvest data from the yield trials are given in **Tables 2 to 5**. In all the trials, three control cultivars were used, namely Black Twig, Perintis and MM 92.

Table 1. Stage of evaluation and selection of CIAT germplasm over the period 1994-1996.

Seedstock	Stage of evaluation	Year	No. clones
CIAT 8	Regional Trials	1993-1995	7
CIAT 7+CIAT 9 (TH)[1)]	Advanced Yield Trials	1993-1995	16
CIAT 10	Advanced Yield Trial	1994-1995	20
	Regional Trial	1995-1997	7
CIAT 11	Preliminary Yield Trial	1994-1995	20
	Advanced Yield Trial	1995-1996	12
CIAT 12	Single-row Trial	1994-1995	25
	Preliminary Yield Trial	1995-1996	5
CIAT 13 (TH)[1)]	Seedling Evaluation	1994-1995	673
	Single-row Trial	1995-1996	37
	Preliminary Yield Trial	1996-1997	14
CIAT 14	Seedling Evaluation	1994-1995	81
	Single-row Trial	1995-1996	16
Meristems 1990	Advanced Yield Trial	1994-1995	10
	Regional Trial	1995-1997	4
Meristems 1991	Single-row Trial	1994-1995	7
	Preliminary Yield Trial	1995-1996	7
	Advanced Yield Trial	1996-1997	7

[1)]TH=introduced from the Thai-CIAT program

Although in a Regional Trial shown in **Table 2**, SM814-18 produced root yields at 6 and 12 months equivalent to those of Perintis and MM 92, its dry matter content was unfortunately as low as these two clones, so the clone did not merit final selection. In the recently harvested Regional Trial (**Table 3**), MKUC28-77-3 and Rayong 60 showed promise at 6 months: their root yields were not significantly different from the controls, while dry matter contents were similar to that of Black Twig. However, at 12 months, the best yield of 41.2 t/ha was obtained with CM6149-30 (although not significantly different from the three controls). Taking root dry matter content into consideration, the highest dry root yield was also recorded for the same clone. CM6149-30 had a dry matter content similar to that of Black Twig, and therefore significantly higher than those of Perintis and MM 92. Rayong 60, together with CM6149-23, CM6149-54 and CM6885-75, had dry root yields (ranging from 10.7 to 11.3 t/ha) similar to the controls because of their intermediate to high dry matter contents. CM6885-75 had a root dry matter content of 43.0%.

Table 2. Mean data from a Regional Trial on "CIAT 8" seed batch over two seasons at Pontian peat station, Johore, Malaysia.

Clone	6-month data			12-month data		
	Root yield (t/ha)	Harvest index	RDMC[1)] (%)	Root yield (t/ha)	Harvest index	RDMC[1)] (%)
OMR32-06-21	20.3	0.47	34.3	33.6	0.60	34.0
OMR32-06-25	20.2	0.45	30.3	29.1	0.48	30.6
OMR32-06-46	27.8	0.60	29.9	39.8	0.63	26.5
OMR32-06-64	21.6	0.50	31.5	35.2	0.58	37.1
OMR32-30-11	20.0	0.55	32.5	33.7	0.62	37.0
OMR32-30-37	23.2	0.48	30.3	30.2	0.52	36.0
SM814-18	32.6	0.60	27.8	52.7	0.66	26.0
Black Twig	20.4	0.44	27.6	34.0	0.50	29.5
Perintis	29.7	0.58	25.8	53.5	0.65	26.0
MM92	34.7	0.65	25.1	51.4	0.63	19.9
LSD(P=0.05)	5.4	0.06	4.5	5.6	0.03	4.4

[1)]RDMC=Root dry matter content

In the Advanced Yield Trial, testing clones selected from CIAT 7 and CIAT 9 (TH), the clone SM967-1 showed promise in terms of dry matter content (higher than that of Black Twig), while having root yields equivalent to that of MM 92 at 6 and 12 months (**Table 4**). Harvest data from the other Advanced Yield Trial (on CIAT 11 clones) showed SM1565-7, SM1562-19 and SM1565-57 to be desirable in terms of dry matter content, with reasonable root yields at six months, while the first two clones as well as SM1794-23 and CM7719-7 were promising in terms of starch content and root yields at 12 months (**Table 5**).

Table 3. Regional Trial on clones selected from "Meristems 1990" and "CIAT 10" seed batch (6-and 12-month data) at Pontian peat station, Johore, Malaysia.

Clone	6-month data			12-month data		
	Root yield (t/ha)	Harvest index	RDMC[1] (%)	Root yield (t/ha)	Harvest index	RDMC[1] (%)
Rayong 3	10.6	0.74	38.3	18.2	0.77	38.1
Rayong 60	19.3	0.66	39.3	28.4	0.69	39.1
CMR28-67-76	17.3	0.66	38.8	17.9	0.64	40.3
MKUC28-77-3	18.1	0.66	43.6	27.0	0.68	35.9
CM6149-23	14.3	0.66	40.5	31.4	0.64	35.7
CM6149-30	22.1	0.63	38.0	41.2	0.67	39.3
CM6149-54	16.1	0.60	38.0	29.8	0.67	37.4
CM6149-55	12.6	0.61	40.8	13.6	0.63	41.5
CM6885-75	16.6	0.64	39.8	24.9	0.68	43.0
CM7752-4	11.8	0.60	35.7	18.6	0.63	40.5
CM8061-2	11.8	0.60	40.3	19.2	0.73	37.8
Black Twig	21.7	0.60	41.9	37.1	0.65	39.8
Perintis	20.2	0.69	32.3	39.5	0.80	27.5
MM92	24.4	0.78	28.5	29.8	0.74	26.9
LSD(P=0.05)	9.7	0.10	5.0	13.1	0.08	5.7

[1]RDMC=Root dry matter content

Table 4. Advanced Yield Trial of selected clones from "CIAT 7" and "CIAT 9 (TH)" seed batches (6-and 12-month data) at Pontian peat station, Johore, Malaysia.

Clone	6-month data			12-month data		
	Root yield (t/ha)	Harvest index	RDMC[1)] (%)	Root yield (t/ha)	Harvest index	RDMC[1)] (%)
OMR33-15-7	18.3	0.71	17.1	23.6	0.65	32.2
OMR33-15-21	18.3	0.60	25.9	30.3	0.59	33.6
OMR33-06-21	12.4	0.50	30.4	18.9	0.38	40.9
OMR33-63-4	16.1	0.68	35.7	24.3	0.62	36.0
OMR33-63-30	16.5	0.65	30.8	28.1	0.58	36.3
OMR33-63-9	14.3	0.68	30.3	22.7	0.59	39.6
SM836-10	20.7	0.58	26.0	32.8	0.60	31.7
SM967-1	22.4	0.66	29.3	31.1	0.63	36.7
SM987-13	20.7	0.62	23.7	36.5	0.60	27.4
Adira 4	15.4	0.62	25.5	31.1	0.60	32.1
Black Twig	24.2	0.68	23.8	34.3	0.64	33.4
Perintis	19.3	0.69	22.8	31.2	0.72	27.1
MM 92	23.1	0.76	21.4	33.3	0.68	19.7
LSD(P=0.05)	5.0	0.08	8.6	8.1	0.06	4.7

[1)]RDMC=Root dry matter content

Table 5. Advanced Yield Trial on selected clones from "CIAT 11" seed batch (6-and 12-month data) at Pontian peat station, Johore, Malaysia.

Clone	6-month data			12-month data		
	Root yield (t/ha)	Harvest index	RDMC[1)] (%)	Root yield (t/ha)	Harvest index	RDMC[1)] (%)
CM6658(C)-2	9.8	0.20	25.3	32.2	0.42	38.2
SM1583-2	16.1	0.37	31.1	36.4	0.52	41.5
CM6098-45	11.8	0.21	29.8	25.6	0.35	39.5
SM1565-7	24.3	0.45	29.6	41.7	0.57	40.3
SM1565-57	20.1	0.45	36.0	28.3	0.51	41.1
CM8223-29	9.7	0.24	29.5	22.6	0.31	40.4
CM8223-30	16.8	0.33	27.1	35.0	0.48	40.7
CM6517-9	11.8	0.30	29.6	30.6	0.44	40.0
SM1562-19	23.6	0.41	31.6	36.8	0.55	37.5
SM1794-23	14.9	0.39	33.7	41.0	0.56	40.3
CM7719-7	12.1	0.25	32.9	43.6	0.47	37.2
CM7719-23	11.2	0.24	31.3	35.3	0.51	38.8
Black Twig	11.4	0.16	27.1	38.1	0.42	36.2
Perintis	23.1	0.43	25.8	50.8	0.55	33.4
MM92	29.6	0.48	25.1	45.7	0.56	32.1
LSD(P=0.05)	5.6	0.12	6.5	9.7	0.10	6.6

[1)]RDMC=Root dry matter content

Recent trends show a growing demand for edible cassava types for processing into oil-fried crisps, a popular snack locally known as *kerepek*. This cottage industry is gaining ground, especially in Johore with its close proximity to the Singapore market. To capitalize on this demand, root samples from the three promising clones at six months (from CIAT 11), which also have low root cyanide contents (<60 μg HCN/g fresh root), were sent to a *kerepek* processor to test their acceptability for this type of utilization. The feedback has been enlightening: SM1562-19 was considered to be superior to the local cultivars currently used, SM1565-57 was acceptable as a substitute, while SM1565-7 was rejected because of its hard texture when so processed. Such information coming from the Advanced Yield Trial will be very beneficial in making the final selections for the Regional Trials.

The above results show that it is becoming increasingly difficult to raise root yields above those of the released cultivars. However, there is still room for improvement of the dry matter content (i.e. the starch content) at this yield level.

AGRONOMY RESEARCH 1994-1996

Agronomy research on cassava terminated in 1995 with the retirement of the agronomist, Mr. Chan Seak Khen, and the resignation of his replacement. Although the breeder shouldered the responsibility of the ongoing research trials for a short time, increasing work pressure from sweetpotato research has caused her to abandon further efforts after completion of those trials. What follows is a summary of the findings of final agronomy research on cassava conducted by MARDI.

Reduction of fertilizer use with an early clone

Using the six-month cultivar MM 92, this trial was conducted on drained peat over six cropping cycles, beginning in 1991. Fertilizer inputs for cassava on peat have been high (200 kg N, 30 P_2O_5 and 160 K_2O/ha) in the past when the 12-month Black Twig cultivar was used (Tan and Chan, 1994). The nine treatments included a combination of fertilizer rates and frequency of application as follows:

Treatment	Application rate over 6 crops[1]						Percent of Control 1
	1st	2nd	3rd	4th	5th	6th	
1 (Control 1)	1	1	1	1	1	1	100.0
2	1	0	1	0	1	0	50.0
3	1	0	0	1	1	0	50.0
4	1	0	0	0	1	0	33.3
5	½	½	½	½	½	½	50.0
6	½	0	½	0	½	0	25.0
7	½	0	0	½	½	0	25.0
8	½	0	0	0	½	0	16.7
9 (Control 2)	0	0	0	0	0	0	0.0

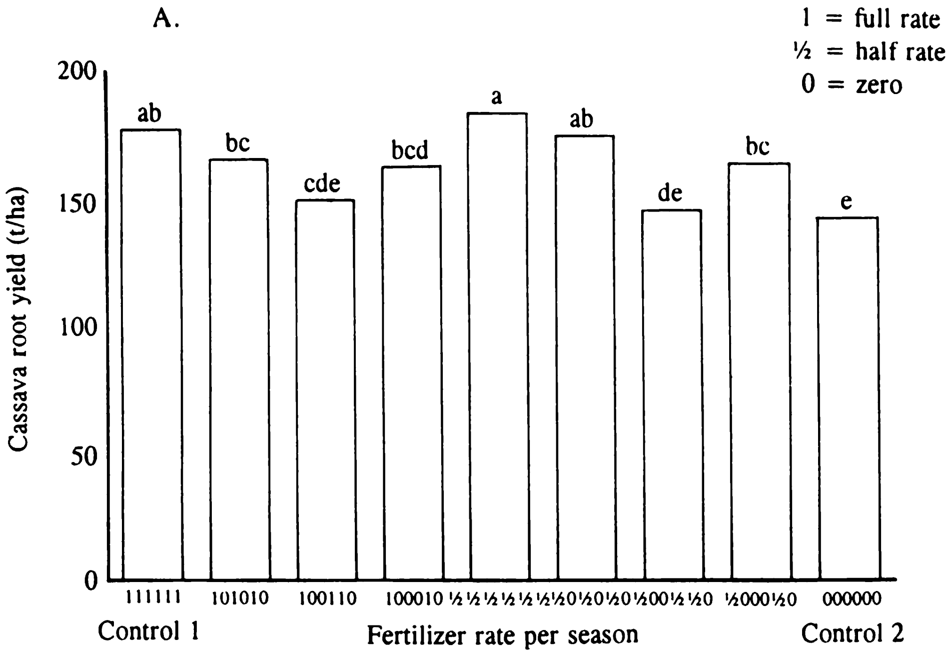
[1] each crop of 6 months duration
1: full rate of fertilizers (200:30:160)
½: half rate of fertilizers (100:15:80)
0: no fertilizers

Results show that when MM 92 was grown, the fertilizer rate could be reduced by half, and this half rate (100:15:80) could be applied to every alternate crop instead of every season without affecting either fresh or dry root yield (**Figures 1A** and **1B**). Root dry matter content was unaffected by any of the fertilizer treatments. The results of this trial have been published (Tan, 1995).

Effect of waterlogging on cassava performance

These series of experiments conducted in fibre-glass lysimeters filled with peat soil, started in 1989 using the cultivar Black Twig (harvested at 9 months); in 1992 the test variety was changed to cultivar MM 92 (harvested at 6 months). The objective of the experiments was to determine the critical stage of plant growth when flooding had the most detrimental effects, as well as the effect of flooding duration at this critical stage.

For Black Twig, the critical stage was at 3½ months after planting, at the stage of storage root initiation, when the subsequent root yield could be reduced by 80%. **Figure 2** shows that flooding at this stage, from 1 to 4 days, did not bring about a significant root yield reduction (although a 25% reduction was observed after 4 days' flooding). **Figure 3** shows that for MM 92 yield reductions up to 80% occurred when flooding was imposed at 4-5 months. MM 92 showed significant yield declines of 25% and 45% after flooding for 4 days at 3½ months and at 5 months, respectively.



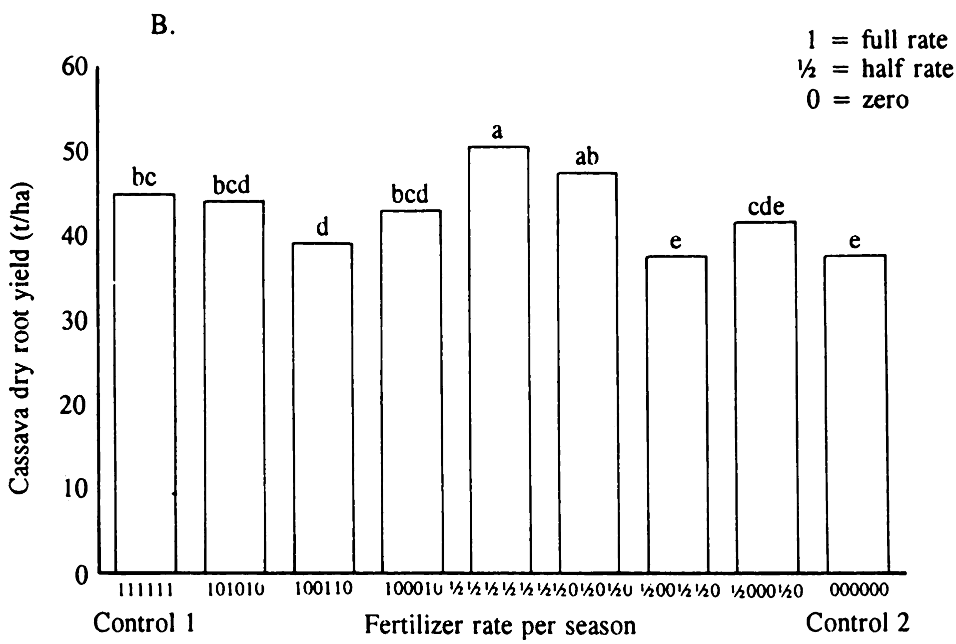


Figure 1. Effect of varying levels and frequencies of fertilizer application on the cumulative (over six 6-month crops) fresh (A) and dry (B) root yields of cassava, cv. MM 92, grown at Pontian peat station, Johore, Malaysia.

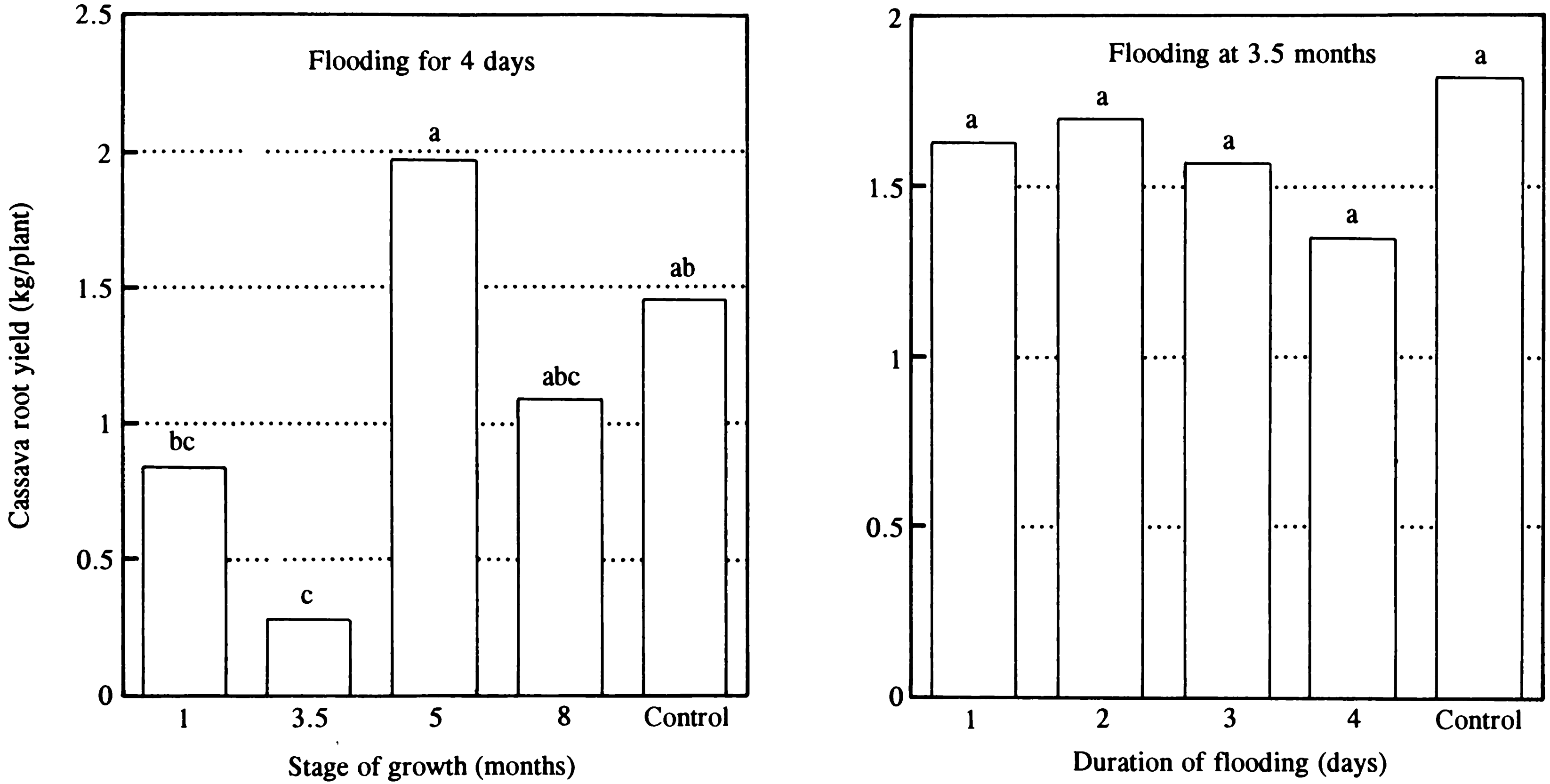


Figure 2. Effect of flooding at various growth stages and for different durations on the fresh root yields of cassava, cv. Black Twig, grown in lysimeters filled with peat soil. The control treatment had no flooding.

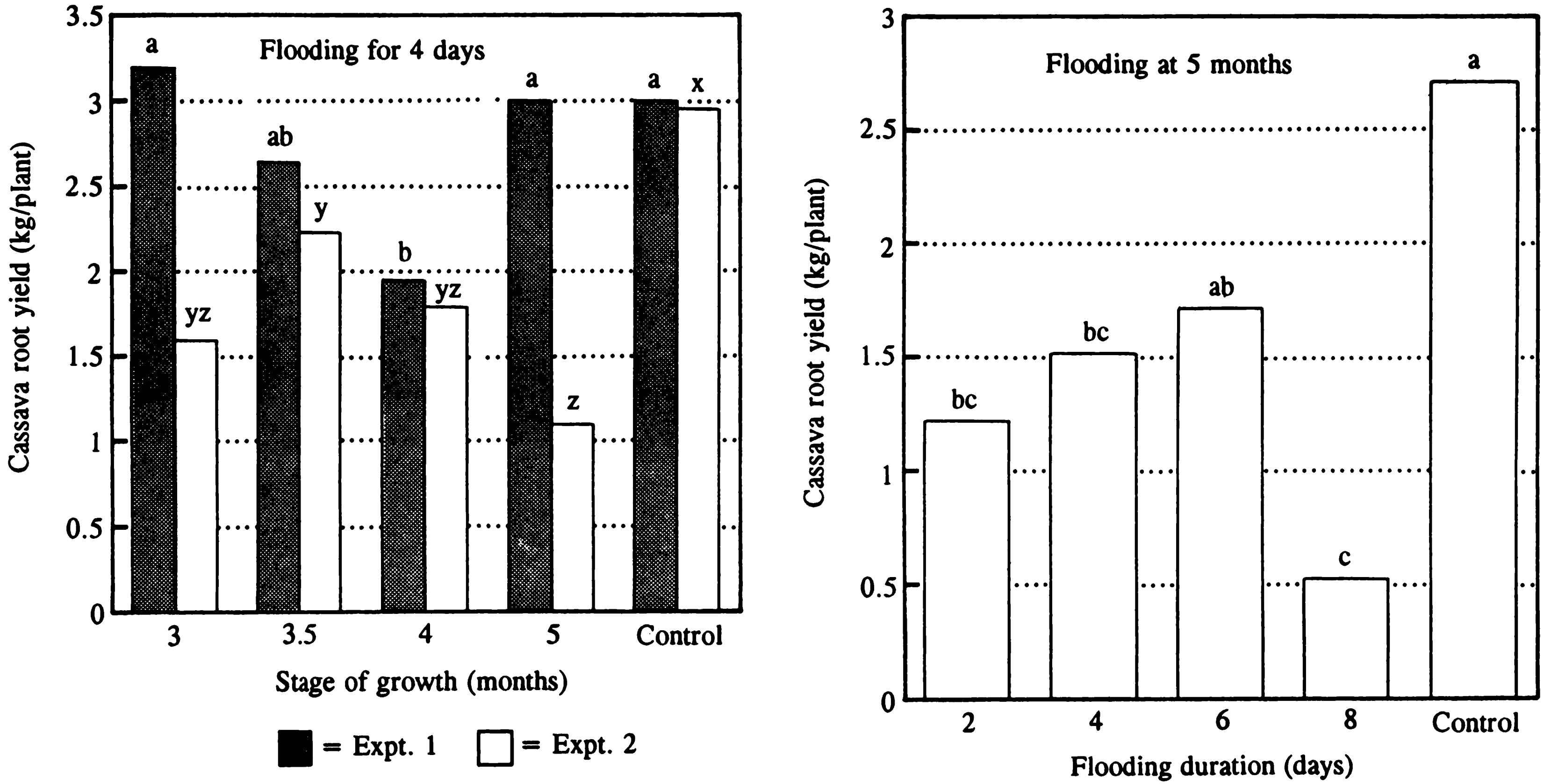


Figure 3. Effect of flooding at various growth stages and for different durations on the fresh root yields of cassava, cv. MM92, grown in lysimeters filled with peat soil.

Effect of Ca on performance of cv. Perintis

Results from an earlier trial suggested a possible role of Ca in enhancing root yield to levels in excess of 100 t/ha, as well as starch content in the cultivar Perintis (Chan and Tan, 1994). The experiment, carried out over two consecutive seasons, tested different sources of Ca (applied in different ways) as well as varying rates on Perintis planted at the peat station in Pontian, Johore. Nine treatments were tested against two controls:

FN1	Foliar spray of 3% $Ca(NO_3)_2$ solution at 2 and 3 months
FN2	Foliar spray of 6% $Ca(NO_3)_2$ solution at 2 and 3 months
FN3	Foliar spray of 9% $Ca(NO_3)_2$ solution at 2 and 3 months
SG1	Soil application of 312.5 kg gypsum/ha at 3 weeks by banding (equivalent to 100 kg Ca)
SG2	Soil application of 625 kg gypsum/ha at 3 weeks by banding (equivalent to 200 kg Ca)
SG3	Soil application of 937.5 kg gypsum/ha at 3 weeks by banding (equivalent to 300 kg Ca)
SL1	Soil application 2 weeks prior to planting by broadcasting of 500 kg $CaCO_3$/ha
SL2	Soil application 2 weeks prior to planting by broadcasting of 1,000 kg $CaCO_3$/ha
SL3	Soil application 2 weeks prior to planting by broadcasting of 1,500 kg $CaCO_3$/ha
000	Control 1: no Ca application
00N	Control 2: similar to Treatment FN3 but with 3.8% NH_4NO_3 solution (equivalent in terms of N to 9% $Ca(NO_3)_2$

While results were far from conclusive, there was some indication that root dry matter content was improved by 12.6-22.0% (over the two controls) when Ca was applied as a foliar spray at 2 and 3 months using a 9% $Ca(NO_3)_2$ solution, or soil application of 1,500 kg $CaCO_3$/ha two weeks before planting (**Table 6**). Fresh root yields were unaffected by any of the treatments, although the foliar spray of 9% $Ca(NO_3)_2$ reduced yield by as much as 12.6% over Control 2.

Alternate sources of nutrients for cassava production

Solid wastes from starch processing factories have traditionally been sold as a cheap feedstuff to livestock farmers and feedmillers. However, there is less and less demand for these wastes because of their poor nutrient content. Such wastes constitute a potential environmental pollution hazard. A logical solution would be to re-use these wastes as a nutrient input to supplement chemical fertilizers.

Varying rates of dry starch factory wastes (0, 0.5, 1.0, 1.5 t/ha) in combination with chemical fertilizers (50-30-40 and 100-30-80 kg N-P_2O_5-K_2O/ha of NPK mixture) were evaluated over two seasons using the cultivar MM 92 as the test variety on peat.

Results show no significant effects on fresh root yield when starch factory wastes were used in combination with chemical fertilizers (**Table 7**). Nevertheless, using the higher rate of chemical fertilizers (Control) produced a 15% yield improvement over the lower rate. However, using from 1.0-1.5 t/ha of starch factory wastes in combination with the lower and higher fertilizer rates, respectively, was able to maintain starch content as high as in the Control (**Table 7**).

Table 6. Effects of source and rate of Ca on fresh root yield and root dry matter content of cultivar Perintis planted at Pontian peat station, Johore, Malaysia.

Treatment		Fresh root yield (t/ha)	Dry matter content (%)
Source	Rate		
$Ca(NO_3)_2$	3% foliar spray	55.1	28.1
$Ca(NO_3)_2$	6% foliar spray	56.1	28.6
$Ca(NO_3)_2$	9% foliar spray	45.8	31.3
gypsum	312.5 kg/ha to soil	47.1	28.5
gypsum	625 kg/ha to soil	47.4	28.7
gypsum	937.5 kg/ha to soil	51.2	29.0
$CaCO_3$	500 kg/ha to soil	53.3	29.2
$CaCO_3$	1000 kg/ha to soil	51.7	26.8
$CaCO_3$	1500 kg/ha to soil	48.6	33.3
Control 1	No Ca	51.4	27.3
Control 2	N equiv. to 9% $Ca(NO_3)_2$	52.4	27.8
Significance level		NS[1)]	NS

[1)]NS = not significant

Table 7. Effect of using starch factory wastes in combination with chemical fertilizers on the yield and starch content of cassava (cv. MM 92) grown at Pontian peat station, Johore, Malaysia.

Treatment[1)]	Fresh root yield (t/ha)	Starch content (%)
M1W0	24.0a[2)]	24.5b[2)]
M1W1	26.1a	24.1b
M1W2	26.7a	25.3ab
M1W3	25.2a	23.9b
M2W0 (Control)	27.6a	26.4a
M2W1	26.3a	24.2b
M2W2	27.4a	23.8b
M2W3	25.6a	25.4ab

[1)] M1 = 50-30-40 kg N-P_2O_5-K_2O/ha of NPK mixture
M2 = 100-30-80 kg N-P_2O_5-K_2O/ha of NPK mixture

W0 = 0 t wastes/ha
W1 = 0.5 t wastes/ha
W2 = 1.0 t wastes/ha
W3 = 1.5 t wastes/ha

[2)] Values in the same column bearing the same letter are not significantly different from one another according to Duncan's new muliple range test (P=0.05)

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CASSAVA AGRONOMY RESEARCH IN ASIA - AN OVERVIEW 1993-1996

Reinhardt H. Howeler[1]

ABSTRACT

During the past three years (1993-1996), cassava agronomy research, conducted by national programs in collaboration with CIAT and with financial support from the Nippon Foundation in Japan, continued as before but at a slightly lower level of activity. Major emphasis remained on soil fertility maintenance and erosion control with the objective of enhancing the sustainability of cassava production in Asia.

Long-term fertility trials have been conducted in 14 locations in four countries. Some of these trials are now in the 8th or 9th cycle of continuous cassava production. During the latest crop cycle there was a significant response to N in ten sites, to P in six sites and to K in eleven sites, indicating the importance of adequate fertilization of cassava with K and N and a lesser need for P. Especially the response to K increased with successive cassava cropping cycles.

Various types of erosion control trials were continued in 13 sites in five countries. Research in Thailand indicate that time of planting has a strong influence on erosion, with greatest soil losses occurring when cassava is planted in the beginning of the rainy season. For cassava monoculture the planting on contour ridges, at closer spacing and with adequate fertilization increased yields and reduced erosion losses. Among various intercropping systems the interplanting of peanuts is generally most effective in reducing erosion, while also providing a good additional income. Intercropping with pumpkin or squash was also quite effective, but watermelons, cucumbers or muskmelon were more difficult to establish. Among various contour barriers tested, the most suitable were hedgerows of *Flemingia congesta* and *Gliricidia sepium* in Malang, E. Java, *Gliricidia* and *Leucaena leucocephala* in South Vietnam, *Thephrosia candida* in North Vietnam, and vetiver grass in Nanning, China, and in Leyte, Philippines; application of grass mulch was even more effective at the latter location. The efficiency of hedgerows of many other grass species are presently being investigated in Thailand.

Maintaining soil fertility with no or little chemical fertilizers is being investigated in South Vietnam, Indonesia and Thailand. A crop rotation of cassava with peanut/pigeon pea was found to be effective in northeastern Thailand. Green manuring with *Crotalaria juncea* or *Canavalia ensiformis* before planting cassava (cassava harvested after 18 months for a 2-year cycle), or interplanting these same two species and cutting and mulching the legumes at 2 MAP for a 12-month cassava crop, were found to be most effective in maintaining high yields when only small amounts of fertilizers were applied. A similar intercropping/mulching treatment with *Tephrosia candida* was also effective in South Vietnam, although intercropping and mulching with cowpea was even more effective.

Weed control trials have been conducted in Thailand and are being initiated in South Vietnam. The preemergence herbicide Metolachlor seems effective in both locations and can also be used when cassava is intercropped with mungbean or peanut. The frequency and cost of weeding was markedly reduced when cassava was planted at the end rather than the beginning of the rainy season in Thailand. More efficient methods of weed control, both chemical and mechanical, need to be further investigated as labor for hand weeding is becoming more and more expensive.

INTRODUCTION

Cassava agronomy research during the past three years (1993-1996), conducted by cassava researchers in national programs in collaboration with CIAT, and with

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financial support from the Nippon Foundation in Tokyo, Japan, has continued as before, *albeit* at a lower level of activity. This was due to a shift in emphasis from on-station research to farmer participatory research (FPR). This has reduced the budget available for basic and strategic research.

As before, the cassava agronomy research has emphasized the maintenance of soil fertility through biological means or through the application of chemical fertilizers, and the control of soil erosion through appropriate soil/crop management practices. A limited amount of research continued on other cultural practices such as plant spacing and weed control.

SOIL FERTILITY MAINTENANCE

While cassava grows better than most other crops on acid and low fertility soils, the crop is much more productive on medium or highly fertile soils. When grown in soils with a limited availability of plant nutrients, cassava plants grow only slowly, remain short and weak, but are quite effective in translocating carbohydrates from the shoots to the roots. This results in a rather low yield in spite of a high harvest index (HI). When grown in a fertile soil or when plant nutrients are added in the form of manures or chemical fertilizer, the greater absorption of essential nutrients results in faster growth, more and bigger leaves, longer leaf life, thicker stems and more and thicker roots. However, if nutrient supply is excessive, especially that of nitrogen (N), some cassava varieties grow too tall and produce too many leaves resulting in a low HI and a reduced root yield. Moreover, the excessive supply of phosphorus (P) or potassium (K) can lead to the reduced uptake of Fe or Zn and Ca or Mg, respectively. Thus, the maintenance of a balanced nutrient supply is essential for obtaining high yields; the application of excessive amounts of some nutrient(s) only increases production costs while it may actually decrease yields. Maintaining adequate soil fertility through application of manures or the judicious use of chemical fertilizers is not only important for the supply of nutrients, but also for maintaining optimum soil physical conditions through the return of organic matter to the soil. This in turn improves the soil's water holding capacity, nutrient retention capacity and stimulates the soil's micro-flora. When cassava (or other crops) are grown continuously without manure or fertilizer application, the soil's nutrient supply as well as its physical properties deteriorate, resulting in decreased productivity.

1. Fertility Maintenance through Fertilizer Application

Long-term NPK trials continued in 14 sites in four countries. Results of most these trials were already presented in previous papers in this Workshop (Zhang Weite *et al.*; Tongglum *et al.*; Nguyen Huu Hy *et al.*; Wargiono *et al.*; and Evangelio and Ladera, 1997). **Figure 1**, showing the cassava response to various levels of application of N, P and K as well as to that of "burned soil" during the 3rd cropping cycle in

CATAS, China, is a good example of this type of trials. In this case there was a significant and a highly significant response to N for SC124 and SC205, respectively; there was no significant response to P and only a highly significant response to K in SC205. Similar to results obtained in Nanning (Zhang *et al.*, 1997), variety SC205 was more responsive to high applications of N, P and K than SC201 or SC124. Due to the high level of available P is the soil in CATAS (17-20 ppm Bray-2 available P) there was no response to P application in that site. The combined application of N, P and K increased yields from 7-8 t/ha to about 26 t/ha. Application of "burned soil" in the presence of low levels of application of N-P-K, had no effect on yield. The application of 100 kg N, 25 P_2O_5 and 100 K_2O/ha can probably maintain soil fertility and high yields of cassava. **Figure 1B** also shows that high applications of N tend to suppress, while high applications of K tend to increase the starch content of roots. Thus, excessive application of N can lead to both reduced yields and starch contents.

Figure 2 shows the change in response to the annual application of N, P, and K during seven consecutive cropping cycles in Nanning, Guangxi, China. With an intermediate application of 100 kg N, 50 P_2O_5 and 100 K_2O/ha high yields of 20-25 t/ha could be maintained over the years. However, without N yields decreased from about 20 t/ha in the first year to 10-14 t/ha in subsequent years. The relative yield, i.e. the yield without the nutrient divided by the highest yield with the nutrient, decreased over the years, especially for N and K, indicating an increasing response to those two nutrients over time. The significant response to K and the lack of response to P (in most years) is reflected by the relatively low K and high P status of the soil (bottom **Figure 2**). Without K application the soil K level generally remained below the critical level, while without P application the soil P content decreased but still remained above the critical level. The highly significant response to N, in spite of a medium level of soil organic matter (OM) of 2-3% is probably due to the low pH (4.5) and high Al content (2-3 me/100g) of the soil, which tend to reduce the rate of N mineralization.

Table 1 shows the significance of response to N, P and K during the last year of several cropping cycles in 14 locations in four countries in Asia. The data shows that there was a statistically significant response to N in ten, to P in six and to K in eleven locations, indicating the more frequent response to applications of K and N than to the application of P. This is due to the relatively large removal of K and N in the root harvest in comparison with that of P, and the presence of a highly effective mycorrhizal population in most soils, which facilitates the uptake of P by cassava, even from very low-P soils.

The relationship between relative yield and the N, P or K concentration in youngest fully-expanded leaf (YFEL) blades at 4-5 months after planting (MAP) is shown for data of four NPK trials in **Figure 3**. There was a good relationship between relative yield and the N and K concentration of the leaves, allowing the estimation of a critical concentration (corresponding to 95% of maximum yield) of 5.7% N and 1.9% K. These critical levels are higher than those reported earlier (4.6% N and 1.7% K) (Howeler, 1995B), but are within the "sufficiency" range reported elsewhere for these elements (Howeler, 1996). **Figure 3** shows no clear relationship between P response and the P concentration in YFEL-blades, probably due to a lack of serious P deficiency in the four locations for which data are available.

Table 1. Response of cassava to annual application of N, P or K after several years of continuous cropping in various locations in Asia.

Country-location		Years of cropping	Response[1)] to N	Response[1)] to P	Response[1)] to K
China	-Guangzhou	4	**	**	**
	-Nanning	7	**	NS	*
	-CATAS	4	**	*	*
Indonesia	-Umas Jaya	8	NS	NS	NS
	-Malang	7	**	NS	*
	-Lampung	4	**	NS	**
	-Yogyakarta	4	NS	NS	NS
Philippines	-Leyte	6	NS	NS	NS
	-Bohol	4	**	NS	**
Vietnam	-Bac Thai	6	**	NS	**
	-Hung Loc(wet season)	6	NS	**	*
	-Hung Loc(dry season)	1	*	*	*
	-Thu Duc	1	**	**	**
	-Traco	1	**	*	*

1/ NS = no significant response.
   * = significant response(P<0.05).
   ** = highly significant response(P<0.01).

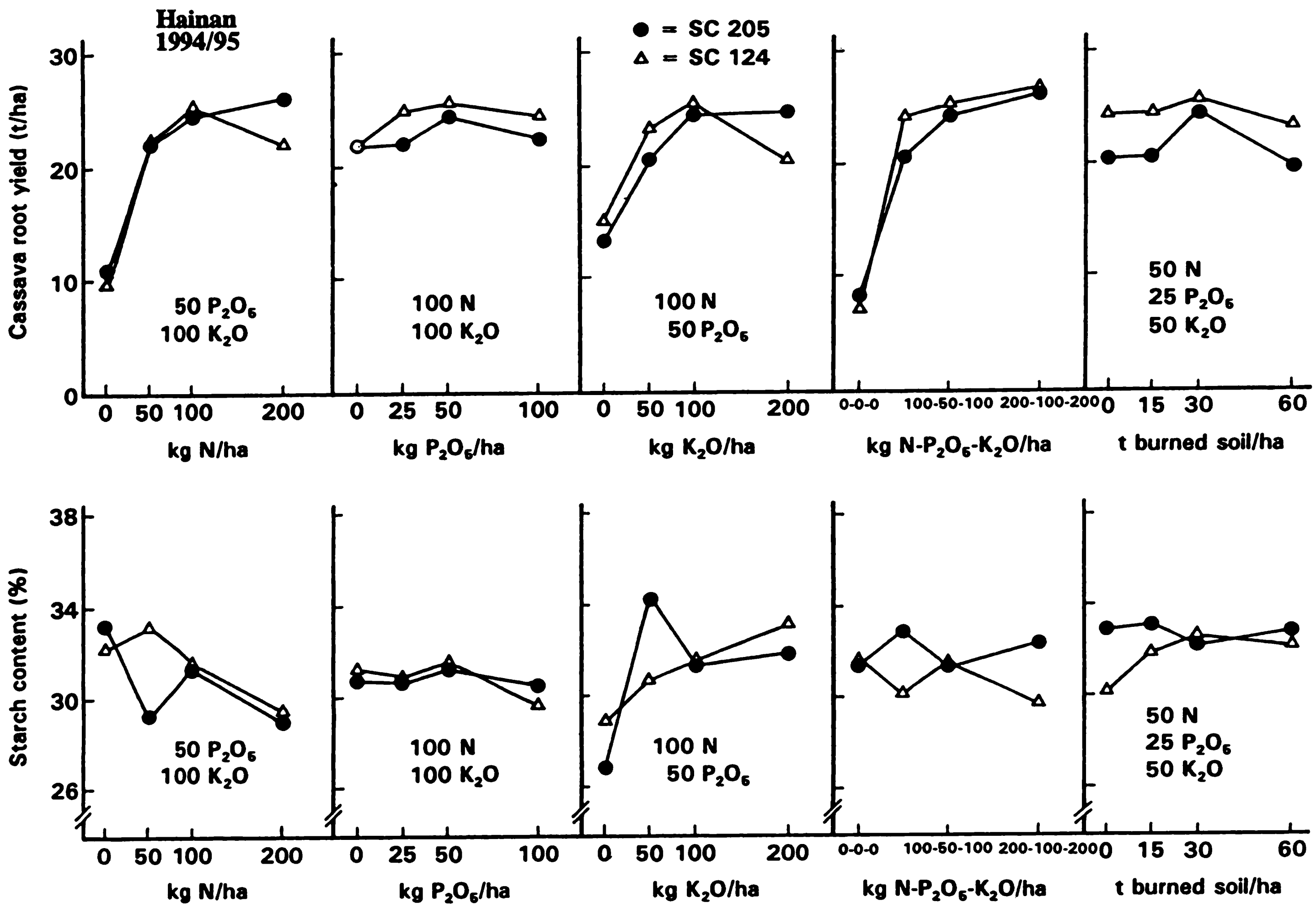

Figure 1. Effect of the annual application of various levels of N, P and K fertilizers and of "burned soil" on the fresh root yield and starch content of two cassava cultivars grown in CATAS, Hainan, in 1994/95 (3rd year).

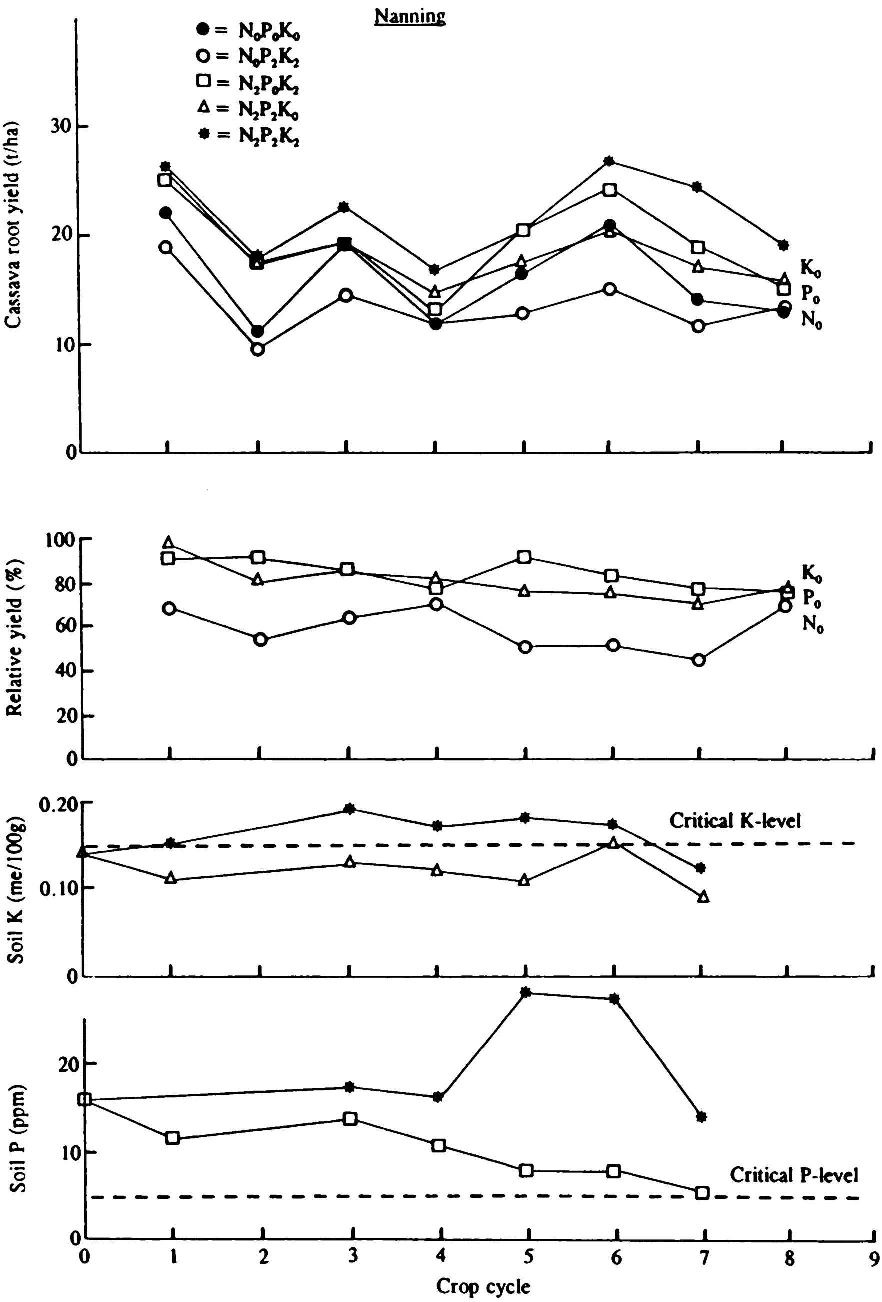

Figure 2. Effect of annual applications of N, P and K on cassava root yield, relative yield (yield without the nutrient over the highest yield with the nutrient) and the exchangeable K and available P (Bray 2) content of the soil during eight years of continuous cropping in the Guangxi Subtrop. Research Institute, Nanning, Guangxi, China.

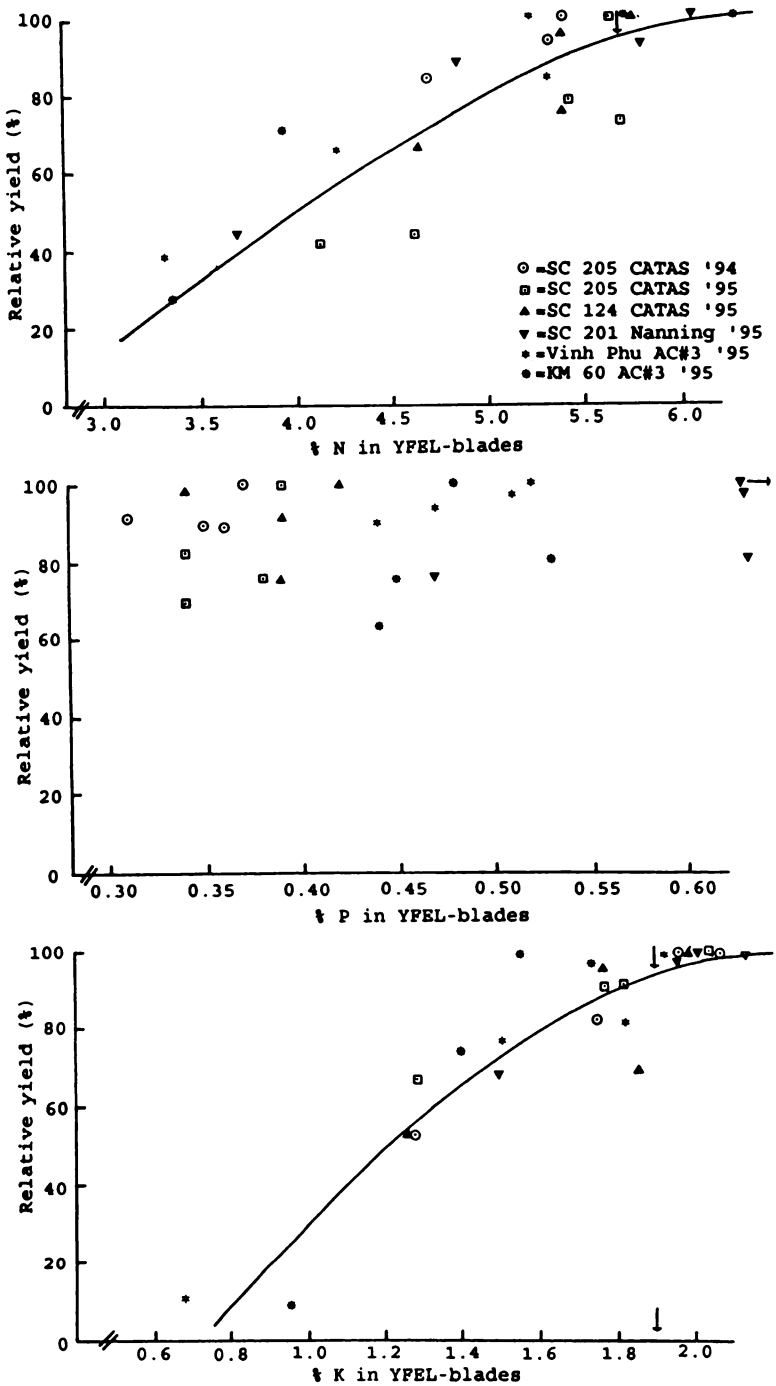

Figure 3. The relation between the relative yield of cassava, i.e. the yield without the nutrient as a percent of the highest yield with the nutrient, and the concentration of N, P and K in the youngest fully-expanded leaf (YFEL)-blades at 3-4 months after planting of various cultivars planted in four fertility trials in China and Vietnam.

Figure 4 shows the relationship between relative cassava yield and the organic matter, available P and exchangeable K contents in the soil, obtained from yield data and soil analyses results of ten long-term NPK trials conducted in Asia between 1993 and 1996. Critical levels of 3.2% OM, 7 ppm P (Bray-2) and 0.14 me K/100 g (55 ppm K) were estimated from these data. These are slightly higher than those estimated from earlier data from almost the same sites, i.e. 4.5 ppm P and 0.12 me K/100 g (Howeler, 1995A), but fall within the "medium" range reported elsewhere for these soil parameters (Howeler, 1995B; and Howeler, 1996). These "critical" levels serve only as a general guide in the interpretation of soil and plant tissue analyses to enable the diagnosis of a likely nutrient deficiency or toxicity, and to estimate the need for application of a particular nutrient.

Fertility Maintenance through Green Manuring

Research on soil fertility maintenance or improvement through green manuring, intercropping or alley cropping has been conducted in Vietnam, Indonesia and Thailand. In Vietnam the experiment was conducted on a highly-fertile red Latosol (probably classified as Eutrustox) in Hung Loc Research Center and not much beneficial effect of green manuring would be expected. **Table 2** shows that there was no significant effect of treatments in the first year, but that some treatments started to improve yields after 3-4 years of continuous cropping. Intercropping and mulching at 2-3 months after planting (MAP) of cowpea or *Canavalia ensiformis* increased yields, probably by increasing the soil moisture conditions during the dry season, or by the slight increase in OM and K contents of the soil. The beneficial effect of alley cropping was less pronounced, but also increased over time, especially the alley cropping with *Tephrosia candida*. Alley cropping with *Gliricidia sepium*, *Leucaena leucocephala* or *Flemingia congesta* also significantly increased cassava yields in a low-N soil of Jatikerto Experiment Station in Malang, Indonesia, after several years of continuous cropping (Wargiono *et al.*, 1995; Wargiono *et al.*, 1997)

In Thailand three green manure species, i.e. *Crotalaria juncea*, *Canavalia ensiformis* and pigeon pea, were either intercropped and cut at 2 MAP, interplanted at 7 MAP and cut and mulched before the following planting, or were used as green manures and pulled up and mulched before planting cassava; in the latter case, cassava was harvested after 18 months for a two-year cropping cycle. **Table 3** shows that in the sandy clay soil of Rayong Field Crops Research Center the intercropping and mulching of all green manures increased yields, with *Canavalia ensiformis* being most effective. Interplanting at 7 MAP had no beneficial effect on cassava yields, but may benefit the next crop; the interplanted *Crotalaria juncea* competed strongly with cassava for soil moisture during the dry season, resulting in low cassava yields. Green manuring with *Crotalaria* or *Canavalia* markedly increased the yield of 18-months old cassava, more than doubling that of cassava harvested at 12 MAP. This may be a promising system for the soil and climatic conditions of Thailand. **Table 3** also shows that mulching *Crotalaria juncea* generally supplied more nutrients than either *Canavalia ensiformis* or pigeon pea.

EROSION CONTROL

1. Effect of Crops on Soil Erosion

A comparative study on the effect of various crops on soil erosion and on nutrient uptake and removal, conducted since 1989 in Sri Racha, Thailand (Putthacharoen, 1993; Howeler, 1995A), was continued for a second cycle of 27 months between 1991 and 1993. Seven crops were grown in adjacent plots on 7% slope and soil losses due to erosion were measured at monthly intervals. **Figure 5** shows the accumulative erosion losses during the second cycle. Similar to the first cycle, cassava grown for root production (spaced at 1.0x1.0 m) resulted in the highest level of erosion, followed by cassava grown for forage production (spaced at 0.5x0.5 m). Soil loss for cassava root production was about 130 t/ha in the first crop and about 40 t/ha in the second crop. The closer spacing of cassava plants used for forage production resulted in considerably less erosion due to a more rapid canopy closure. Sugarcane also produced high levels of erosion during the first year after planting, but almost no erosion during the following ratoon crop. The short-cycle crops of maize, sorghum, peanut and mungbean produced much lower levels of erosion, ranging from 35 to 55 t/ha in two years (three crops). Pineapple caused the least amount of erosion since it was not replanted but left as a ratoon crop during the second cycle. **Table 4** shows that cassava yields were low in the first cycle, but rather normal in the second. Soil losses due to erosion, however, were very high for cassava in both cycles, about two to six times higher than those of other crops grown during the same four year period. Thus, under the soil and climatic conditions of Thailand is seems that cassava indeed causes a lot more erosion than other crops.

In a similar comparative study conducted on 5% slope in Tamanbogo, Lampung, Indonesia, cassava again caused higher levels of erosion than any of the other food crops, but the differences were much smaller than in Thailand, partially because the soils in Tamanbogo are less erodible than in Sri Racha, Thailand, and partially because the longer wet season in Tamanbogo allowed the planting of two short-cycle food crops per year, *versus* usually only one crop in Thailand. Similar to data presented by Wargiono *et al.*, (1997), **Table 5** shows that erosion in cassava was considerably higher than in other crops when no fertilizers were applied, but only slightly higher than other crops when each crop was adequately fertilized. The consecutive planting of two peanut crops in one year produced the highest net income and lowest levels of erosion, while cassava grown in monoculture produced a low income and serious erosion. For that and other reasons, most farmers in Indonesia plant cassava intercropped with other food crops, which generally increases income and reduces erosion.

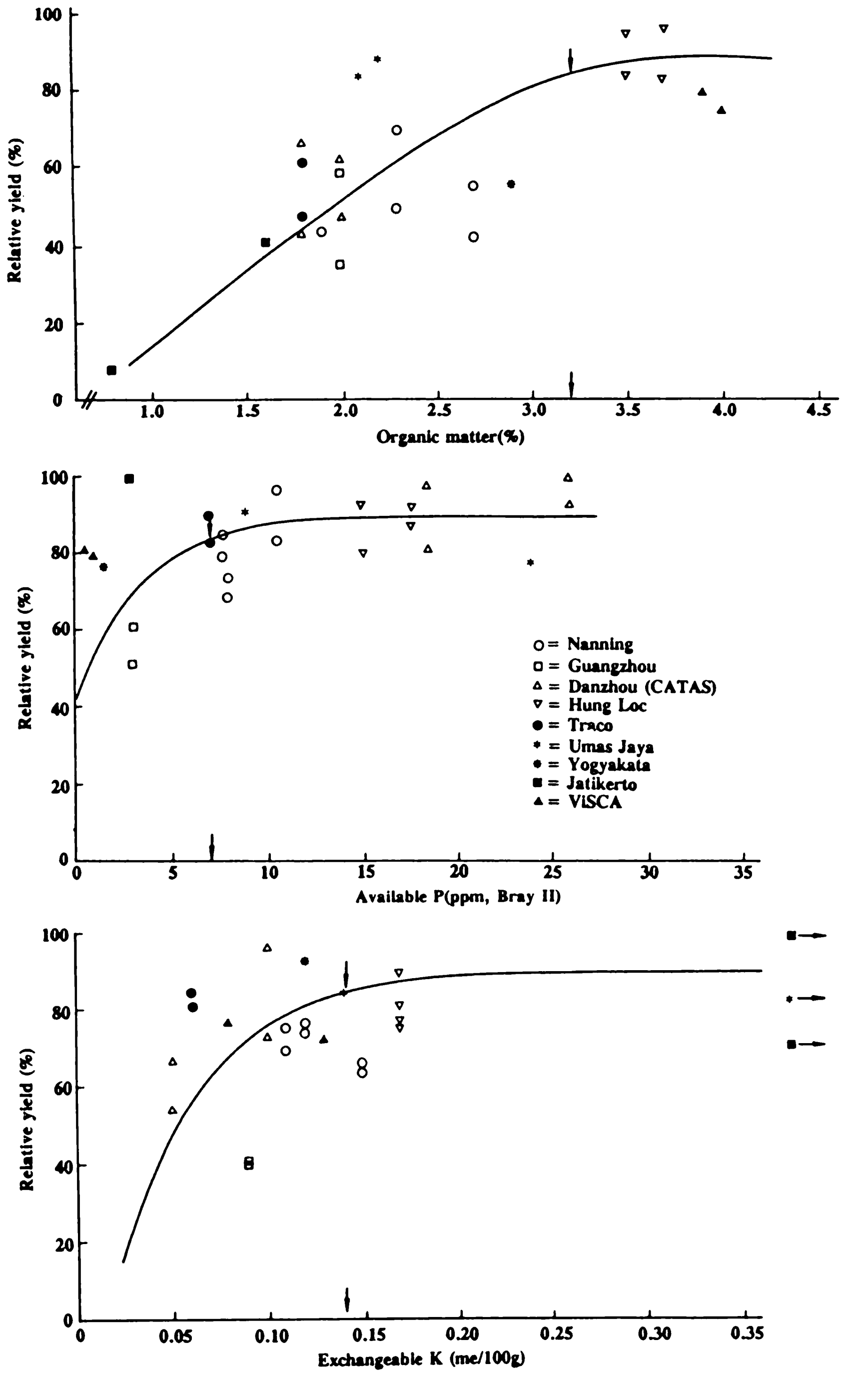

Figure 4. The relation between the relative yield of cassava, i.e. the yield without the nutrient as a percent of the highest yield with the nutrient, and the organic matter, available P and exchangeable K contents of the soil in ten long-term NPK trials conducted in Asia from 1993 to 1996.

Table 2. Effect of intercropping and alley-cropping on the yield of cassava during four years of successive cropping in Hung Loc Agric. Research Center, South Vietnam, from 1992 to 1996.

Treatments[1]	Cassava root yield (t/ha)			
	1992/93	93/94	94/95	95/96
1. Cassava monoculture	19.6	26.0a	25.5a	25.5bc
2. C intercropped with C for forage production	15.7	20.2bc	21.1b	25.5bc
3. C intercropped with C for mulch application	15.1	22.9ab	21.0b	24.4c
4. C alley-cropped with *Tephrosia candida*[2] for mulch	16.1	15.5d	26.1a	27.9ab
5. C intercropped with cowpea[3] for mulch	17.7	23.0ab	22.9a	29.8a
6. C intercropped with *Canavalia ensiformis* for mulch	16.7	24.7a	26.2a	27.2abc
7. C alley-cropped with *Leucaena leucacephala*	16.7	20.3b	24.9a	26.0bc
8. C alley-cropped with *Gliricidia sepium*	16.0	19.0c	25.4a	26.5bc
Fntest	NS	**	**	*

[1] In treatments 2,3,5 and 6 the intercrop was cut and mulched (except T2 which was cut and removed) at 2-3 months after planting; in treatments 4, 7 and 8 the hedgerow species were cut and mulched at planting.
[2] *Tephrosia candida* was intercropped during the first two years
[3] *Centrosema acutifolium* was used as the intercrop instead of cowpea during the first three years

Table 3. Effect of fertilizer application and/or green manuring or mulching of three legume species on the yield of cassava, Rayong 90, planted in Rayong Field Crops Research Center, Thailand, in 1994-1996. Cassava was harvested after either 12 or 18 months.

Treatments[1)]	Nutrients in legumes (kg/ha)			Cassava yield (t/ha)
	N	P	K	
1. Cassava without green manures or mulch, with 156 kg 13-13-21/ha	-	-	-	17.56
2. Cassava+*Crotalaria juncea*, mulched at 2 MAP	45	3.0	28	23.75
3. Cassava+*Canavalia ensiformis*, mulched at 2 MAP	20	2.4	15	26.94
4. Cassava+pigeon pea, mulched at 2 MAP	27	2.2	13	21.39
5. Cassava+*Crotalaria juncea*, interplanted at 7 MAP and mulched[2)]	262	23.7	103	8.75
6. Cassava+*Canavalia*, interplanted at 7 MAP and mulched[2)]	37	4.1	28	22.83
7. Cassava+pigeon pea, interplanted at 7 MAP and mulched[2)]	222	20.5	109	15.86
8. Cassava without green manure; harvested at 18 months	-	-	-	38.86
9. *Crotalaria juncea* green manure; cassava for 18 months	40	3.6	15	46.17
10. *Canavalia ensif.* green manure; cassava for 18 months	18	2.3	16	42.98
11. pigeon pea green manure-cassava for 18 months	26	2.3	13	38.81
12. Cassava without green manures or mulch with 469 kg 13-13-21/ha	-	-	-	29.78

[1)]treatments 1-11 received 156 kg/ha of 13-13-21; in treatments 1-7 and 12 cassava was harvested at 12 months.
[2)]mulched at planting of next crop.

Table 4. Soil loss due to erosion and yield of eight crops grown on 7% slope at Sri Racha Research Station during 1989-1991 (22 months) and during 1991-1993 (27 months).

Crop	Dry soil loss (t/ha)		Yield (t/ha)	
	1st cycle (1989-1991)	2nd cycle (1991-1993)	1st cycle (1989-1991)	2nd cycle (1991-1993)
Cassava for root production	142.77	168.52	22.11[2]	41.93[2]
Cassava for forage production	68.83	138.51	11.79[3]	17.07[3]+33.60[4]
Maize	28.54	35.51	7.81[5]	10.37[5]
Sorghum	42.91	46.14	4.31[5]	9.16[5]
Peanut	37.60	36.23	4.42[5]	4.07[5]
Mungbean	70.92	55.29	2.13[5]	3.09[5]
Pineapple	31.37	21.31[1]	69.00[6]	12.54[6]
Sugarcane	-	93.99	-	75.08[7]

[1] = ratoon crop
[2] = fresh roots (2 crops in each cycle)
[3] = dry weight of leaves + soft stem
[4] = fresh roots at final harvest
[5] = air dry grain; maize, sorghum, peanut: 2 crops in 1989-1991, 3 crops in 1991-1993; mungbean: 3 crops in each cycle
[6] = fresh fruit, second cycle is ratoon crop
[7] = fresh stem (planted + 1 ratoon crop)

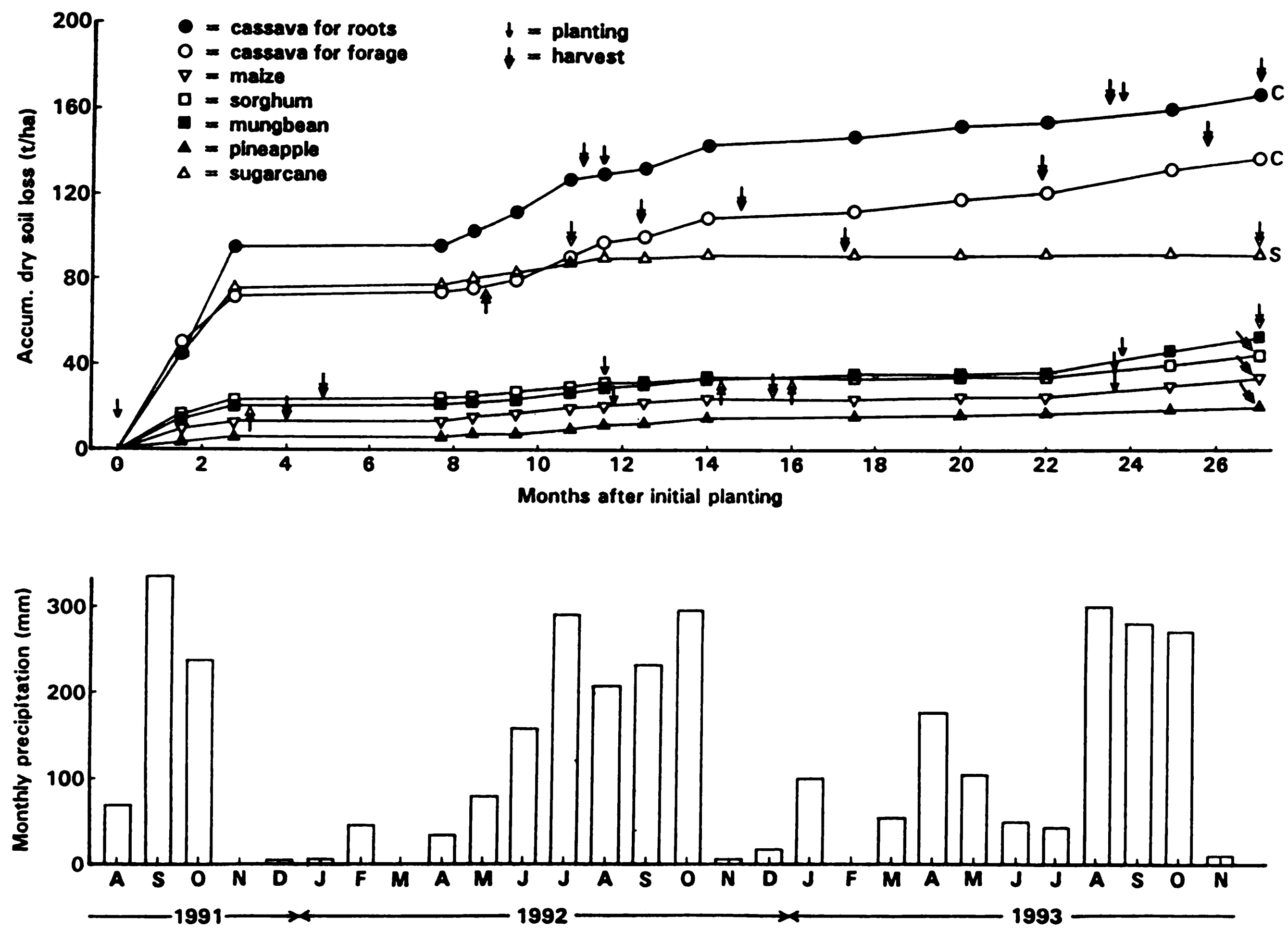

Figure 5. Accumulative dry soil los due to erosion in various crops grown during a 27 month period on 7% slope in Sri Racha, Thailand, from 1991 to 1993. Arrows indicate time of planting and harvest. Rainfall distribution is shown below.

Effect of Varieties on Soil Erosion

Cassava varieties differ in their plant architecture (mainly branching habit), height and early vigor, which all have an effect on the rate of canopy closure and thus on soil erosion. Canopy closure and early vigor, however, can also be affected by management practices, particularly fertilization and plant spacing. To determine the effect of both plant architecture and management practices on soil erosion, four cassava varieties of distinct plant architecture were planted with three management treatments, i.e. with fertilizers at either wide (1.0x1.0 m) or close (0.8x0.8 m) plant spacing, or without fertilizers at close spacing. **Table 6** shows the average results for three years of cropping. As expected, the highly-branched variety, Rayong 3, had low early vigor, resulting in slow canopy closure and low yield, but, surprisingly, this had no significant effect on erosion. The erect non-branching variety, Hanatee, had rather good canopy cover, also a low yield, but a similar level of erosion as the higher yielding, intermediately branched varieties, Rayong 1 and Rayong 90. Thus, intrinsic varietal characteristics, such as branching habit seems to have little effect on soil loss due to erosion. However, application of fertilizers reduced erosion significantly, from 10.0 to 6.8 t/ha. Closer plant spacing markedly increased the degree of canopy cover and increased cassava yields of Rayong 1 and Rayong 90, but it actually increased erosion as compared to the wider spacing; this is contrary to most other trials, which generally show that closer plant spacing decreases erosion. It may be concluded that management practices, particularly the application of fertilizers, had a much greater effect on soil erosion that did differences in plant architecture of different varieties.

3. Effect of Soil/Crop Management on Erosion

Management practices, such as date of planting, plant spacing, land preparation, fertilizer application, weeding, and intercropping all may have an effect on plant growth and yield as well as on erosion. Other practices, such as contour ridging, mulching and the planting of contour barriers, are intended mainly to reduce erosion but these also have an effect on yield.

a) *Date of planting*

Preliminary data from Thailand (Tongglum *et al.*, 1997) indicate that planting during the early dry season (Oct-Dec) markedly reduced erosion compared with planting in the early wet season (April), because heavy rainfall in the early growth stage caused severe erosion in the latter treatment. Planting in the early part of the dry season not only resulted in low erosion but also in high yields, while weeding costs could be reduced. These data need to be confirmed, but may point to several advantages of planting cassava in the early dry season instead of the common practice of planting at the onset of the rainy season.

Table 5. Effect of various crops and cropping systems on dry soil loss due to erosion and on net income during an 8 month cropping cycle on 5% slope in Tamanbogo, Lampung, Indonesia. Data are average values for two years (1994-1996).

	Dry soil loss (t/ha)	Net income[1)] ('000Rp/ha)
Without fertilizers		
Cassava	41.92	322
Rice-soybean	26.29	570
Maize-maize	30.64	159
With fertilizers		
Cassava	29.06	804
Rice-soybean	24.31	1477
Maize-maize	24.98	892
Peanut-peanut	17.92	2488
Soybean-soybean	27.61	2031
Cassava+maize+rice+soybean	19.60	1301

[1)]Net income = total crop value minus fertilizer costs.

b) *Contour ridging*

Erosion control trials conducted for many years in Jatikerto, Indonesia (Wargiono *et al.*, 1995; 1997), in Nanning, China (Zhang *et al.*, 1997) and in Bac Thai, Vietnam (Nguyen Huu Hy *et al.*, 1997) have clearly shown that contour ridging is an very effective way to reduce erosion. This generally also results in increased yields; however, yields can also be depressed if cassava is planted during a dry period when ridging may reduce soil moisture, thus effecting germination, or when too much run-off water is retained behind the ridges resulting in waterlogging.

c) *Fertilizer application*

The application of fertilizers when cassava is grown on low-fertility soils, generally stimulates early plant vigor, increases the rate of canopy closure, which protects the soil from the direct impact of raindrops and thus reduces erosion; at the same time, it increases cassava yields. This was one of the most effective ways to reduce erosion in Nanning, China (Zhang *et al.*, 1997); in Jatikerto, Indonesia (Wargiono *et al.*, 1997); in demonstration plots in Bac Thai, Vietnam (Nguyen The Dang *et al.*, 1997); and on farmers' fields in Rayong province of Thailand (Tongglum *et al.*, 1997).

d) *Intercropping*

Intercropping with peanut or black bean has been shown many times to reduce erosion in China, Vietnam, Indonesia and Thailand. Similarly, intercropping with upland rice and maize, followed by mungbean, soybean or peanut, as practiced in Indonesia, usually reduces erosion compared to cassava monocropping (Wargiono *et al.*, 1997). Intercropping cassava with low-growing economic crops that cover the soil surface quickly, like watermelon, cucumber, muskmelon or pumpkin, significantly reduced erosion and increased the total gross income (Tongglum *et al.*, 1997).

e) *Covercrops*

The planting of a permanent legume cover crop, such as *Mimosa envisa*, under cassava was tested in Jatikerto, Indonesia; it was found to be quite effective in reducing soil erosion, but the cover crop also competed strongly with cassava resulting in low yields (Wargiono *et al.*, 1997). This would generally not be acceptable to farmers.

f) *Mulch application*

Application of mulch of dry grass, rice straw or maize residues among cassava plants as a way to reduce erosion has not been studied extensively in Asia, since cutting and carrying grass mulch is usually considered too time consuming, while crop residues are generally used as feed or bedding for farm animals. Still, during several years of testing in Baybay, Leyte, in the Philippines, the use of grass mulch was found to be the most effective among various treatments in reducing erosion, while also increasing cassava yields (Evangelio *et al.*, 1995). *In situ* production of mulch, such as the intercropping with legume species, like *Crotalaria juncea, Canavalia ensiformis* and pigeon pea, which are cut and mulched at about 2 MAP, is another alternative. This treatment had no significant effect on soil loss or yield in Nanning, China (Zhang *et al.*, 1997). but increased yields in Thailand **(Table 3)**

g) *Alley cropping with leguminous tree species*

Planting contour hedgerows of leguminous tree species, such as *Leucaena leucocephela, Gliricidia sepium, Flemingia congesta* and *Tephrosia candida* among food crops are intented mainly to improve the soil's chemical and physical characteristics when branches and leaves are lopped-off regularly and mulched between crop plants. In Jatikerto, Indonesia, these treatments markedly increased cassava yields (Wargiono *et al.*, 1997), but in Khaw Hin Sorn, Thailand, this had no beneficial effect on yield **(Table 7)**; in the latter location, hedgerows of *Crotalaria juncea* or pigeon pea were slightly better in this respect. In both locations these hedgerows were quite effective in reducing erosion, either by slowing the flow of run-off water down the slope, by the application of mulch of leaves and branches which protect the soil from rainfall impact while improving cassava canopy cover (at least in Indonesia), or by permitting only contour land preparation, which, over time, results in terrace formation.

h) *Contour barriers of grasses*

The planting of contour hedgerows of grasses, such as vetiver grass (*Vetiveria zizanioides*), lemon grass (*Cymbopogon citratus*), citronella grass (*Cymbopogon nardus*), or elephant grass (*Pennisetum purpureum*) are generally intended to reduce erosion by slowing the flow of run-off water. However, they may reduce yields by occupying 10-

20% of crop land, as well as by direct competition; or they may increase yields by the retention of soil, fertilizers and water. Planting of contour barriers of elephant grass in Jatikerto, Indonesia, was quite effective in reducing eroison, but generally reduced cassava yields (Wargiono *et al.*, 1995; 1997); it did provide, however, a good source of animal feed. Contour barriers of vetiver grass, were found to be very effective in reducing erosion, both in Nanning, China (Zhang *et al.*, 1997) and in Khaw Hin Sorn, Thailand (**Table 7**). While they actually increased cassava yields in Nanning. Once well-established, vetiver grass forms a dense hedge that reduces the speed and spreads the flow of water down the slope, allowing soil sediments to deposit behind the hedge and water to infiltrate into the soil. When regularly cut, the vetiver grass leaves are also a good source of *in-situ* mulch to be spread between cassava plants. This seems to be one of the most promising methods to control soil erosion when cassava is grown on slopes; it was also the method most preferred by farmers participating in Farmer Participatory Research (FPR) trials in Vietnam (Nguyen the Dang *et al.*, 1997) and Thailand (Vongkasem *et al.*, 1997); intercropping with citronella was found to be rather effective in controlling erosion in Malaysia (Chan *et al.*, 1994).

Thus, although cassava seems to cause more erosion than many other food crops there are many ways to reduce erosion in cassava-based cropping systems, each having certain advantages and disadvantages (Howeler, 1995). Which method is the most suitable for a particular situation depends very much on the local bio-physical and socio-economic conditions, as well as on the farmer's traditional practices. Instead of recommending one particular practice throughout the country or region, farmers should be shown a range of practices and they should be encouraged to try out several of these in FPR trials on their own fields before deciding on the best practice for their own conditions. Once farmers themselves have developed an effective erosion control package of practices, they are more likely to adopt these on a larger scale on their own production fields.

Table 6. Effect of plant type and management treatments on canopy cover, root yield and soil loss due to erosion when four cassava varieties were grown on 5% slope in Pluak Daeng, Rayong province of Thaiand. Data are average values for three years (1991-1994).

Variety	Plant type	Canapy cover (%)[1]				Root yield (t/ha)				Total dry soil loss(t/ha)			
		T_1[2]	T_2	T_3	Av.	T_1	T_2	T_3	Av.	T_1	T_2	T_3	Av.
Rayong 1	erect, late branching	44	65	53	54	14.6	17.2	11.0	14.3	4.5	4.8	13.6	7.7
Rayong 3	prostrate, profuse branching	44	56	39	46	10.0	10.5	6.1	8.9	6.8	6.3	7.4	6.8
Rayong 90	prostrate, early primary branch	45	63	53	54	14.8	16.5	13.4	14.9	5.8	6.0	12.4	8.1
Hanatee	erect, no branching	50	59	48	52	12.6	12.1	8.5	11.1	5.3	10.1	6.5	7.3
Average		46	61	48	52	13.0	14.1	9.8	12.3	5.6	6.8	10.0	7.5

[1] Average of 7 measurements per year

[2] T_1 = with fertilizers (312 kg/ha of 15-15-15); 1.0 x 1.0 m plant spacing
T_2 = with fertilizers (312 kg/ha of 15-15-15); 0.8 x 0.8 m plant spacing
T_3 = without fertilizers ; 0.8 x 0.8 m plant spacing

Table 7. Effect of various soil/crop management treatments on cassava yield and erosion in cassava grown on 5% slope in Khaw Hin Sorn, Prachin Buri, Thailand, in 1995/96.

Treatments	Cassava root yield (t/ha)	Cassava top yield (t/ha)	Dry soil loss (t/ha)
1. Cassava monoculture, no barriers	32.53	22.67	10.01
2. Cassava monoculture, vetiver (native) hedgerows[1)]	25.65	16.40	3.60
3. Cassava monoculture, vetiver (Sri Lanka) hedgerows[1)]	25.65	13.28	3.40
4. Cassava monoculture, *Crotalaria juncea* hedgerows[1)]	25.94	15.47	7.92
5. Cassava monoculture, pigeon pea hedgerows[1)]	27.48	18.45	7.75
6. Cassava monoculture, *Leucaena leucocephala* hedgerows[1)]	23.99	14.83	7.61
7. Cassava monoculture, *Gliricidia sepium* hedgerows[1)]	21.17	12.27	6.04
8. Cassava (Rayong 1) intercropped with cassava (Rayong 60)	27.39	26.32	10.07

[1)] The hedgerows occupied about 20% of the total area, resulting in lower yields.

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FARMER PARTICIPATORY ADAPTATION AND ADOPTION OF CONTOUR HEDGEROWS FOR SOIL CONSERVATION

Sam Fujisaka[1]

ABSTRACT

From 1987 through 1992 a team of on-farm researchers worked at Claveria in northern Mindanao to improve the productivity and sustainability of the local upland rice and maize-based agroecosystems. Adaptive research goals were to improve crop productivity, control soil erosion, and improve nutrient cycling. A "strategic" goal was to develop methods by which research programs could work with farmers to develop locally appropriate and adoptable innovations. We used contour hedgerow systems as a general technology to control soil erosion; worked with farmers on their adaptation of the technology; and eventually our results included lessons for farmer-participatory research, technology development, and technology transfer.

INTRODUCTION

Soil erosion and soil nutrient depletion are major problems in cultivated upland areas in southeast Asia. Agroforestry technologies developed to address these problems include vegetative strips to reduce soil erosion on sloping lands and use of legume tree biomass to improve soil nutrient cycling (Huxley, 1986; Kang and Wilson, 1987; and Young, 1986, 1987). Innovations, however, have not been widely adopted because of technical problems and lack of fit with farmers' circumstances. With a goal of increasing the local appropriateness and, therefore, adoption rates of such technologies, recent approaches have actively involved farmers in the development of such conservation technologies (Fujisaka, 1989a; Getahun and Njenga, 1990; Pahlman, 1990; Raintree and Hoskins, 1988; Roucheleau, 1987; and Scherr, 1991).

This paper describes a case in which farmers adapted a "knowledge-intensive" technology of contour hedgerows to fit their needs and local circumstances. Contour hedgerows harness erosive forces (plowing and rainfall runoff) to naturally form terraces. The technology is appropriate for areas with sloping land, use of tillage, intense rainfall, and land scarcity.

Researchers from the International Rice Research Institute (IRRI) and the Philippines' Department of Agriculture facilitated farmer-to-farmer training and farmers' adaptation of contour hedgerows in Claveria, Misamis Oriental province. Claveria farmers were able to: 1. modify hedgerow establishment methods in order to substantially reduce labor requirements (Fujisaka, 1993); and 2. select locally suitable species for use in the hedgerows (Fujisaka *et al.*, 1994).

LOCATION AND METHODS

Claveria is an on-farm research site located at 390 to 550 m above sea level. A

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mean of about 200 t/ha/year of soil are lost from slopes given that rainfall is moderate to high and about 59% of the cropping occurs on land with >15% slope. Average rainfall is 2200 mm/year, with 5 to 6 wet months (July-Dec >200 mm/month) and 2 or 3 drier months (<100 mm/month). Soils are classified as oxic Dystropepts, ranging from clays to silty clay loams; these are acidic (pH 4.5-5.8) with low available P (1.3-4.7 ppm), low CEC (6-12 me/100g), medium to high Al saturation (11-51%), and moderate organic matter (3.16%) and exchangeable K (113.1 ppm).

Farmers settled in the area in the 1950s following deforestation by logging and used some of the resulting grasslands for large-scale cattle ranching in the 1960s and 1970s. Agriculture is now semi-permanent with all lands *de facto* or *de jure* owned; some land fallowing is practiced; and lands are prepared by oxen-drawn plow. Main crops are traditional and improved maize, traditional and improved upland rice, cassava, and, on smaller plots, tomato for commercial sale. Farmers adopting contour hedgerows grow these same crops in the alleys formed between hedgerows.

Farmer-to-farmer procedures were used to introduce contour hedgerows to Claveria farmers (Fujisaka, 1989b). In 1987, six farmers who reported yield declines due to soil erosion and two IRRI technicians learned from farmers in the non-government World Neighbors project in the neighboring island of Cebu how to use an A-frame to establish contour lines, construct contour bunds and ditches, and plant hedgerows. The "original" hedgerows were comprised of one or two rows of the leguminous tree *Gliricidia sepium*, and one or two rows of Napier grass, *Pennisetum purpureum*.

These farmers and later adoptors trained more than 200 farmers from 1987 through 1991 using the farmer-to-farmer techniques applied in Cebu. Approximately 80 Claveria farmers adopted some form of contour hedgerows by late 1992. Researchers at the site recorded field areas and slope, length of hedgerows, area occupied by hedgerows, heights of embankments formed over time, labor used for establishment, farmers' technical changes and adaptations, and effectiveness of methods. Open-ended interviews were used to obtain farmers' perceived benefits, associated problems, and evaluations of technology components. Slopes of alleys (areas between hedgerows) were calculated based on measurements of the embankments, assuming that hedgerows were placed at 1 m vertical intervals.

Fifty-five of the adoptors were again interviewed and their 60 hedgerow fields monitored at the end of 1992. Many later adoptors (within the 1987-92 period) relied--solely or combined with other species--upon naturally occuring "weeds" in their hedgerows. We identified these in each of 57 fields (three fallowed fields were not included). Forty-six of the fields with hedgerows utilized at least some weeds. For each of these fields and during the main cropping season, ten 10-meter lengths of hedgerow were randomly selected across each field; the five weed species with the greatest number of individuals were identified, with actual counting done if there was any doubt as to which weeds were the most frequent. "Main" weeds presented include any listed as one of the five most frequent in any of the 57 fields monitored. Weed species encountered in the natural hedgerows were compared to major weeds in upland rice and maize identified by farmers in an earlier study.

Farmers also evaluated the contour hedgerows. We asked, "How do you now evaluate your contour hedgerow system?" The question was intentionally open-ended to allow answers reflecting what was important to each individual, e.g. hedgerow functions, problems, and/or species choice. No specific or further prompts were used. Each response is presented in terms of its percentage of the total number of answers given.

Farmers who did not adopt the technology after farmer-to-farmer training were interviewed about reasons for non-adoption. Slopes of the lands of adoptors and non-adoptors were measured and compared.

Crop yields on farmers' fields with and without contour hedgerows were monitored in the wet season of 1991, a severe drought year, by taking crop samples. Other data on yields and on soil erosion rates with and without contour hedgerows were provided by other researchers working at the site.

RESULTS

Contour Hedgerow Adoption in Claveria

By the end of 1990, each of 75 adoptors in Claveria contoured a mean of 0.7 ha and established 761 m of hedgerow per field. Mean slope of fields was 22%. On average, hedgerows occupied 9% of the field areas on which they were established. Because farmers placed one hedgerow per meter of vertical drop within a field, length of hedgerows per ha increased as initial field slope increased, with a corresponding increase in labor required, although this was influenced by evolving hedgerow establishment methods.

Terracing took place rapidly after hedgerow establishment. For nine fields established in 1987, mean heights of hedgerow embankments were 36 cm after one year, 44 cm after two years, and 49 cm after three years, indicating that slopes of alleys decreased from an initial mean field slope of 16% to 9% after one year, 8% after two years, and 7% after three years. Furthermore, 75% of the embankment formed after three years had already formed in the first year, suggesting that alleys reached relatively stable slopes after one year. Height of terrace embankments in front of the hedgerows tended to increase as slope increased.

Farmer Modification of Hedgerow Establishment Methods

Working as a group, farmers established hedgerows on 10 parcels of land having an average size of 0.8 ha in the first year. Labor for establishment (average 29 days/ha with 55% for shoveling) and hedgerow density (673 to 1555 m/ha) depended on field slope and resulting variation in distances between strips. Farmers established 17 to 57 m/person/day of hedgerow; labor to establish hedgerows was least on fields already plowed after initial rains and greatest on grassy fallowed fields on which hedgerows had been established prior to the rains.

In 1987 farmers spent an average 14 hours per 100 meters of hedgerow established, and 29 days of labor per ha on which hedgerows were placed. By 1990 farmers needed only 8 hours per 100 meters and 16 days per ha **(Table 1)**. The original hedgerow establishment method consisted of using the A-frame to determine contour lines, double plowing to create a bund, shovel work to reinforce bunds, and planting of a double row of trees plus a single row of grasses. Farmers saved labor by reduced plowing, virtual elimination of shovel work, planting of either trees or grasses rather than combinations, or--by 1989 and 1990--the staking of contour lines (usually but not always bunded), which were then left to be covered by "weeds" or native grasses (discussed below). There were no differences among farmers' various hedgerow establishment methods in terms of embankment formation and terracing, but establishment labor per ha also decreased with increasing field size, suggesting some "economy of scale".

Table 1. Farmer contour hedgerow adoption and labor used for hedgerow establishment, Claveria, Misamis Oriental, Philippines, 1987-1990.

	1987	1988	1989	1990
Number of adoptors	14	13	29	6
Mean labor (hrs) per 100 m of hedgerow	14	14	10	8

Farmers' Evolving Hedgerow Species Choice

Following what they learned from farmers in Cebu, initial adoptors in 1987 and 1988 planted hedgerows largely of *Glyricidia sepium* and *Pennisetum purpureum*. Farmers gradually shifted species in the hedgerows. Those adopting in 1989 planted mulberry and *Flemingia congesta* in addition to *G. sepium*; and planted *Setaria* spp and *Panicum maximum* (Guinea grass) in addition to *P. purpureum*. Farmers also started to develop contour hedgerows of purely natural vegetation in 1989. In 1990 and 1991, new adoptors planted mainly *Setaria* or Guinea grass, or developed hedgerows of weeds. Other less used species included *Chloris* sp (signal grass), *Stylosanthes* spp, *Helianthus annuus* (wild sunflower), "ginseng" (an unidentified medicinal plant), cassava, taro, coffee, and fruit trees.

Table 2 shows the species planted (or utilized in the case of natural weed contour hedgerows) in the hedgerows by year of establishment (1987-1992). Entries per column total more than the number of fields as more than one species were often planted or utilized. By the end of 1991 and for 60 fields belonging to 55 hedgerow adoptors: 47% included *G.sepium*, 38% included *P.purpureum*, 32% included *Setaria* spp, 20% included *P.maximum*, 17% included mulberry, and 18% were of weeds alone. Adoption of *G.sepium* and of *P.purpureum* decreased; and adoption of *Setaria*, *P.maximum*, and weed strips increased over the study period. Mulberry adoption was high only in 1989. For the 15 of 60 fields established in 1990 and 1991, only one included trees (mulberry), 8 fields had planted grasses, and 7 had weeds alone. Farmers evaluations of their different hedgerow species are shown in **Tables 3** and **4**.

Farmers had several sources of seed or planting material. They used cuttings of locally indigenous *G.sepium*, *P.purpureum* and *H.annuus*. Seed of *F.congesta* came from a stand of trees planted by a farmer several years prior to our work in the area. IRRI conducted trials on forage species and small quantities of seed of *Chloris* sp, *Stylosanthes* spp, and *P.maximum* were given away upon request. Others later obtained seeds of these forages from the first farmers planting them in hedgerows. Mulberry cuttings came from a 10 ha area where trees had been planted in the mid-1980s for a government silkworm project. Farmers had tried to eradicate the mulberry; and their lack of success meant that there was ample planting material when farmers were again induced to rear silkworms. Although farmers had free access to researchers' forage trials, their selection and testing reflected their own search for useful and suitable hedgerow species.

The main species found in the contour hedgerows utilizing natural, *in situ* weeds (and in hedgerows combining both planted species and weeds) were *Pennisetum polystachion* (in 67% of 57 fields with hedgerows), *Paspalum conjugatum* and *Borreia laevis* (58% each), *Ageratum conyzoides* (44%), *Chromolaena odorata* (42%), *Digitaria longiflora* (37%), *Mimosa invisa* (32%), *Rottboellia cochinchinensis* (25%), *Hyptis suaveolens* (25%), and *Imperata cylindrica* (23%). Twenty-two other weeds occured as a main weed in farmers' hedgerows, but each of these in less than 10% of the hedgerows. Only 11% of fields had hedgerows with no natural grasses or weeds **(Table 5)**.

A previous study (Elliot and Moody, 1986) elicited farmers' worst weeds in terms of effort needed to control each one. These were, in order, *R.cochinchinensis*, *D.longiflora*, *P.polystachion*, *B.laevis*, *M.invisa*, *I.cylindrica*, *P.conjugatum* and *Brachiaria mutica*. These same problem weeds--and especially creeping weeds such as *D.longiflora* and *P.conjugatum*--have provided a good alternative for farmers interested in soil erosion control and in reducing hedgerow establishment costs, but not interested in other supposed "multipurpose" uses (i.e., fodders, green manures, or cash crops such as coffee or fruit trees) of hedgerow species. Farmers knew that they needed to slash the weedy hedgerows before seeding in order to avoid creating additional weed problems in their crops.

Table 2. Species planted by farmers in contour hedgerows established on 60 fields in 1987-1991, in Claveria, Misamis Oriental, Philippines.

	Year established					% of all
	1987 (n=8)	1988 (n=13)	1989 (n=24)	1990 (n=13)	1991 (n=2)	hedgerows w/species
Gliricidia sepium	8	12	8	0	0	47
Cassia spectabilis	1	2	1	0	0	7
Flemingia congesta	1	2	3	0	0	10
Mulberry	0	2	7	1	0	17
Pennisetum purpureum	6	10	5	2	0	38
Setaria spp.	2	4	6	7	0	32
Panicum maximum	1	1	4	5	1	20
Pineapple	1	2	1	1	0	8
"Weeds" alone[1/]	0	1	3	6	1	18

Note: farmers also planted *Chloris* spp, *Stylosantes sp*, wild sunflower, "ginseng" (unidentified), and a few coffee and gwelina trees into hedgerows.

[1/] Many hedgerows with planted species also included weeds.

Table 3. Farmer evaluations of napier grass (*Pennisetum purpureum*) and *Gliricidia sepium* planted in hedgerows, in Claveria, Philippines in 1990.

	Number of farmers
Pennisetum purpureum	
Positive evaluations	
Controls soil erosion	15
Provides animal feed	11
Grows easily	4
Competition not a problem if maintained	1
Negative evaluations	
Crops near hedgerows were stunted and yellowed	11
Competitive and too vigorous	6
Roots spread into alleys and make plowing difficult	3
Deteriorates with constant pruning	2
Shelters rats	1
Total	54
Gliricidia sepium	
Positive evaluations	
Source of organic fertilizer	16
Improves the soil and gives a higher yield	1
Provides feed for animals	1
Reduces soil erosion	1
Negative evaluations	
Caused shading if not maintained	1
Difficult to plow when roots spread to the alley	1
Total	21

Table 4. Farmer evaluations of other contour hedgerow species in Claveria, Philippines.

	Number of farmers
Mulberry prevents soil erosion and provides income	13
Will extend mulberry hedgerows to other parcels	2
Flemingia congesta does not compete with the alley crop and is easy to maintain	1
Grasses control soil erosion and provide fodder	5
Grasses hold the soil better than trees	2
S.guyanensis is good, but competes with crops	1
Andropogon sp is good, but spreads into the alley	1
Roots of *Desmanthus virgatus* do not hold the soil	1
Pineapple holds the soil and provides cash and food	2
Taro holds the soil and provides cash and food	1
Sunflower holds the soil, provides green manure, but can be a weed problem	1
Total	30

Adoptors' Evaluations of the Technology

Ninty-six percent of the 55 adoptors interviewed in 1992 viewed hedgerows as a way to control soil erosion **(Table 6)**. Almost half (45%) mentioned production of fodder--especially in the dry season--for their draft animals as a desirable function of the hedgerows. Fifteen percent reported that biomass from *G.sepium* could be used as a green manure for the alley crop, although only three cases during one rice growing season (1991) of biomass use for green manure were observed. The same percentage of farmers thought that inorganic fertilizers could be applied to their alley crops without being washed downslope by rains. A few farmers reported that natural grass strips were easy to maintain (and survived drought periods better than introduced grasses); while others thought that hedgerow pruning and deep plowing in the alley solved the problem of crop-hedgerow competition.

On the other hand, 35% of the farmers reported that hedgerows--especially those with grasses such as *P.purpureum*--competed with the crop grown in the alley. Our observations made it clear that rice and, to a lesser degree, maize were very affected by such competition for moisture and soil nutrients (and light in the case of trees in the hedgerows). Competition between hedgerow and crop led to farmer testing and selection of species (including weeds) other than the orignal *P.purpureum*.

Almost a third (31%) of the farmers found it necessary to fallow land on which they had established contour hedgerows due to combinations of soil nutrient depletion and competing demands and higher opportunities from their flatter lands and from off-and non-farm income sources. Continued fallowing of adoptors' fields was noteworthy because researchers had regarded contour hedgerows as a possible way to sustain permanent cropping. Some landowners fallowed parcels on which they had established contour hedgerows, and then selected and became tenant farmers on other parcels--in a unique form of shifting cultivation.

Fallowed fields have traditionally been an open-access grazing resource in Claveria. Neighbors' staked or freely grazing animals were mentioned as a problem by 18% of the hedgerow adoptors. We observed that grazing was especially a problem in cases in which forage species preferred by animals were planted in the hedgerow. Destruction of hedgerows by neighbors' cattle is a "social" problem in that the solution would require community or group cooperation and action.

About a fifth of the farmers planted mulberry trees in their hedgerows after a silkworm project was started in the area. By 1992, however, the project was no longer in business and 16% of the adoptors thought that mulberry was useless without the project.

Non-Adoptors

Farmers who did not adopt hedgerows after attending farmer-to-farmer training sessions gave their reasons. These were lack of labor or draft animals or competing demands for labor on non-sloping areas for farmers with large proportions of such lands or for off-farm and non-farm activities **(Table 7)**. Although a few non-adoptors mentioned that their tenant status barred adoption, about 16% of adoptors were share tenants.

In light of non-adoptors' responses, adoptors' and non-adoptors' land sizes and slopes were measured. Differences between total land holdings and between percent slopes on sloping lands did not differ significantly between the groups, but a significantly higher proportion of adoptors' lands was sloping (>7% slope) compared to that of non-adoptors' **(Table 8)**.

Crop Performance and Soil Erosion

Yields of maize and rice on farmers' fields with or without contour hedgerows were similar in the wet season of 1991, a year of severe drought **(Table 9)**. The lack of response to hedgerow adoption was not discouraging because hedgerow species are susbtiantally more competitive for moisture than rice or maize in drought periods. Data from researcher designed and managed trials in Claveria also showed that cereal yields were similar with and without hedgerows when leaf prunings from the hedgerows were not applied to the crop, although there was a substantial maize yield increase following incorporation of *Cassia spectabilis* biomass (Mercado *et al.*, 1991).

Soil erosion was monitored by researchers in controlled experiments. In normal rainfall years, approximately 200 t/ha were lost on open slopes and 20 t/ha from fields with contour hedgerows. In the 1991 drought year less soil was lost, but some 40 t/ha were still lost on open slopes and 4 t/ha on fields with contour hedgerows (Garrity *et al.*, 1993).

Table 5. Main "weeds" in 57 contour hedgerows[1/], Claveria, 1992.

Weed species	% of Hedgerows	Worst weeds[2/]
No "weeds" used in hedgerows	11	-
Pennisetum polystachion[3/]	67	3
Paspalum conjugatum	58	7
Borreria laevis	58	4
Ageratum conyzoides	44	-
Chromolaena odorata	42	-
Digitaria longiflora	37	2
Mimosa invisa	32	5
Rottboellia cochinchinensis	25	1
Hyptis suaveolens	25	-
Calopogonium mucunoides	23	-
Imperata cylindrica	23	5
Bidens pilosa	21	-
Digitaria setigera	16	-
Mimosa pudica	14	-
Sida rhombifolia	12	-
Elephantopus tomentosus	12	-
(*Brachiaria mutica*)	(2)	(7)

[1/] Three fallowed or abandoned contour hedgerow fields not included.

[2/] Eight most difficult to control weeds in farmers' order.

[3/] "Main" weeds were among the five most frequently occurring in the given % of hedgerows; 22 other species were each one of the five highest occurring, but each in less than 10% of the hedgerows.

Table 6. Farmers[1] evaluations of contour hedgerows established in 1987-1991, in Claveria, Misamis Oriental, Philippines.

Evaluation	% of farmers
Postitive[2]	
Hedgerows control soil erosion	96
Hedgerows provide fodder	45
G.sepium provides green manure	15
Inorganic fertilizer can be applied and not lost downslope	15
Natural grasses are easy to maintain	9
Negative[3]	
Hedgerows (especially grasses) compete with crop	35
Fallowed due to poor soil, flatter lands, off/non-farm work	31
Neighbors' animals graze and destroy hedgrows in dry season	18
Mulberry serves no purpose without silkworm project	16

[1] n=55

[2] Other positive evaluations: *Setaria* is good for erosion control and fodder; hedges are not crop-competitive if pruned and plowing in the alley is deep; and *G.sepium* can be used for fence stakes

[3] Other negative evaluations: crop stunted in upper rows due to soil scouring; pruning hedgerows required too much labor; contours on uneven slopes mean uneven alley widths, which are difficult to plow

Table 7. Trained farmers' reasons for non-adoption of contour hedgerows (140 observations).

	No. of observations
Work demands on non-sloping or lowland parcels	40
High labor for contour hedgerow establishment	27
Off-farm and non-farm work opportunities	18
Lack of draft animal	16
Lack of capital for labor and inputs	12
Left the area	10
Does not own the land	7
Miscellaneous	10
Total	140

Table 8. Areas and slopes of lands of adoptors and non-adoptors of contour hedgerows in Claveria, Philippines.

	Adoptor	Non-adoptor
Total land area (ha)	1.70	1.68
area of flat land (ha)	0.43	0.79
area of sloping land (ha)	1.27	0.89
% slope of sloping land	21	25

Table 9. Farmers' yields of rice and maize (t/ha) of fields with and without contour hedgerows in Claveria, Philippines, wet season 1991 (number of cases in parenthesis).

	With hedgerows	Without hedgerows
Rice	0.68 (6)	0.77 (16)
Maize	1.22 (12)	1.23 (10)

CONCLUSIONS

Findings suggest that a permanent, sustainable contour hedgerow system would have several features.

1. Sufficient soil tillage and rainfall is needed to cause both soil erosion as a problem and to enable natural terracing to take place as a solution.
2. Farmers should have mostly sloping land and a lack of off- and non-farm labor opportunities if they are to invest in their land.
3. The land frontier needs to be closed if farmers are not to shift more profitably to other parcels.
4. Hedgerow species are needed that survive the dry season, do not overly compete with the crop in the alley, and are fairly easy to maintain.
5. Farmers should be able to apply inorganic fertilizers to the alley crops or should have sufficient labor to apply the biomass from perennial legumes planted in the hedgerows to maintain soil fertility.

6. A social system is needed in which community members cooperate in the control of grazing animals in a way that animals are not allowed to graze and destroy hedgerows.

Perhaps more importantly, both researchers and farmers contributed to developing appropriate and adoptable technologies. Researchers facilitated initial farmer-to-farmer technology transfer and monitored farmers' progress in solving problems. Farmers modified the basic technologies--use of the A-frame and vegetative contour strips--in order to save labor and reduce crop-hedgerow competition. Adoptors greatly reduced soil erosion on their sloping lands, but now need to solve the problem of soil nutrient depletion.

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FARMER PARTICIPATORY RESEARCH IN CASSAVA SOIL MANAGEMENT AND VARIETAL DISSEMINATION IN CHINA

Zhang Weite, Lin Xiong, Li Kaimian and Huang Jie[1]

ABSTRACT

This paper mainly describes the objectives of the FPR project, the results of the RRA that was conducted in Hainan and the demonstration plots at CATAS, as well as the demonstration and FPR trials at the pilot sites (especially in Kongba village of Baisha county). The major existing problems and suggestions to improve the FPR trials in the future are also presented.

INTRODUCTION

During the 4th Asian Cassava Workshop in India in 1993, a new project on "Improving the Sustainability of Cassava Production in Asia" was first discussed and the possibility explored of having a pilot site in Hainan, not only because of serious soil fertility and erosion problems in cassava producing areas in the mountains of central Hainan, but also because of the active collaboration between cassava researchers at CATAS with agricultural officers and farmers in the area. This project proposed to use farmer participatory research (FPR) methodologies to improve the development and adoption by farmers of more sustainable management practices.

Objectives of the FPR Project

The objectives of this project are: a) to reconcile the short-term needs of farmers to increase crop yields and income with the long-term objective of preserving the soil's productivity, i.e., to provide benefits to both farmers and society; and b) the essence of this approach is that farmers own the process: they develop the most suitable practices for their own conditions by testing a range of options on their own fields.

Workshop on FPR Methodologies

The Nippon Foundation project organized an FPR training workshop in Rayong, Thailand, in July of 1994, to explain about the importance of the FPR approach, and to develop a work plan of activities for the project in each participating country. Also included were discussions on Rapid Rural Appraisal (RRA) methods as well as practical training in interviewing farmers. During the workshop, the Chinese participants made a work plan for the FPR project in Hainan, as shown in **Figure 1**.

FPR PROJECT IN HAINAN

1. Rapid Rural Appraisal (RRA)

An RRA was conducted in Hainan from August 14 to 20, 1994. The major

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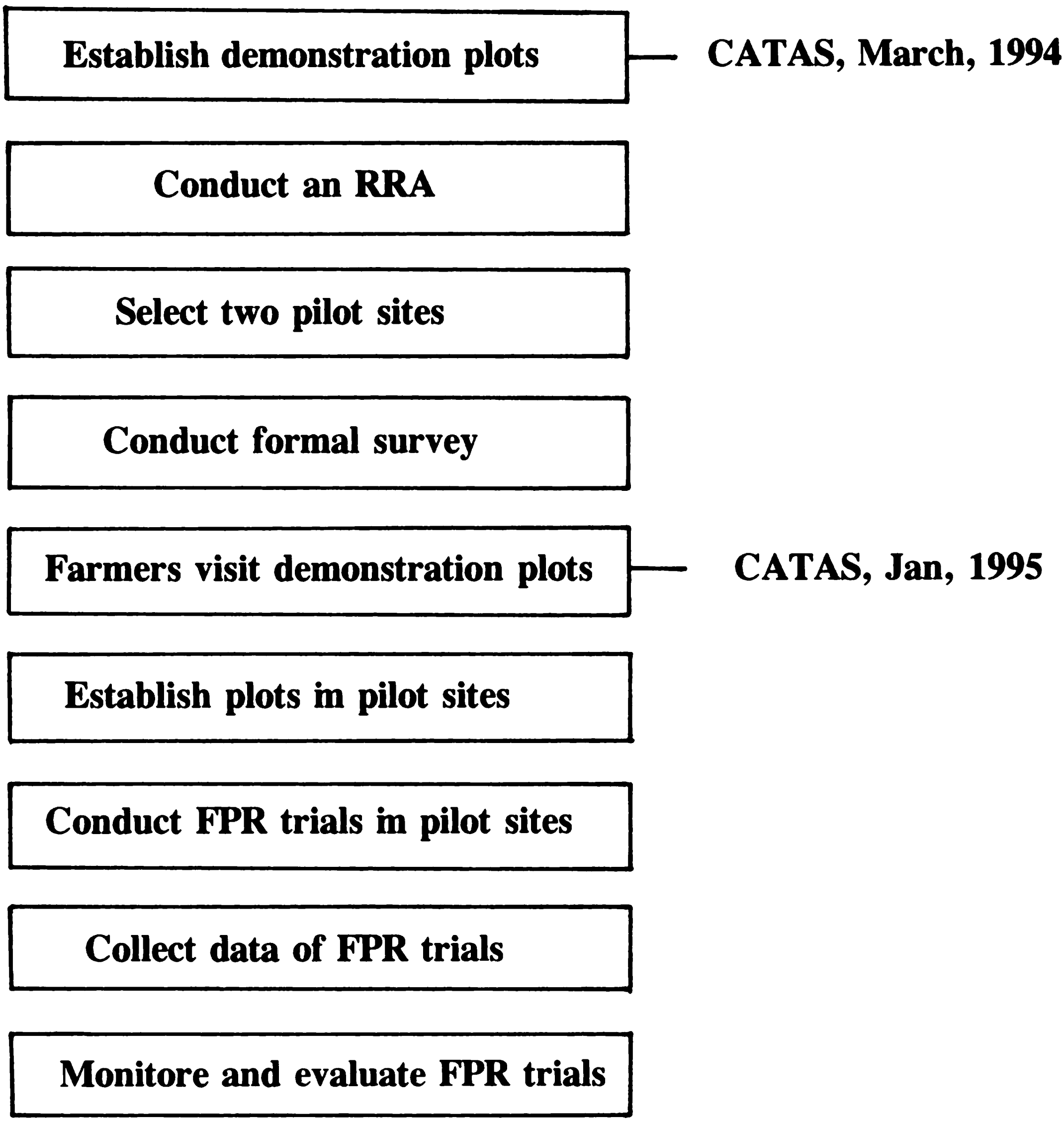

Figure 1. Design of FPR project in Hainan.

objectives of this RRA were:

a) To gain a better understanding of cassava production and utilization in Hainan and to analyze the major constraints and opportunities.

b) To select two pilot sites for the FPR project.

RRA Methodololy

Before conducting the RRA, we discussed the methodology to be used in the group and individual interviews with farmers and the type of information to be collected. The selection of locations to be visited was based on: a) the importance of cassava in the area; and b) the representativeness of the production and/or processing system. As such, based on secondary information, a pre-stratification was attempted as follows: 1) lowland vs. highland areas; 2) near vs. far away from processing factories; 3) collective/state farm vs. "private" farm production.

In most districts or counties we first contacted the local government officials, mainly from the Agricultural Bureau or the Agricultural Committee. They usually provided us with secondary data about climate, soils, landscape etc, and the production of the major crops. We also discussed the problems of cassava production, processing and marketing as well as future opportunities. After talking with the government officials, we were usually taken to a cassava growing village by local extension agents. In each village, we separated our team into two groups. One group would usually discuss socio-economic issues and processing with one group of farmers, while the second group would discuss varieties and cultural practices with another group of farmers; usually, about ten to fifteen farmers were interviewed in each village. Most discussions were held in a farmer's house or in the courtyard in front of the house. Each session lasted about one and a half to two hours. After the discussion we were often taken to a farmer's field, where we could see different cropping systems and evaluate the crops. Sometimes we were taken to steep mountains slopes where cassava was planted, providing an opportunity to ask farmers questions about erosion control and maintenance of soil fertility.

Results of RRA

In recent years, the cassava growing area in Hainan has been about 24,000 ha with a total annual production of 320,000 ton of fresh roots; this corresponds to about 6% of total cassava production in China. In Hainan, cassava production is concentrated in the foothills of the central mountain range, with greatest production in Baisha and Qiongzhong counties (**Figure 2**), In the past decade, cassava production area and yield have fluctuated for several reasons. The decline in cassava area and production in Hainan is mainly due to the aggressive promotion of other more valuable crops, like rubber and fruit trees, as well as the absence of a significant expansion of cassava processing facilities. While in Guangdong and Guangxi cassava further-processing into glucose, MSG, maltose, alcohol and sorbitol is being promoted, in Hainan the processing is still confined mainly to production of raw starch, using rather antiquated processing facilities. However, farmers reported that during the past couple of years the cassava area may have expanded again due to increasing prices as well as problems in the transport of competing sugarcane. In the counties visited, cassava was generally the third or fourth most important crop after rubber, rice and/or sugarcane (**Table 1**).

Hainan has a tropical and sub-tropical climate and is influenced by tropical monsoons and typhoons, but with sunshine all year round. Its annual mean rainfall is 1500-2000 mm, 75-90% of which is concentrated during the rainy season of May to October. Sometimes the precipitation per hour reaches 80-100 mm, which is a major factor causing high levels of soil erosion. The annual mean temperature is 23-25°C. In Hainan, being located between 18 and 20°N, cassava can be planted year-round without danger of frost but with occasional short-term cool temperatures of 4-7°C during the winter months, especially in the northwestern region and the northern part of the central region; however, this does not affect cassava yields. Cassava is planted in Jan-March in most of Hainan, but planting is delayed to March-April in the western part of the island because of drought. Meanwhile, Hainan is the only place in China where cassava pollination and hybridization can be successful.

In Hainan the cropping area per family is similar or slightly larger than in Guangdong and Guangxi, except in Kongba village of Qifeng town where farmers cultivate rather large areas by planting crops also on illegal land with steep slopes. Moreover, in that area most farmers also manage 0.5-1 ha of rubber trees. Thus, time for attending the crops is limited to 4-5 hours a day, usually in the afternoon. This explains the prevalence of cassava monocropping, the less intensive management of the crop and the use of herbicides in some locations.

Table 2 shows that cassava is grown mainly on gentle slopes with some production on very steep slopes (up to 100%), especially in Tongzha city. Cassava in Hainan is seldom grown on terraced fields except on State Farms; in contrast, rubber is often planted on narrow terraces in the mountains. Cassava is generally planted as a monocrop, although some intercropping with maize or peanut, or with maize plus sweet potato was found; in some places the crop is also rotated with sugarcane. In Baisha and Tongzha counties cassava is sometimes grown between young rubber or fruit trees.

Where cassava is grown on steep hillsides, the land is usually prepared only by making individual planting holes of 10 x 20 cm with a hoe, after slashing and burning the weed or bush vegetation (**Table 3**). On more gentle slopes the land is prepared by buffalo or oxen, usually 1-2 plowings followed by 1-2 rakings. Ten to twenty cm long stakes are planted horizontally 6-10 cm deep in each planting hole, spaced at random or at 0.6 x 0.6 or up to 0.8 x 0.8 m. Plant populations are very high and farmers think that this may be useful for reducing soil erosion. Depending on the type of previous vegetation, the land clearing, soil preparation and cassava planting may take up to 15 man-days/mu (225/ha). On the Bayi state farm and in Kongba village, farmers spray with pre-emergent and/or contact herbicides after planting, followed by one hand weeding at 2-4 MAP. In other areas weeds are controlled with a hoe or knife, while in Longtang town fields are weeded using a buffalo and plow.

In the mountainous areas of Hainan, fertilizer and/or FYM are seldom applied to cassava, or are applied only after the second crop. Farmers often reported that yields increase from the first to the second year of cropping due to the slow decomposition of the previous fallow vegetation, but yields decrease again in the third and subsequent years due to nutrient extraction and erosion. Thus, 2-3 crops of cassava are usually rotated with sugarcane or the land is returned to fallow for 1-2 years. If cassava cultivation continues beyond two years, farmers usually apply some urea, SSP or 15-15-15 fertilizers, either at planting or at 2-3 MAP.

In most areas of Hainan, cassava is harvested in Nov to Dec, but in some cases this extends to Feb or even March. In the highland area of Tongzha city some farmers leave cassava for a second cycle, harvesting only after about 18-20 months due to labor shortage or because the crop did not grow well. If a starch factory is nearby, such as in Maoyang and Maoqui towns of Tongzha and in Hongdao town of Qiongzhong county, cassava is mainly sold as fresh roots (**Table 4**). But in the absence of a nearby factory, cassava is chipped and dried; in the Bayi state farm and in Qifeng most of this is sold to traders, while in Longtang town the chips are ground to a powder in a local mill and this is fed mainly to the farmer's own pigs or is sold at the local market. Some of the chips are taken to the animal feed mill in Wenchang county. In Hainan, on the average, 80-90% of cassava is sold off-farm. In many areas, especially near urban centers or main roads, on-farm pig feeding is highly lucrative. It was estimated that cassava-based pig-feed (mixed on-farm) is 15-25% cheaper than commercial pig feed. With the current strong economic development, especially around the larger industrialized cities, demand for pork is very strong. In China, pork is the animal protein most consumed.

Economic data show that labor requirements for cassava production in Hainan are higher than on the mainland. It ranges between 12-20 man-days/mu (180-300/ha). To a large extent this can be explained by the fact that cassava fields are on steeper slopes, farther away from the village and because of climatic conditions chip drying takes longer. Cassava income (labor not accounted for) ranges from Y250-300/mu. Although sugarcane is often used as a crop alternative, and has a higher income (Y300-400/mu), in several areas there were demand problems. Also, cane, once harvested, needs to be factory processed at once. Cassava, on the other hand can be chipped and stored, and has more utilization alternatives. As such, these are typical criteria entering the farmer's decision-making process regarding crop choices.

In Hainan most farmers had mixed feelings about cassava. On the one hand they like the crop because it is well-adapted to the local soil and climatic conditions, it is easy to grow with a minimum of inputs and it gives a quick return on labor; the harvest and

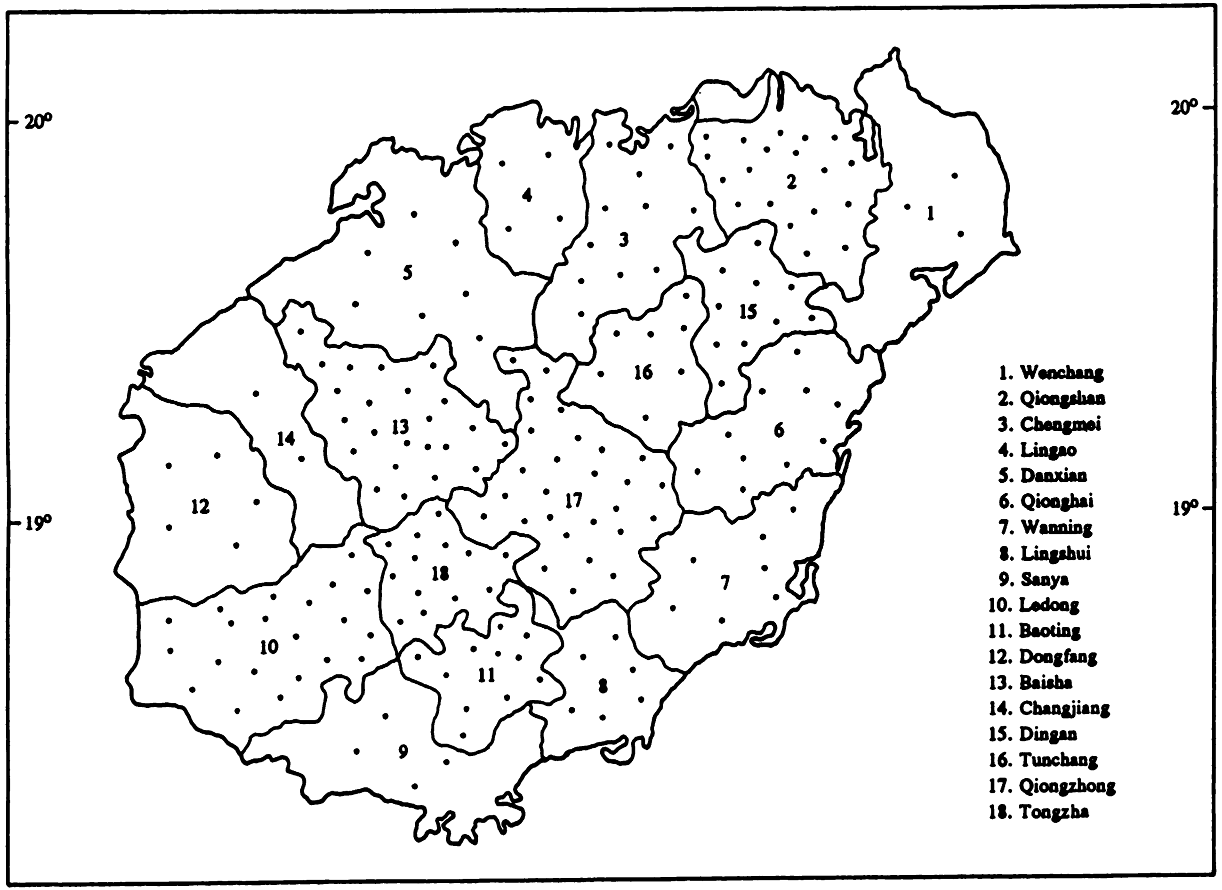

Figure 2. Cassava production areas in the various counties of Hainan province of China in 1992. Each dot indicates 100 ha of cassava.

Table 1. Secondary data of Hainan province (1994).

	Bahyi State F. Tongshan branch	Bayi State F. Production Team #2	Baisha County	Tongzha city	Qiongzhong county	Dingan county Longtang town
Latitude(°N)	19° 30'	19° 30'	19° 20'	18° 45'	19° 5'	19° 25'
Altitude(masl)	<150	<150	150-300	300-500	250-500	100-200
Soils	Hapludult	Hapludult	yellow-red Hapludult	rocky Paleustult	rocky Paleustult	dark Hapludult
Landscape						
-general	hilly	hilly	hilly	mountain	hilly-mount.	60% upland 40% irrig.
-cassava	on flat and steep slopes	on flat and steep slopes	on flat and gentle slopes	on steep slopes	on gentle slopes	onflat and gentle slopes
Climate						
Average temperature (°C)	23.0-23.5	23.0-23.5	23.5-24.0	22.5	22.0-22.5	22.0-23.0
Absolute minimum temp.						
Mean minimum temperature	5-7		5-7	4-5	4-5	5-7
Absolute maximum temp.						
Mean maximum temperature						
Rainfall (mm)	1,600-1,800		1,600-1,800	1,600-1,800	>2,400	2,000-2,400
No. of frost-free days	365	365	365	365	365	365
Typhoon incidence	medium	medium	low	low	medium	high
Main crops (mu)[1]						
rice - irrigated	1,416			30,500	72,773	15,600
- upland				4,032	3,087	
cassava	2,500	300	36,778(#3)	15,748	42,012	4,100
maize				9,382	904	
peanut				2,866	6,738	4,600
sugarcane	5,136	100	(#2)		8,182	14,000
fruit trees	410				10,300	4,200
vegetables				5,023	11,303	
rubber		1,000	(#1)			4,800
sweet potato	239		62,937	8,050		4,500
bamboo	1,000					
pineapple					14,167	
Cassava yield (kg/mu)						
- fresh			1,419		988	
- dry		500-750				
Total farm size (mu/lf)[2]						
- upland	5.0					
- irrigated	0.5					
Average income (Y/person)	3,200					

[1] 1 ha = 15 mu
[2] lf = Labor force
[3] 1 US$ = 8.4Y

Table 2. Land use, crops and cropping systems in Hainan province.

	Danxian city	<—Baisha county—>		<—Tongzha city—>		<—Qiongzhong county—>		Dingan county
	Bayi State F. Production Team #2	Shifeng Production Team #1	Shifeng Kongba village	Maoyang Maolu village	Maogui Zhatong village	Hongdao Fongju village	Hongdao Xinchi village	Longtang various villages
Main crops[1]	rubber sugarcane forest cassava rice	rubber sugarcane cassava rice	rubber sugarcane rice cassava	rubber rice, maize cassava sugarcane fruit trees	rubber cassava rice maize soybean	rubber rice cassava bamboo beetle nut	rubber rice cassava beetle nut	sugarcane rice cassava rubber fruit
Land use-cassava	on steep slopes Rotate with SC	on gentle slopes Rotate with R or SC	in hills Rotate with SC or fallow	on very steep slopes	on gentle and steep slopes	on lower slopes	on gentle slopes	on flat Cl yr→ SC 2 yrs
Cropping systems	C monocult. Some C+M or C+P in fertile soil	C monocult. R+C intercr. 1 yr C→ 3 yrs SC	C monocult. some C+M or 2-3 yrs C→ fallow	C monocult. 3 yrs C→ 2 yrs fallow	C+M+SP R+C intercr. for 2 yrs→ 2 yrs fallow	C monocult. no R+C	C monocult. no R+C 4-5 yrs C →1-2 yrs fallow	C monocult. some C+P
Crop area (mu/fam.)[2]-total	8-10	3-7	40-50	20	15-18	10-12	6-8	12-20
-Cassava (mu/fam.)	2-5	1-3	30-40 (legal-20)	4-6	5-10	4-7	2-4	1-5
-Irrigated (mu/labor force)[3]	0.5		1.9	2.5-3.0	2.5-3.0	2.0-2.5	1-4	
-Upland (mu/labor force)	5.0		15-17	4-5	5	2.0-3.5	2-4	
-Rubber (mu/labor force)	11-12	8-9	7-8	5-10	8-12	0-8	7-8	10-12
Yield (kg/mu)								
-Cassava-fresh roots	1,500-2,000	500-1,000	1,000-2,500	1,000-2,000	750-2,000	1,500-2,500	750-1,500	1,000-1,500
-dry chips	500-750							
-Sugarcane		3,000-5,000						
-Maize					150-250			
-Sweet potato					400			

[1] C=cassava, M=maize, P=peanut, SC=sugarcane, SP=sweet potato, R=Rubber
[2] 1 ha=15 mu
[3] Note: in Hainan province land is assigned according to the number of labor force in the family

Table 3. Cassava utilization and socio-economics in Hainan province in 1994.

	Bayi State F. Production Team #2	Shifeng Production Team #1	Shifeng Kongba village	Maoyang Maolu village	Maoqui Zhatong village	Hongdao Fongju village	Hongdao Xinchi village	Longtang various village
Utilization (%)	chips	chips	chips	fresh	fresh	fresh	fresh	chips/flour
Sold-factory	80-90	80	90	90-100	90-100	80-90	70-80	
-local market								10-30
On-farm use	10-20	20	10	0-10	0-10	10-20	20-30	70-90
Chipping	Chip. machine	hand or chipper					chipper	chipping board or chipper
Labor use (mandays/mu)								
land preparation	6-9 (new land)			5	4-5 (new land)	3-6 (new land)	2-3	0.5-1.0
	2-3 (old land)	2-5	15	6-7	3 (old land)	1-3 (old land)	<1	1
stake prep. + planting						0.5-1.0		
fert. application					4-5	1.5		1
weeding	3-6	3-6		4	2-4	2-4	2-6	1
harvest and transport	3-6	2-3		3-4	6-9	>2	2	3
chipping	0.5-1.0	1-2		-	-	-	0.5-1.0	1-2
drying	2-3 (1)	1		-	-	-	-	2 (1)
Total	11-23	9-17		18-20	15-23	7-15	8-13	8-10
Prices and costs (Y)								
fresh roots/t	240	180	160-180	140	160	180	150-160	
dry chips/t	500-600	500-600	500-600					500-800
starch (grade 1)/t		1,600-1,700						
maize/t	1,300				1,000			
sweet potato/t					300-400			
rubber/kg	14							
urea/50kg								80
SSP/50kg			23-32			30	30	30-38
15-15-15/50kg (imported)	80-100		100-120			>80		130
compound/50kg (local								60
Cost of labor/day	12-15		5-10					
Total cost of fert./mu	30-36	0	0-15	0	0	0-14	0-30	20-50
Net income (Y/fam.)								
-cassava	100-300	100-200		150-300	220-300	200-250	100-250	240
-sugarcane	100-380	100-300						

1 US $ = 8.4 Y; 1 ha = 15 mu

Table 4. Cassava varieties and agronomic practices in Hainan province in 1994.

	Bayi State F. Production Team #2	Shifeng Production Team #1	Shifeng Kongba village	Maoyang Maolu village	Maoqui Zhatong village	Hongdao Fongju village	Hongdao Xinchi village	Longtang various villages
Varieties	SC205 SC6068	SC205	SC205	SC205 Hainan narrowleaf	3 from SCATC	SC205 Bread var.	SC205	SC102 Red stem
Fertilizer use (kg/mu)	very little FYM 15 (15-15-15) 4 urea	250 FYM no fert. for SC: 20-25 urea 5 (15-15-15)	In 3 rd yr: 25 SSP 17 (15-15-15)	none	none	0-250 FYM 0-20 SSP	In 3 rd yr: 50 SSP	250 FYM or 50 SSP 12 urea
Land preparation	slash/burn planting holes 10x20 cm	slash/burn planting holes 10x20 cm	slash/burn planting holes	slash/burn planting holes	slash/burn hoe all area	buffalo 2 plow + 2 rake	buffalo 1-2 plow 1-2 rake	buffalo 1-2 plow 1-2 rake
Plant spacing (m)	0.6x0.6 0.8x0.8 at random	0.8x0.8 1.0x0.6 at random	0.5x0.5 0.6x0.6	0.6x0.6	0.6x0.6 0.8x0.8 at random	0.6x0.7	0.5x0.6 0.7x0.7	0.6x0.6
Planting method	horizontal	horizontal		horizontal	horizontal	horizontal	horizontal	horizontal
Planting depth (cm)	6-10				10	10	10	15
Stake length (cm)	10-20	10-15			10-15	15-20	15-20	
Weed control	PreE heribicide + hand	hand	PreEherbicide contact herb. + hand	hoe/knife	hoe/knife	hoe/hand- pulling	hoe	buffalo + ridging up
No. of weedings	1+1	2	2+1	2	2	2	1-2	1-2
Time of planting	Feb-Mar	Feb-Mar	Feb-Mar	Mar-Apr	Mar-Apr	Jan-Feb	Jan-Feb	Jan-Mar
Time of fert. applic.	at planting urea 2-3 MAP							at or after planting
Time of weeding: - 1st	1-4 DAP	2 MAP		2 MAP	2 MAP	2 MAP	1-2 MAP	2 MAP
- 2nd	2 MAP	4-5 MAP		4 MAP	4 MAP	5-6 MAP	5-6 MAP	
Time of harvest:								
- intercrops					June-July			
- cassava	Nov-Feb	Nov-Dec	Nov-Jan	Nov-Apr	Nov-Jan	Nov-Dec	Oct-Jan	Nov-Jan
Intercropping system				sometimes 2 yr C cycle	C+M with SP in between			

transport of the roots is also more flexible and thus more easily organized than that of sugarcane. But farmers complain that yields and profits are low, that it requires more labor than sugarcane, which is harvested three times before replanting, that the transport of fresh roots from far-away fields is hard work and that the drying of chips is a problem during the rainy season. They also mentioned that cassava cultivation reduces the productivity of the soil, either through nutrient extraction or erosion. Thus, they either had to apply fertilizers to cassava or return the plot back to fallow for 1-2 years, after which it would require considerable labor again to slash and burn the fallow for further cropping. On the relatively fertile soils and with favorable climatic conditions, an abundant fallow vegetation is generally produced in a short time. Farmers in the upland areas still prefer to first plant cassava after opening up new land (often illegally).

Erosion was also recognized as a serious problem, but besides digging diversion channels to prevent water from entering the cassava fields, very little was done to prevent erosion. This is because of lack of labor or because they do not own the land, as in State Farms or Township Communal Farms, where crop land is rotated among farmers or can be used any time for rubber tree planting. Erosion was found to be very severe on the steep slopes in Tongzha city, as well as on the gentle slopes at CATAS.

Table 5 indicates the major cassava starch and animal feed factories in Hainan, while **Figure 3** shows their locations. The small private starch factory in Qifeng town of Baisha county is modernizing its equipment and expanding its processing capacity to 2500 ton starch/year, but this factory can operate only for three months of the year, Nov-Jan, due to the unavailability of fresh roots during the other months. The factory will start making contracts with farmers and pay a guaranteed price of Y140/ton (fresh root). The state-run starch factories in Maoyang and Qiongzhong also process mainly fresh roots, operating only from Nov-March. The latter has rather modern equipment and an installed capacity of 10,000 ton starch/year, but due to lack of raw materials it produces only 3000-4000 ton starch/year. The starch factory in Baisha county has a capacity to produce 3,000 ton/year, but actually produces only 300 t/year. Most of these state- or county-owned starch factories use old equipment, have too much personnel, and, in general, are poorly managed, resulting in high product costs and financial losses. While all are producing below capacity due to lack of raw materials, they do not seem to compete aggressively with each other to secure this raw material; this is resulting in stagnating prices and a reduction in cassava area. Hainan needs about 15,000 ton starch/year, mainly for the food, candy and card board industries. Besides the two large factories in Qiongzhong and Qiongshan counties there are another seven starch factories still operating in Hainan, but with a total capacity of less than 12,000 ton starch/year (**Table 5**).

Without exception, all managers of starch factories ranked lack of raw material and lack of capital as the top two constraints. Typically, state-run factories face worse problems than private-run factories, especially regarding technology, working capital, and

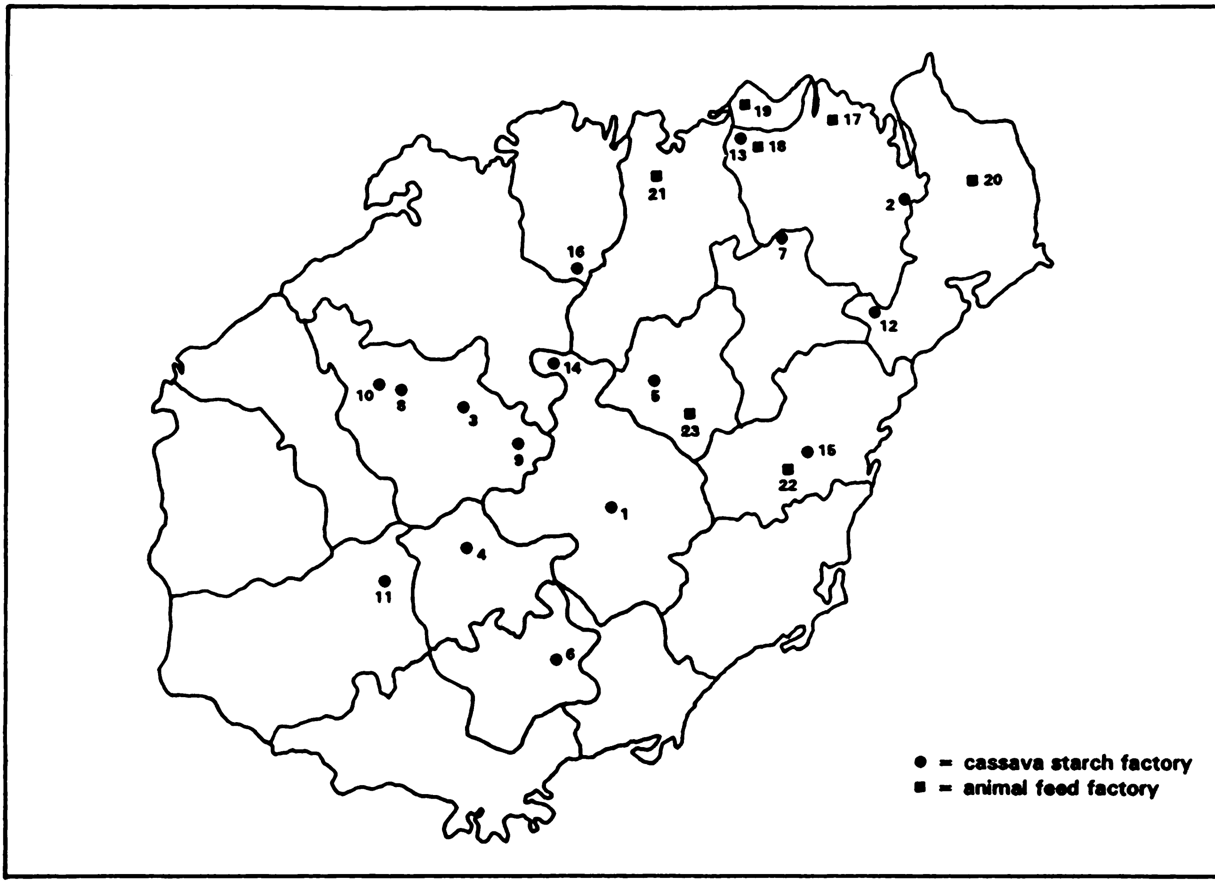

Figure 3. Location of casava starch and animal feed factories in Hainan province (see Table 5).

Table 5. Major cassava starch and animal feed factories in Hainan province.

Factory	Location[1]	Capacity (t/year)
1. Qiongzhong Starch Factory	Qiongzhong county	6,000*[2]
2. Dazhipo Starch Factory	Qiongshan county	6,000*
3. Baisha Starch Factory	Baisha county	3,000*
4. Maoyang Starch Factory	Tongzha city	3,000*
5. Nankun Starch Factory	Tunchang county	3,000*
6. Baoting Starch Factory	Baoting county	2,000
7. Dingan Starch Factory	Dingan county	2,000
8. Lixiegu Private Starch Factory	Baisha county	1,000*
9. Xishui Starch Factory	Baisha county	500
10. Longjiang Starch Factory	Baisha county	500
11. Wanchong Starch Factory	Ledong county	500
12. Fenglai Starch Factory	Wenchang county	500
13. Shishan Starch Factory	Qiongshan county	500*
14. Songtao Starch Factory	Qiongzhong county	500*
15. Yangjiang Starch Factory	Qionghai county	500
16. Heshe Starch Factory	Lingao county	500*
17. Nanfeng Feed Factory	Qiongshan county	80,000
18. Qiongzhou Feed Factory	Qiongshan county	50,000
19. Huaxin Feed Factory	Haikou city	50,000
20. Baoli Feed Factory	Wenchang county	10,000
21. Fushan Feed Factory	Chengmei county	10,000
22. Yangjiang Feed Factory	Qionghai county	10,000
23. Xiangshan Feed Factory	Tungchang county	10,000

[1] see Figure 1
[2] *indicates that factory is still processing

labor. However, this seems to be a phenomenon applicable to the majority of Chinese state-run enterprises.

Thus, in Hainan cassava is still an important crop, but cassava has suffered a downward trend due to inefficient processing facilities and government interest mainly in rubber, sugarcane and fruit trees. It remains an important crop mainly in the foothills of mountains in central Hainan, especially in those areas close to starch factories.

2. Pilot Site Selection

The RRA confirmed that the areas of Qifeng town in Baisha county and Hongdao town in Qiongzhong county are probably the most suitable for the Nippon Foundation FPR project. When we interviewed the members of production team #1 of Qifeng town, it became quite clear that due to non-ownership of land and limited availability of labor, there was very little interest in collaborating with the project. The nearby village of Kongba seemed to be much more promising. Here, farmers ranked erosion as one of the top problems. They estimated that on the steep slopes cassava yields decreased by more than 1500 kg/mu between the first and third crop cycle. In addition, some farmers had already implemented some "traditional" measures to reduce erosion, i.e. increased planting density. They also knew that some kind of ridges would decrease soil loss. However, little was done on this because of labor constraints. In general, one family only has 0.1-0.2 ha land for planting cassava in China; however, in some villages (such as Kongba) of Baisha county, every family used more than one ha land for cassava production. In this area cassava is usually planted in monoculture on hill-sides in the mountainous areas by small farmers, and soil erosion is very serious. After more detailed RRAs were conducted in these areas, Kongba village and Hongdao town were finally identified to be the most suitable pilot sites for the FPR project.

3. Demonstration Plots at CATAS

Based on the actual cassava situation in Hainan and our previous research experience, 17 treatments on erosion control practices were selected and installed in demonstration plots with 5-10% slope at CATAS. Along the bottom end of each plot was a plastic-covered channel to collect the soil that washed down the slope with the runoff water. By weighing these sediments, the amount of erosion in each plot could be estimated.

4. Farmers' Field Days at CATAS

A farmers' field day/workshop was organized at CATAS from Jan 10 to 12, 1995. About 20 farmers participated; they had been selected from the two pilot sites by officials from the Agricultural Bureau or by extension agents.

After explaining the objectives and some of the proposed activities of the projects, farmers were taken to see the demonstration plots as well as all the trials of the cassava program at CATAS. Researchers explained the advantages and disadvantages of the various treatments in the demonstration plots. The soil that had eroded into the channels had already been removed and weighed, so farmers could not see in the field the difference among treatments in terms of soil erosion. But, they could harvest two varieties in each plot, and thus observe the characteristics of the new variety SC124, as compared to the local variety SC205. The results of the demonstration plots (**Table 6**) were presented to the farmers during the discussion session; unfortunately, the results were rather unusual due to various problems, such as poor germination and damage by herbicides. During the discussion session, farmers voted on each management option to select those that they were most interested in. Mr. Xie Dahe, who worked at the Agric. Bureau of Qiongzhong county, and Mr. Zhou Shao Xiong from the extension station of Qifeng town of Baisha county, were appointed to be the local coordinators for the project. Farmers seemed to be most interested in the new varieties and in fertilizer application.

5. Farmer Participatory Research (FPR) Trials in the Pilot Sites.

As a follow-up to the field day/workshop for farmers at CATAS, demonstration plots were then established in the farmer's own fields by each of the coordinators at the pilot sites in March-April of 1995. CATAS provided technical guidance and supplied the basic planting materials. A total of 52 farmers collaborated in the project, 43 in Kongba village in Qifeng town of Baisha county, and nine in Hongdao town of Qiongzhong county. Of these, 44 farmers conducted FPR variety trials with a total of 20 cassava clones/varieties; 24 farmers implemented soil erosion trials with a total of eight treatments; and 11 farmers conducted fertilizer trials with nine treatments. In the FPR erosion trials each farmer had only two treatments, a "traditional" practice and an "improved" practice. Plastic-covered ditches were installed below each plot to determine erosion. The number of farmers who wanted to participate was much higher than expected, but we did not want to refuse those farmers that wanted to collaborate in the project. The large number of participants did cause some problems.

Table 6. Effect of various management practices on soil erosion and fresh cassava yield (cv SC205) in demonstration plots on 5-10% slope at the South China Academy of Tropical Crops in Danzhou, Hainan in 1994. In the right hand column is the farmers' preference ranking.

	Treatments					Dry soil loss (t/ha)	Root yield[6] (t/ha)	Farmers' preference ranking
	Fertilizer[1]	Spacing (m)	Intercrop	Tillage	Barriers			
1	no	1.0x0.8	no	plow	no	168	30.0	17
2	½ NPK	1.0x0.8	no	plow	no	208	43.5	16
3	½ NPK+FYM	1.0x0.8	no	plow	no	188	36.5	7/8
4	NPK	1.0x0.8	no	plow	no	219	42.7	2
5	NPK	1.0x0.8	no	contour ridge	no	288	34.0	10
6	NPK	1.0x0.8	no	up-down ridge	no	273	46.8	5
7	NPK	1.0x0.8	no	planting hole[2]	no	280	29.2	11
8	NPK	1.0x0.8	no	strip prepar.[3]	native grass	242	37.8	7/8
9	NPK	1.0x0.8	no	no tillage	no	255	29.5	15
10	NPK	0.8x0.8	no	plow	no	318	26.1	13/14
11	NPK	1.0x1.0	no	plow(zx)	no	252	32.1	13/14
12	NPK	1.0x0.8	peanut	plow	no	207	28.0	4
13	NPK	1.0x0.8	mungbean	plow	no	241	37.5	3
14	NPK	0.8x0.8	no	plow	*Styl. guianensis*[4]	256	31.5	1
15	NPK	0.8x0.8	no	plow	*Brach. brizantha*[4]	175	27.0	6
16	NPK	0.8x0.8	no	plow	vetiver grass[5]	296	25.8	9
17	NPK	0.8x0.8	no	plow	*Flemingia cong.*[5]	370	31.0	12

[1] NPK = 100 kg N, 40 P_2O_5 and 135 kg K_2O/ha, applied as urea, SSP and KCl, respectively
½ NPK = 50 kg N, 20 P_2O_5 and 67.5 kg K_2O//ha; FYM = 400 kg/ha of pig manure
[2] only planting holes of 30x30 cm
[3] 4.5 m wide prepared strips alternated with 0.5 m contour grass strip without preparation
[4] about 1 m wide contour strip
[5] about 0.5 m wide contour strip
[6] Average of SC205 and 124

6. Field Days at Kongba Village

To assess the farmers' opinions about the various treatments in the FPR trials, a preliminary field day was organized at Kongba village in October 1995 when cassava was only eight months old. Because farmers did not want to harvest these young plants yet, we mainly conducted an evaluation of cassava clones/varieties, which had been planted in the extension station's experimental field. More than 40 farmers (including some women farmers) participated in this activity. Five plants of each variety were pulled out and taken to be lined up at an empty field for evaluation. The result of the farmers' evaluation (**Table 7**) indicate that farmers were mainly interested in cassava yield and wind resistance rather than in other characteristics, such as starch content.

Table 7. Varietal characteristics considered of importance by farmers in Kongba village, Baisha county, Hainan, China.

Character	Total score
Fresh root yield	420
Starch content	40
Plant type	15
Ease of harvest	5
Typhoon tolerance	135
Number of roots	105
Plant height	25
Branching[1)]	150
Sweetness of roots[2)]	0
Color of roots	0
Weight of each root	5

[1)] Prefer some but not excessive branching; no branching gives low yield.
[2)] Bitter varieties are always preferred over sweet ones, because they are considered higher yielding; if they had the same yield, sweet vareties would be preferred.

Another field day was organized during the final harvest in Jan, 1996. This time, farmers and researchers pulled out ten plants in each plot and weighed the fresh roots to determine the yield. Varieties were again evaluated by the farmers for various characteristics. The results of the trials were quickly calculated and were then discussed with the farmers to select those that were most suitable for the region. These would be included in the next year's trials.

Table 8 shows the results of the FPR erosion control trials. Most farmers had not determined the yields of hedgerow barrier crops, but did determine those of intercrops. The total value of the harvested cassava and that of the intercrops was usually higher than those of other treatments without intercrops. The intercropping with peanut produced high total income as well as a low level of erosion, which convinced farmers that this was a good practice. Farmers also showed interest in continuing experimentation on intercropping with maize and would like to try intercropping with sweet potato.

Table 9 shows the results of the six FPR fertilizer trials. As soils are quite fertile in this area, there was no response to any of the nutrients applied, nor to application of farm yard manure (FYM). Actually, not applying any fertilizers produced the highest net income. Only in the case of Mr. Tan Ya Zhui, whose land had been cultivated continously for many years, was there any significant response to fertilizer or FYM application; the response was mainly to application of P as the soil P-level in his field was below the critical level of 4-5 ppm P (see soil analyses **Table 9**).

The results of the 15 FPR variety trials are shown in **Table 10**. Yields were very high, averaging about 36 t/ha, both for the improved varieties and the local variety SC205. Only the clones ZM9057 and OMR33-10-4 produced significantly higher yields than the local check variety. Both these clones had earlier been selected by farmers for their high yield and wind resistance.

7. Demonstration and FPR Trials at CATAS and at Pilot Sites in 1996

Since the demonstration and most FPR trials in Qiongzhong county had failed in 1995, it was decided to change this second pilot site to Tunchang county, where farmers pay more attention to cassava production, while the local cassava starch factory has shown great enthusiasm to participate in the FPR project.

In Kongba village six farmers will continue to conduct erosion control trials (each with five treatments), four will do variety trials (each with 4-5 clones) and five will continue with fertilizer trials (each with ten treatments).

In CATAS a new demonstration plot with 17 treatments was installed to show farmers a range of new management options.

MAJOR PROBLEMS AND CONSTRAINTS

1. Little attention has been paid to soil erosion problems by officials of local governments. In some cases they talk well but do little.
2. In the first year, too many participants in Kongba village caused too many problems; some just wanted to get paid for their participation.
3. It is difficult to find a good local coordinator, who is willing and able to spend a lot of time working with the farmers. The two coordinators did not always conduct the trials at the pilot sites as we had requested.
4. Up to now, except for new varieties, no new technologies could really produce an obvious impact in the demonstration plots. This means that the results of our demonstration were not very convincing to the farmers.

5. It is a lot easier to release new varieties than to transfer new technologies of soil and water conservation to farmers. However, the supply of planting materials of new varieties could not meet the local demand, which also caused frustration with the farmers.

SUGGESTIONS AND COMMENTS

1. Most farmers nowadays don't believe something just because we say so; farmers have to see with their own eyes the good results of new technologies. Therefore, we have to take advantage of our past experience with farmers and try to make the recommended practices also more profitable so as to stimulate farmers to adopt these new technologies.
2. It is very important and neccessary to convince officials of the local governments to support and help our work. We have to let them know clearly about the importance and the objectives of our FPR project.
3. Transfer of new technologies of soil and water conservation should be combined with the release of new varieties. In order to release new varieties quickly, there are two important things that should be considered first: one is to establish some multiplication fields, using rapid and simple propagation methods in order to produce a large amount of planting material; another is to set up some representative demonstration sites for training of extension officials and farmers, to teach them new ways to propagate cassava planting material. Presently, the multiple shoot system developed at CIAT is being tried at CATAS.
4. It seems to be realistic to train one local farmer to be the local coordinator of the FPR participants, and to function also as a contact between researchers and farmers. Because he knows the local situation clearly, he can inform us better about farmer's needs and preferences.
5. Researchers should participate more directly in the planning, laying-out, planting, collecting of eroded sediments, and the harvesting of intercrops. In addition, the FPR trials should be standardized as much as possible in order to allow for better comparisons between treatments.

CONCLUSIONS

Up to now, although there have been many problems and constraints, we have obtained some good results and gained a lot of experience from our FPR project in the first year. To further succeed, we need to explain more clearly the objectives of our project and seek the government's support and help, in order to achieve a wider adoption of results by participating as well as non-participating farmers.

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Table 8. Results of 12 FPR soil erosion control trials with cassava, cv. SC205, conducted in Hongba village, Qifeng town of Baisha county in Hainan, China in 1995/96.

Farmer's name	Treatment	Slope (%)	Soil loss (t/ha)	Soil loss (%CK)	Cassava yield (t/ha)	Cassava yield (%CK)	Intercrop yield (t/ha)	Gross income[4] ('000 ¥/ha) Cassava	Gross income Intercrop	Gross income Total
1. Zhou Shao Xiong	check (CK)[1]	16-23	54.99	-	22.20	-	-	7.10	-	7.10
	C+maize	16-27	41.25	75.0	22.20	100	1.325	7.10	2.11	9.21
	C+peanut	16-24	30.67	55.8	27.00	122	0.762	8.64	3.05	11.69
	C+soybean	16-20	43.60	79.3	22.20	100	0.861	7.10	3.10	10.20
2. Tan You Chai	check	5-11	52.38	-	67.95[2]	-	-	21.74	-	21.74
	C+peanut	5-11	22.86	43.6	78.15[2]	115	0.952	25.01	3.81	28.82
3. Tang Ya-e	check	3-12	92.46	-	27.15	-	-	8.69	-	8.69
	peanut barrier	3-12	74.68	80.8	33.30	123	-	10.66	-	10.66
4. Ma Guo Lei	check	8	27.49	-	28.35	-	-	9.07	-	9.07
	soybean barrier	8	21.25	77.3	30.75	109	-	9.84	-	9.84
5. Tan Ya Lao	check	5-12	34.12	-	24.30	-	-	7.78	-	7.78
	soybean barrier	5-12	27.25	79.9	25.05	103	-	8.02	-	8.02
6. Tan Huan Cheng	check	8	23.19	-	28.05	-	-	8.98	-	8.98
	pigeon pea barrier	8	25.74	111.0	25.05	89	-	8.02	-	8.02
7. Tan Yin Chai	check	17	21.70	-	22.20	-	-	7.10	-	7.10
	maize barrier	17	21.22	97.8	22.80	103	-	7.30	-	7.30
8. Pu Yong Chuan	check	7	105.00	-	28.05	-	-	8.98	-	8.98
	pigeon pea barrier	7	33.00	31.4	28.80	103	-	9.22	-	9.22
9. Tan Yin Jiu	check	17	57.19	-	31.20	-	-	9.98	-	9.98
	cowpea barrier	17	50.40	88.1	32.85	105	-	10.51	-	10.51
10. Tan Weng Li	check	11	17.50	-	25.65[3]	-	-	8.21	-	8.21
	cowpea barrier	17	18.12	103.5	22.95[3]	89	-	7.34	-	7.34
11. Tan Jing Zhou	check	8	32.67	-	30.45	-	-	9.74	-	9.74
	contour ridges	8	27.66	84.7	34.35	113	-	10.99	-	10.99
12. Tan Jia Chai	contour ridges	14	63.63	-	22.50	-	-	7.20	-	7.20

[1] check = farmer's normal practice: cassava monoculture without ridges or contour barriers.
[2] cultivar SC8013: yields are

Table 9. Results of six FPR fertilizer trials with cassava, cv. SC205, conducted in Kongba village, Qifeng town of Baisha county in Hainan, China in 1995/96.

Treatments[2]	Cassava root yield (t/ha) Farmers[1] A	B	C	D	E	F	Av.	Costs and returns ('000 ¥/ha) Gross income[3]	Cost fertilizers	Net income
1. Control	56.25[4]	33.60	28.05	28.95	39.75	22.65	34.87	11.16	-	11.16
2. N	39.00	27.30	22.65	36.75	43.80	18.75	31.37	10.04	2.022	8.02
3. P	34.35	35.10	19.50	39.00	30.45	24.15	30.42	9.74	0.555	9.18
4. K	32.85	32.85	14.10	32.85	35.85	22.65	28.52	9.13	0.300	8.83
5. PK	37.50	31.95	21.90	26.55	42.15	21.15	30.20	9.66	0.855	8.80
6. NP	29.70	32.85	31.20	-	-	-	-	-	2.577	-
7. NK	28.05	31.20	21.75	-	-	-	-	-	2.322	-
8. NPK	25.05	28.05	24.15	35.85	38.25	31.20	30.42	9.74	2.877	6.86
9. FYM	20.25	26.55	27.30	39.00	37.50	30.45	30.17	9.66	0.750	8.91

[1] Farmer's name and soil analysis:

		pH	OM (%)	total N (%)	P (ppm)	K (ppm)
A =	Zhou Shao Xiong	5.86	3.40	0.173	32.6	371
B =	Tan Jing Zhou	4.78	4.99	0.238	5.6	254
C =	Pu Yong Chuan	4.55	2.70	0.135	10.6	117
D =	Tan Jia Chai	4.80	3.67	0.202	13.9	177
E =	Tan Yin Chai	5.01	4.60	0.225	5.5	362
F =	Tan Ya Zhui	5.16	3.25	0.156	1.4	87

[2] N = 337 kg N/ha as urea.
P = 135 kg P_2O_5/ha as simple superphosphate (18% P_2O_5).
K = 750 kg burned rice husks/ha. (9.5kg K_2O/ha)

[3] Prices:

cassava fresh roots	= ¥	0.32/kg.
urea	=	2.70/kg.
SSP	=	0.74/kg.
ash of burned rice husks	=	0.40/kg.
FYM	=	0.10/kg.

[4] Yield overestimated due to many missing plants.

Table 10. Combined results of 15 FPR cassava variety trials conducted in Kongba village, Qifeng town of Baisha county in Hainan, China in 1995/1996.

Varieties/Clones	Farmer's name	Improved variety	Check (SC205)
SC8013	Fu Yong Chuan	40.6	29.7
	Tan Yin Chai	36.7	37.5
	Tan Ya Zhui	29.7	37.7
	Tan Huan Chong	35.7	37.7
	Tan Ya-e	36.1	30.5
	Zhou Shao Xiong[1)]	35.9	42.9
	Average	**35.8**	**36.0**
SC8002	Ma Guo Lei	28.4	32.7
	Tan Jing Zhou	28.5	38.4
	Tan Ya Zhui	24.9	37.7
	Zhou Shao Xiong[1)]	50.7	42.9
	Average	**33.1**	**37.9**
ZM9038	Tan Jing Zhou	26.7	38.4
	Tan Ya Lao	42.8	31.2
	Average	**34.7**	**34.8**
ZM9036	Liu Ya Chun	44.4	33.3
ZM9057	Fu Jin Yu	28.5	32.6
	Tang Ya Han	46.0	24.1
	Zhou Shao Xiong[1)]	53.1	42.9
	Average	**42.5**	**33.2**
ZM9066	Tan Yin Chai	32.1	37.5
ZM8639	Tan Ya Qing	34.9	28.8
	Zhou Shao Xiong[1)]	34.4	42.9
	Average	**34.6**	**35.8**
ZM8641	Tan Jia Chai	24.9	28.8
	Zhou Shao Xiong[1)]	42.1	42.9
	Average	**33.5**	**35.8**
OMR33-10-4	Tan Wen Fu	36.3	23.4
	Zhou Shao Xiong[1)]	53.1	42.9
	Average	**44.7**	**33.1**
SC124	Tan Yin Chai	50.4	27.7
	Zhou Shao Xiong[1)]	28.1	42.9
	Average	**39.2**	**35.3**
ZM9045	Zhou Shao Xiong[1)]	34.3	42.9
ZM9076	Zhou Shao Xiong[1)]	48.8	42.9
ZM8803	Zhou Shao Xiong[1)]	22.2	42.9
SM1592-3	Zhou Shao Xiong[1)]	32.0	42.9
ZM8316	Zhou Shao Xiong[1)]	26.5	42.9

[1)]These data maybe overestimated due to unclear spacing.

FARMER PARTICIPATORY RESEARCH IN SOIL MANAGEMENT AND VARIETAL SELECTION IN THAILAND

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ABSTRACT

A pilot project on the use of Farmer Participatory Research (FPR) methodologies with the objective of enhancing farmer adoption of practices that minimize soil erosion in cassava-based cropping systems, was conducted jointly by DOA and DOAE with technical and financial support from CIAT in two sites in Nakhon Ratchasima and Sra Kaew provinces. The activities involved a preliminary survey using RRA methodologies, the setting out of demonstration plots, as well as farmers meetings and farmers field trips to observe the demonstration plots. The activities also included conducting various types of FPR trials with farmers on their own land and organizing a farmer's field day to harvest these trials, to discuss the results, and to select the best treatments for next-year's trials.

The results revealed that the highest yield of cassava in Soeng Saang district of Nakhorn Ratchasima province was obtained from planting contour barriers of vetiver grass within cassava plots; this practice also resulted in the lowest level of soil erosion. On the contrary, in Wang Nam Yen district of Sra Kaew province, the highest cassava yield was obtained in plots with up-and-down ridging, while the lowest level of soil erosion was observed with contour ridging. However, from the discussion between participating farmers and FPR team members it was concluded that the planting of contour barriers of vetiver grass was the most effective method to reduce erosion in the long-term, even though this treatment neither had produced the highest yield of cassava nor the highest income.

Within the same pilot project, FPR trials on cassava varieties and on rates of fertilizer application were conducted in order to motivate farmers to participate in the project. In Wang Nam Yen district, Rayong 90 had the highest yield and ranked second in starch content, while Rayong 5 had the second highest yield but the highest starch content. In Soeng Saang district, Rayong 90 ranked first in yield and starch content, while Kasetsart 50 ranked second in both yield and starch content. With respect to the fertilizer trials, it was found that in Soeng Saang district the application of 156 kg/ha of 15-15-15 resulted in both the highest yield of cassava and highest net income.

INTRODUCTION

Cassava is an important cash crop in Thailand. Due to its favorable characteristics, such as relative ease of cultivation, drought tolerance and adaptation to poor soils, casava has become very popular, especially for poor farmers. During the past five years (1990-1994) the total planted area of cassava in Thailand ranged from 1.40 to 1.52 million hectares. The annual production of fresh roots was 19.0-20.7 million tons, while the value of exports of dry cassava products was more than 18 billion baht (US $

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[1] Dept. of Agricultural Extension (DOAE), Rice and Field Crops Promotion Division, Chatuchak, Bangkok, Thailand.

[2] Dept. of Agriculture (DOA), Rayong Field Crops Research Center, Huay Pong, Rayong, Thailand.

720 million) per year (Office of Agricultural Economics, 1995). The major cassava growing areas have spread mainly to the poor-soil and drought-prone areas in the northeastern and eastern parts of Thailand.

Despite the poor soil and droughty conditions in these areas, cassava grows fairly well. However, when cassava is grown on slopy land soil erosion may be serious even in areas with gentle slopes of less than 10%. Moreover, in an intensive four-year study it was shown that soil erosion caused by cassava cultivation was about twice as high as that caused by cultivation of mungbean, and three times as high as that caused by maize, sorghum or groundnut (Puttacharoen, 1992).

Due to the wide spacing used in planting cassava and its rather slow early growth during the first three months after planting, a lot of the soil surface remains exposed to the direct impact of fallen rain, causing severe soil erosion. Therefore, the Dept. of Agriculture (DOA), Kasetsart University and the Centro Internacional de Agricultura Tropical (CIAT) have conducted collaborative research into practical ways to decrease erosion in cassava production areas. The research showed that there were many ways to manage or improve cassava cropping systems that will enhance nutrient conservation and reduce erosion. Each management practice has its advantages and disadvantages: for example, some practices that control erosion require more money or more management, while the yield or income does not necessarily increase. The researchers did not know whether farmers would adopt these practices or not. Therefore, CIAT initiated collaboration with the Dept. of Agricultural Extension (DOAE) and DOA to establish a cassava-based cropping system management project and work with cassava farmers in the provinces, using a farmer participatory research approach. The objective of this project is to enhance farmers' awareness of the importance of soil conservation, to demonstrate a wide range of soil erosion control practices, to let farmers select the most appropriate ones and test these methods on their own fields, so they will develop the most useful practices for their own conditions. This in turn is likely to enhance adoption and the continued use of these practices even after the project is finished.

FARMER PARTICIPATORY RESEARCH (FPR) ON CASSAVA SOIL MANAGEMENT

Objective

To enhance the development and adoption by farmers of improved cassava cropping systems and cultural practices that will maintain soil productivity and reduce erosion while sustaining a reasonable farm income.

Location of the study

1. Soeng Saang district of Nakhon Ratchasima province in the lower Northeast.
2. Wang Nam Yen district of Sra Kaew province in the eastern part of Thailand.

Responsible organizations

1. Rayong Field Crops Research Center of the Field Crops Research Institute of the Dept. of Agriculture (DOA).
2. Field Crops Sub-Division, Rice and Field Crops Promotion Division, Dept. of Agricultural Extension (DOAE).
3. Centro Internacional de Agricultura Tropical (CIAT).
4. Thai Tapioca Development Institute (TTDI) Research and Training Center in Nakhon Ratchasima province.

Plan of Implementation

1. To select appropriate areas and within those select the most suitable pilot sites.
2. To collect information on the agro- and socio-economic conditions of cassava farmers in the pilot sites.
3. To develop a plan of action together with research/extension staff and farmers in group meetings in the selected pilot sites.
4. To establish demonstration plots in Pluak Daeng, Rayong province (1st year), and at the TTDI Research and Training Center in Nakhon Ratchasima (2nd year).
5. To provide training for participating farmers and let farmers select the most useful treatments in the demonstration plots:
6. To let farmers select treatments and implement farmer participatory research trials on soil erosion control, fertilization and varieties on their own fields in the two pilot sites.
7. To organize a study tour for participating farmers to the TTDI Research and Training Center to see and discuss alternative management practices.
8. To jointly harvest the trials and present and discuss the results during a farmers' field day in order to select best-bet treatments for next year's trials.

Procedure

1. Approprriate Area Exploration and Selection

The criteria for the selection of appropriate areas are: 1. cassava is an important crop in the area, both at present and in the future; and 2. cassava is planted on slopes with serious soil erosion problems. The first step in the process was area exploration. Three provinces, namely Rayong, Nakhon Ratchasima and Sra Kaew, were explored by conducting preliminary rapid rural appraisals (RRA). The most suitable pilot sites were selected by analyzing the RRA results. It was found that in Rayong province most farmers favored the planting of rubber and fruit trees as the main crop and cassava only as an intercrop. Thus, the cassava growing area there is likely to decrease. After this initial exploration, only two locations, i.e. Soeng Saang district in Nakhon Ratchasima province and Wang Nam Yen district of Sra Kaew province were selected.

2. Exploration of Agro- and Socio-economic Conditions of Farmer in the two Pilot Sites

A Rapid Rural Appraisal (RRA) technique was used to select the pilot sites, to ensure that the selected locations are indeed suitable for this project, and to collect baseline information about the socio-economic conditions and the agricultural practices used at the onset of the project. The results of these RRAs are summarized in **Tables 1-13**.

3. Group Meetings with Farmers

Farmers' meetings were held in the two selected pilot sites, i.e. Wang Sombuun village in Wang Nam Yen district and Noon Sombuun village of Soeng Saang district, to discuss the objectives, principles and procedures of the project with the farmers, local extension staff and village leaders. The farmers analyzed and decided for themselves whether they wanted to participate in the project.

4. Demonstration Plots at the Research Center

Demonstration plots were established along contour lines by cassava researchers to show farmers a wide range of management practices to help reduce soil erosion in cassava fields. These demonstration plots were established in two locations, one in 1994/95 in Pluak Daeng, Rayong province, and the other in 1995/96 at the TTDI Research and Training Center in Huay Bong of Nakhon Ratchasima province. Unfortunately, some demonstration plots in Pluak Daeng were lost due to flooding. There were 24 treatments in the demonstration plots, such as the growing of peanut, mungbean, soybean, sesame, pumpkin and sweet corn as intercrops in cassava. Also included were contour barriers or hedgerows of vetiver grass, lemon grass, citronella grass, sugarcane, ruzie grass (*Brachiaria ruziziensis*), mulberry and king grass; as well as practices like the application of grass mulch, planting cassava at closer spacing, on contour ridges, and the use of chemical fertilizers and/or chicken manure or various green manuring practices. Soil lost due to erosion collected in plastic-covered channels dug along the lower side of each plot. These sediments were weighed twice during the cropping cycle and a sample was taken to the laboratory and dried to calculate the amount of dry soil lost in each treatment. The amount of sediments in the channel of each plot was a clear demonstration to the farmers about the quantities of soil lost by erosion due to each treatment. Results of these FPR demonstration plots are shown in **Tables 14** and **15**. It is clear that each treatment had a different effect on cassava yield and on erosion. These demonstrations plot in two locations provided farmers with examples or alternatives for them to select some methods that may be useful in their own fields and under their own conditions.

Table 1. Secondary data of Soeng Saang district of Nakorn Ratchasima, Baan Khai district of Rayong and Wang Nam Yen district of Sra Kaew provinces in Thailand in 1994.

District Province	Soeng Saang Nakorn Ratchasima	Baan Khai Rayong	Wang Nam Yen Sra Kaew
Latitude (°N)	14° 20'N	12° 40'N	13° 40'N
Altitude (masl)	~100	~400	~300
Rainfall (mm/yr)	948	~1400	1404
Rainy season (>60mm)	April-Oct.	April-Oct.	April-Nov.
<u>Soils</u>	loamy Paleustults white sandy loams red or black clay loams	loamy Paleustults white sandy loams	clayey Haplustults dark brown or red clay soils with many rocks
<u>Landscape</u>	rolling	rolling	hilly
- cassava	on long gentle slopes	on long gentle slopes (upper part)	on short steep (10-20%) slopes
- sugarcane		lower part of slope	
- rubber		lower part of slope	
<u>Main crops</u>(rai)[1]			
- cassava	122,200		63,259
- rubber	190		-
- pineapple	-		
- sugarcane	11,900		57,090
- maize	10,000		116,370
- rice	39,234		38,341
- soybean	-		83,215
- fruit trees	15,651		-
- cotton	-		13,238
- sunflower	-		5,911
- mungbean	-		10,290
- sorghum	-		3,722
<u>Yield</u> (t/rai)			
- cassava	2.7	2.5-5.0	2.65
- sugarcane	10		8.25
- maize	0.5		0.70
- rice	0.5		0.41
- soybean	-		0.26
- mungbean	-		0.11
<u>Farm size</u> (rai/fam.)			
Total	25-150		20-140
- cassava	15-20		10-60
- sugarcane	30		36
- rubber	20		-
- maize	10-15		10-80
- rice	-		12
<u>Land ownership</u>	presently STK next year SPK 4-01[2]		presently STK in future SPK 4-01

[1] 1 ha = 6.25 rai
[2] maximum 100 rai per family

Table 2. Cropping systems, cassava varieties and agronomic practices in various subdistricts of Nakorn Ratchasima, Rayong and Sra Kaew provinces of Thailand in 1994.

Subdistrict District Province	Noon Sombuun Soeng Saang Nakorn Ratchasima	Baang But Baan Khai Rayong	Wang Sombuun Wang Nam Yen Sra Kaew
Cropping Systems [1]	C monocrop on gentle slopes	C monocrop on gentle slopes C between rubber	C monocrop on gentle slopes, rotated with M-Mu
Varieties	R60, R1, R3	R1, R3, R60, R90	R60, R3, R90
Yield (t/rai)[2]	2.5-4.0	2.5-5.0	2-4
Land preparation	tractor+3 disc (1x) no ridge or ridge-up with weeding	tractor+7 disc (2x) ridge with tractor contour or up-down	tractor+3 disc (1x) ridge with tractor mainly up-down slope
Planting method			
stake size (cm)	15-20	15-20	15-20
stake position	vertical	vertical	vertical
spacing (cm)	70x50 to 120x100	90x60 5-6 C rows between rubber	-
Fertillizer use			none to cassava
- manure (t/rai)	some	-	
- 15-15-15 (kg/rai)	12-50 at 2 MAP	-	to maize or soybean
- 13-13-21 (kg/rai)	-	50 at 1-2 MAP[3]	
Weeding - first	hoe or Gramoxone	hand, 1-2 MAP[3]	Pre-emerg. herb.
- second	hoe or hand tractor	Gramoxone	hoe
- third	Gramoxone or knife	Gramoxone	
Time of planting			
- cassava - first crop	March-May (red soil)	April	April
- second crop	Oct-Nov (white soil)	June	-
- sugarcane	March-May	March-May	-
- maize	-	-	May-June
Time of harvest			
- cassava - first crop	Dec-Febr	-	Nov-Febr
- second crop	Sept-Dec	-	-
- sugarcane	Dec-Febr	Dec-Febr	-
- maize	-	-	Aug
Method of harvest	by hand or tool	by hand or tool	tractor + blade

[1] C = cassava, M = maize, Mu = mungbean
[2] 1 ha = 6.25 rai
[3] after first weeding

Table 3. Cassava utilization and socio-economics in various villages of Nakorn Ratchasima,Rayong and Sra Kaew provinces of Thailand in 1994.

Subdistrict District Province	Noon Sombuun Soeng Saang Nakorn Ratchasima	Baang But Baan Khai Rayong	Wang Sombuun Wang Nam Yen Sra Kaew
Cassava utilization (%)			
- chipping floor	10-50	in dry season	100
- starch factory	50-90	in wet season	0
Prices			
- fresh roots (B/kg) [1/]	1.25-1.50	0.9	1.10-1.15
- dry chips (B/kg)	2.80	-	-
- 15-15-15 fert. (B/50 kg)	285	280	-
- 13-13-21 fert. (B/50 kg)	-	290	-
- urea (B/50 kg)	-	-	-
- Grammoxone (B/5 liters)	-	470	-
- pre-emerg. herbicide (B/rai)	-	-	55
- labor (B/day)	70	80	-
Costs (B/rai)			
-land preparation- plowing	100	110	100-120
- discing	-	70	80-90
- ridging	-	90	80-100
-planting	70-100	90-100	80-100
-fertilization	85-315	350	0-185
-weeding	400-500	400	260[2)]-760
-harvest[3]	250-400	300-600	440-600
-transport[4]	150-600	325-650	210-240
Total	1,055-2,015	1,645-2,370	1,150-2,075
Gross income (B/rai)	3,125-6,000	2,250-4,500	3,600-4,200
Net income (B/rai)	1,485-4,625	505,2,300	1,525-4,200

[1/] Root prices	Dec'94	Aug'94	Jan'94
[2/] own labor not included			
[3/] Harvest cost (B/ton)	100	120	150
[4/] Transport cost (B/ton)			
- to local chipping floor	50-100	100	70-80
- to starch factory	130-150	130	160

Table 4. Topography, soils, crops and cropping systems in various villages of Noon Sombuun subdistrict, Soeng Saang district, Nakorn Ratchasima province of Thailand in 1994.

Village:	#1 and 2	#4	#10
Topography	gentle slopes	gentle slopes with some hills	rolling with some steep slopes
Soil types	black soil red soil white soil (s.c.l.)[1] some laterite	white soil (low fert.) red soil (fertile) black soil (fertile) no stones	red soil (100%) some big stones
Land use [2]			
- red soil	C, Sc, M ,Pa, Ch, F	C, M, Veg, Sp, F	C, F
- white soil	C, Sc, Wm, Pu	C	
- black soil		Veg, Pu	
- lowlands		rice	
- irrigated land	Pa		Pa, Ta
Crop choices	SC mainly by rich farmers Pa in irrig. areas	Many crops to spread income over year Rice in lowlands	Ta or Pa in irrig areas Too dry for M cotton ,soybean
Livestock	Few have cattle,pigs	Few have cattle, water buffaloes, pigs, chickens, ducks, fish	somme have cattle
Off-farm activities	sericulture	none	none
Cassava yield(t/rai)			
- initially or now with fert.		4-5	4-5
- now with little/no fert.		2-3	2.5-3
Cassava utilization (%)			
- to local chipping floors	mainly poor	mainly poor	10-20
- to starch factory in Korat	mainly rich	mainly rich	80-90

[1] s.c.l. = sandy clay loam

[2] C = cassava, M = maize, Sc = sugarcane,
F = fruit trees (banana, tamarind, mango, papaya),
Ta = tamarind, Pa = papaya, Sp = sweet potato, Ch = chili peper, Pu = pumpkin,
Wm = watermelon, Veg = vegetables

Table 5. Cassava cropping systems, varieties and agronomic practices in various villages of Noon Sombuun subdistrict, Soeng Saang district, Nakorn Ratchasima province of Thailand in 1994.

Village:	#1 and 2	#4	#10
Cropping systems	C monoculture continuous cropping	C monoculture sometimes rot. M	C monoculture continuous cropping
Varieties	R60, R1, R3, R5 Pumpuang	R60, R1, R3, R90 R5, KU-50, CMC Pumpuang	R60 (80%), R3 R90, KU-50, R5 Red Rayong, Red KU
Land preparation	tractor+3disc (1x) no ridging	tractor+3disc (1x) no ridging	tractor+3disc (1x) no ridging
Planting method			
-stake position	vertical	vertical	vertical
-spacing (cm)	-	70x50 (white soil) 120x100 (red soil)	- 120x100 (red soil)
Fertilization (kg/rai)			
-15-15-15	12-25	25-50 (white soil)	25
-manure	-	sometimes	sometimes
Weeding			
-first	hoe	hoe or Gramoxone	hoe
-second	hoe	hoe or hand tractor	Gramoxone
-third	hoe	knife	knife
Time of planting			
-first crop	March	Febr-Apr (red soil)	March-Apr
-second crop	Nov	Oct-Nov (white soil)	-
Time of harvest			
-first crop	Dec	Dec-March	Jan-Febr
-second crop	Aug	Sept-Dec	-

Table 6. Principal cassava varieties and their characteristics in several villages of Noon Sombuun subdistrict, Soeng Saang district, Nakorn Ratchasima province of Thailand in 1994.

Village:	# 1 and 2	#4	#10
Main varieties	R60, R1, R3	R60, R1, R3	R60, R3, R1
Secondary varieties	R90, R5	R90, R5	R90, R5
Characteristics			
Rayong 1	-	Drought tolerant Low yield Low starch	-
Rayong 60	High yield Low starch Good plant type Convenient-weeding	High yield Low starch Susc. root rots Good in white and red soil	High yield Low starch Drought tolerant
Rayong 3	High yield (esp. 1st yr) High starch Short stature	High starch	High yield High starch Low germination after storage Difficult harvest
Rayong 90	-	Only good yield in white soil High starch	High yield High starch Difficult weeding Low germination after storage
Rayong 5	-	High yield High starch	Drought tolerant

Table 7. Main problems and farmer solutions in several villages of Noon Sombuun subdistrict, Soeng Saang district, Nakorn Ratchasima province of Thailand in December 1994.

	Problems	Solutions
Village #1 and 2	1) Low price (except this year)	
	2) Lack of labor	Need cassava harvester
	3) Decreasing yields (20% in second yr)	Increasing use of fertilizer
	4) Root rots (7-14% yield loss)	
Village #4	1) Erosion (5-10% yield loss)	Lemon grass barriers Fill gulleys back in Plant bamboo in higher areas
	2) Root rot in white soil during last 2 years (esp.in R60)	
	3) Spider mites (esp.in red soil, R60)	
	4) Decreasing yields	Need to apply fertilizers after 4-5 years
Village #10	1) Drought (25% yield loss)	
	2) Erosion (14% yield loss)	Plant vetiver grass Plant on contour ridges (but break with heavy rain) Tamarind + ruzie grass in contour strips
	3) Spider mites (50% yield loss in some areas)	
	4) Lack of labor (esp.for harvest)	Use cassava harvester

Table 8. Cassava processing in Soeng Saang district and in Korat city of Nakorn Ratchasima province of Thailand in December 1994.

	Soeng Saang district	Korat city
Manufacturer	Tirapong Chipping Factory	Sa-Nguan Wongse Industries Co.
Ownership	private	private
Products	cassava chips	raw starch modified starch glucose (next year)
Production capacity	2.56 ha drying floor	185,000 starch (largest in Thailand)
Actual production (t/year)	about 3,000 chips	140,000 starch 6,000-12,000 mod. starch
Production period	5 months (Oct-Febr)	year-round, 24 hrs/day
Raw mat. needs (t fresh roots/year)		875,000
Price fresh roots (B/kg)	1.0 → 1.35-1.40[1)]	→ 1.58 (at 30% starch)
Price products (B/kg)	2.80 chips	
Conversion ratio	2.0-2.4 fresh roots=1 chips	5 fresh roots=1 starch
Starch content determ.	by variety and break roots	measure starch content
Technology	chipped roots spread, turned over, dried in 3 days	washed roots grated, centrifuged flash-dried
By products/waste		1) Waste fiber (50-58% starch) pressed, dried, used in pellets or chicken feed 2) Peel sold as compost or for mushroom production (B300/t) 3) Waste water sedimented,→ irrigate eucalyptus plantation
Raw material cost/total cost	95-100	85-88

[1)]plus B 0.02/kg for truck driver

Table 9. Topography, soils, crops and cropping systems in two villages of Wang Sombuun subdistrict, Wang Nam Yen district, Sra Kaew province of Thailand in 1995.

	Village #5	Village #3
Topography	rolling, foothills	rolling, foothills
Soil types	reddish-brown clay loam many brown/purple stones	brown/purple stones big rocks on 30% of area
Land use	high areas: cassava or cassava rotated with maize and soybean low areas: cassava, maize, soybean, mungbean, cotton, sunflower, eggplant, custard apple, banana, cucumber, mango	cassava rotated with maize and soybean
Crop choices	1. maize 2. cassava 3. soybean/mungbean/sunflower	1. maize 2. cassava 3. mango
Livestock	chickens, water buffalo beef cattle, fish	chicken, beef cattle
Off-farm activities	part-time work mainly in construction	part-time work
Cassava yield	Rayong 1: 2-3 t/rai Rayong 60: 3-4 t/rai Rayong 90: 4-6 t/rai	Rayong 3: 2-3 t/rai Rayong 60: 3-5 t/rai Red Tip: 2-3 t/rai
Cassava utilization (%)		
-chipping floor (mainly for sale to starch factory)	99	100
-starch factory (>100 km)	1	0

Table 10. Cassava cropping systems, varieties and agronomic practices in two villages of Wang Sombuun subdistrict, Wang Nam Yen district, Sra Kaew province of Thailand in January 1995.

	Village #5	Village #3
Cropping systems	cassava monocropping rotated with maize and soybean	cassava monocropping rotated with maize and soybean
Varieties	R90 > R3 > R60 > R1	R60 > Red Tip > R3 > R90
Land preparation	tractor + 3disc (2x) tractor + 7disc (1x) ridging (mostly up-down slope)	tractor + 3disc (1x) ridging
Planting method		
-stake position	vertical or inclined	vertical or inclined
-spacing (cm)	R60 at 50x100 R90 at 50x75 or 50-60x100 R1 at 100x100	R90 at 50-60x100
Fertilization (kg/rai)	no fertilizer to cassava or 6-20 of 15-15-15 at 3 MAP	20 of 15-15-15, 13-13-21 or 25-7-7
Weed control	1) Alachlor, Diuron as pre-emerg. 2) Gramoxone as post emerg. 3) hoe	1) Alachlor as pre-emerg. 2) Gramoxone as post emerg. 3) hoe or knife
Harvest	by tractor + harvester manual lifting and loading	
Time of planting	Apr-May	Apr-May
Time of harvest	Dec-Jan	Nov-Jan

Table 11. **Principal cassava varieties and their characteristics as well as the main problems mentioned by farmers in two villages in Wang Sombuun subdistrict, Wang Nam Yen district, Sra Kaew province of Thailand in January 1995.**

Village	Village #5	Village #3
Main varieties	R90, R3, R60, R1	R60, Red Tip, R3, R90
Characteristics		
-Rayong 1	low yield	-
-Rayong 3	yields are decreasing	high yield, high starch, small plant
-Rayong 60	high yield, low starch, good weed control, not always accepted by starch factory	high yield, good soil cover
-Rayong 90	high yield, high starch good weed control	good price, decreasing yield
-Red Tip	-	tall plant, low yield, good weed control
Problems	1. low price 2. irregular rainfall 3. lack of labor 4. lack of capital 5. erosion 6. good varieties difficult to find and expensive 7. decreasing yields when planted contiuously	1. lack planting material of good varieties 2. lack knowledge about fertilizers 3. erosion 4. diseases 5. lack of labor

Table 12. Cassava utilization and socio-economics in two villages in Wang Sombuun subdistrict, Wang Nam Yen district, Sra Kaew province of Thailand in January 1995.

	Village #5	Village #3
Cassava utilization (%)		
- chipping floor [1]	99	100
- starch factory [2]	1	0
Prices		
- fresh roots (B/kg)	1.19-1.20 in chipping yard 1.32 in starch factory	
- 15-15-15 fert. (B/50 kg)	285	
- 13-13-21 fert. (B/50 kg)	300	
- urea (B/50 kg)	250	
- labor (B/day)	100	
Production costs (B/rai)		
- land preparation - plowing	100-120	100
- discing	80-90	-
- ridging	80-100	80
- planting	100	80
- weed control		
- pre-emergent		
- herbicide cost	160	60
- labor	100	40-50
- post emergent		
- Gramoxone cost	200	160
- labor	100	-[3]
- manual control with hoe or knife	200	-[3]
- fertilization		
- fertilizer cost	100	120
- labor	85	-[3]
- harvest		
- digging (by tractor)	150	150
- collecting	300-450	290
- transport	210-240	225
- land rent	400	-
Total	1,500-2,195	1,310[3]
Gross income (B/rai)	3,600-4,200[4]	3,600[4]
Net income (B/rai)	1,800-2,700[4]	2,290[3]

[1] most chipping floors do not chip, but transport fresh roots to starch factories
[2] starch factories in Kabin Buri or Chanta Buri, both about 100 km away
[3] own labor not included
[4] high gross and net income due to unusually high cassava price

Table 13. Cassava processing in three chipping factories in Wang Nam Yen district of Sra Kaew province of Thailand in January 1995.

Manufacturer	Wangmai Chanaphon	Wangsombuun	Rungjaroen
Products	cassava chips fresh roots	cassava chips (150) fresh roots (100)	cassava chips fresh roots (little)
Production capacity	5 rai drying floor	16 rai drying floor	15 rai drying floor
Actual production (t fresh roots/3days)	-	150	100
Production period	Nov-March	Nov-March	Nov-Jan
Raw mat.needs (t fresh roots/year)	-	4,500	-
Conversion ratio (fresh roots to chips)	2.08-2.33	2.08	2.20
Starch content determination	by variety and break roots	by variety and break roots	by variety and break roots
Technology	chipped roots spread, turned over, dried in 3 days	same	same
Price fresh roots (B/kg)	1.00-1.20	1.00-1.23	1.00-1.15
Price product (B/kg chips)	2.80-3.00	2.75-2.95	2.70-2.80
Production cost (B/kg chips)	-	2.50	2.67
Raw material cost/total cost	-	0.83-1.02	0.82-0.95

5. Farmers Training

Farmers from the two pilot sites that were interested in participating in the project were invited to join a two-day training course at the Rayong Field Crops Research Center with the objective of: 1. increasing the farmers' knowledge and understanding of soil and water conservation in cassava production; 2. to discuss with the farmers how to conduct, with the help of researchers and the extension workers, FPR trials on their own fields, and 3. to increase their knowledge on new cassava varieties and production techniques. Furthermore, they visited the demonstration plots on management practices to reduce erosion and discussed the advantages and disadvantages of each treatment. Each farmer was asked to score the various soil erosion control treatments, considering their likely effect on yield and income, their effectiveness in reducing erosion, and whether they seem to be useful under the farmer's own conditions in the village. The results of these farmers' evaluations are also shown in **Table 14**.

6. FPR Trials on Soil Erosion Control, Varieties and Fertilizer Use

After the training session and farmers' evaluation of the demonstration plots, researchers from DOA, together with extension workers from DOAE, discussed with collaborating farmers in the pilot sites the type of FPR trials that they wanted to do on their own land, as well as the treatments to be included, plot size, management etc. Farmers in Soeng Saang district decided to conduct trials on erosion control, on fertilization and on cassava varieties, while farmers in Wang Nam Yen district decided to conduct only trials on erosion control and varieties.

6.1 Soil erosion control trials

FPR team members and collaborating farmers selected the most appropriate areas and layed out the FPR erosion control trials for the farmer along contour lines. The farmers participating in the project discussed and selected the treatments they wanted to test in their own trials:

- Nine farmers in Soeng Saang chose to do erosion control trials and selected five treatments, namely 1. their own traditional practice of up-and-down ridging; 2. vetiver grass contour barriers; 3. contour ridging; 4. sugarcane contour barriers; and 5. intercropping. However, farmers selected different intercrops: five farmers selected peanut, one selected sweet corn and one farmer selected mulberry bushes instead of vetiver grass as contour hedgerows.

6.2 Cassava varieties and fertilizer trials

FPR trials were also conducted on varieties and fertilizer use by those farmers that wanted to participate but did not have slopy land to conduct erosion control trials. In the variety trials, five varieties were compared, namely Rayong 1, Rayong 3, Rayong 5, Rayong 60, Rayong 90 and Kasetsart 50.

In the FPR fertilizer trials different combination of N, P and K were applied with the objective of determining which nutrients produced the greatest benefits at the lowest

Table 14. Preference rating by 24 farmers from Soeng Saang and 35 from Wang Nam Yen districts of the various treatments in the demonstration field in Pluak Daeng, Rayong province in Thailand in January, 1995.

Treatments	Land preparation	Ridging	Spacing (m)	Fertilization (kg/rai)[1]	Farmer rating[2]	
					Soeng Saang	Wang Nam Yen
1. traditional	plow+harrow	no	1.0x1.0	50 15-15-15	1	3
2. close spacing	plow+harrow	no	0.8x0.8	50 15-15-15	4	16
3. no fertilizers	plow+harrow	no	0.8x0.8	-	1	17
4. little fertilizers	plow+harrow	no	0.8x0.8	25 15-15-15	5	19
5. chicken manure	plow+harrow	no	0.8x0.8	250 manure	2	12
6. fert. +manure	plow+harrow	no	0.8x0.8	25+250 manure	0	16
7. no tillage	plant with hoe	no	0.8x0.8	50 15-15-15	0	1
8. cassava harvester	plant after harvester	no	0.8x0.8	50 15-15-15	4	15
9. reduced tillage	plow only	no	0.8x0.8	50 15-15-15	6	19
10. up-down ridging	plow+harrow	up-down	0.8x0.8	50 15-15-15	1	4
11. contour ridging	plow+harrow	contour	0.8x0.8	50 15-15-15	3	26
12. dry grass mulch	plow+harrow	no	0.8x0.8	50 15-15-15	0	10
13. *Crotalaria* mulch [3]	plow+harrow	no	0.8x0.8	50 15-15-15	3	1
14. *Canavalia* mulch [3]	plow+harrow	no	0.8x0.8	50 15-15-15	3	3
15. vetiver grass barriers	plow+harrow	no	0.8x0.8	50 15-15-15	12	26
16. elephant grass barriers	plow+harrow	no	0.8x0.8	50 15-15-15	1	2
17. ruzie grass barriers	plow+harrow	no	0.8x0.8	50 15-15-15	7	22
18. lemon grass barriers	plow+harrow	no	0.8x0.8	50 15-15-15	0	25
19. *Leucaena leuc.* barriers	plow+harrow	no	0.8x0.8	50 15-15-15	0	4
20. *Flemingia conj.* barriers	plow+harrow	no	0.8x0.8	50 15-15-15	2	7
21. peanut intercrop	plow+harrow	no	0.8x0.8	50 15-15-15	5	20
22. mungbean intercrop	plow+harrow	no	0.8x0.8	50 15-15-15	1	9
23. maize intercrop	plow+harrow	no	0.8x0.8	50 15-15-15	8	19
24. watermelon intercrop	plow+harrow	no	0.8x0.8	50 15-15-15	1	5

[1]1 ha = 6.25 rai

[2]number of farmers giving highest rating to that treatment

[3]*Crotalaria* and *Canavalia* were planted between cassava rows, pulled up at 2 months and mulched on the soil surface

costs. The treatment were as follows:

1. $N_0P_0K_0$ No fertilizer application
2. $N_{50}P_0K_0$ 50 kgN/ha as urea
3. $N_{50}P_{50}K_0$ 50 kgN/ha as urea and 50 kg P_2O_5/ha as triple superphosphate
4. $N_{50}P_0K_{50}$ 50 kgN/ha as urea and 50 kg K_2O/ha as potassium chloride
5. $N_{25}P_{25}K_{25}$ 166 kg/ha of 15-15-15 compound fertilizer
6. $N_{50}P_{50}K_{50}$ 332 kg/ha of 15-15-15 compound fertilizer

In Soeng Saang district three farmers conducted variety trials and five farmers conducted fertilizer trials. On the other hand, in Wang Nam Yen only varietal trials were conducted by seven farmers.

7. Study Tour

In 1995/96 demonstration plots with 24 treatments were established at TTDI's Research and Training Center in Huay Bong of Daan Kun Tod district in Nakhon Ratchasima province. Therefore, in August 1995 participating farmers from the two pilot sites and farmers from nearby villages visited the demonstration field. They studied and compared the advantages and disadvantages of each soil erosion control method and then scored each treatment in terms of yield potential, effectiveness in erosion control and general usefulness for their own conditions. Results of the demonstration plots as well as the farmer's preferences are shown in **Table 15.**

8. Harvesting Field Day

All FPR trials were harvested at about ten months after planting. The participating farmers in each pilot site were asked to harvest their trials on the same day so that the FPR team members could help in determining the yield and starch content in each treatment. After all harvest data were tabulated they were presented and discussed with the participating farmers. These data from the various FPR trials were then used as the basis for developing a plan for the following year.

Results of FPR Trials

1. FPR Erosion Control Trials

Results from the FPR erosion trials in Soeng Saang (**Table 16**) show that growing sugarcane as contour hedgerows gave the highest net return of 34,715 baht/ha, while planting vetiver grass contour barriers was the most effective treatment in reducing soil erosion. In this treatment only 8.5 t/ha of dry soil was lost due to erosion, while the highest soil loss of 24.8 t/ha was observed with up-and-down ridging.

Research results from Wang Nam Yen district (**Table 17**) indicate that mungbean intercropping produced the highest net return of 30,880 baht/ha (1,235 US$/ha), followed by Ruzie grass contour barriers, which produced 30,300 baht/ha (1,212 US$/ha). Ruzie grass contour barriers were also very effective in reducing erosion, but it was observed

Table 15. Cassava yield, starch content and dry soil loss due to erosion in 24 treatments in demonstration plots at TTDI in Huay Bong, Nakorn Ratchasima province of Thailand in 1995/96.

Treatments	Root yield (t/ha)	Dry soil loss (t/ha)	Farmer preference	
1. peanut intercrop	8.73[3]	30.81	19[1]	0[2]
2. soybean intercrop	17.11	25.14	14	0
3. sesame intercrop	11.72	20.02	1	0
4. pumpkin intercrop	19.62	26.93	21	10
5. vetiver grass barrier	20.32	23.90	11	24
6. sugarcane barrier	19.50	34.07	16	0
7. lemon grass barrier	18.33	26.48	15	20
8. ruzie grass barrier	10.82	19.14	3	11
9. contour ridging	20.61	18.79	24	5
10. mulberry tree barrier	11.04[4]	14.76	7	0
11. citronella grass barrier	14.32[4]	16.81	8	8
12. King grass barrier	5.62[4]	16.43	0	0
13. *Crotalaria* mulch	15.61	15.66	1	2
14. *Canavalia* mulch	17.65	11.99	1	2
15. pigeon pea mulch	13.95	14.61	0	0
16. sweet corn intercrop	22.17	18.92	32	4
17. chicken manure	19.26	21.59	28	9
18. fertilizer+manure	23.44	18.66	30	15
19. fertilizer+compost	20.94	13.47	23	6
20. traditional practices	18.33	18.00	15	9
21. up-down ridging	17.15	24.57	3	0
22. closer spacing	19.82	33.59	11	7
23. no fertilizers	19.48	28.46	0	0
24. little fertilizers	15.54	27.06	2	4

[1]number of farmers from Soeng Saang considering treatment as "good"
[2]number of farmers from Wang Nam Yen considering treatment as "good"
[3]low yield because of continuous intercrop competition as peanut was not harvested
[4]low yield due to excessive shading from hedgerow species

that the seed and stolens of the grass soon spread into the cassava field, thus becoming a serious weed problem. Vetiver grass contour barriers were only intermediately effective in reducing erosion (**Table 17**). Vetiver grass contour barriers were less effective in reducing erosion in this location because the grass established a solid hedgerow only gradually, while heavy rains after cassava planting caused rather severe soil loss due to erosion.

After the harvest, the FPR team presented the collected data to the participating farmers in the two pilot sites. They exchanged opinions and discussed together the advantages and disadvantages of the different methods for soil erosion control. Farmers in Soeng Saang indicated that vetiver grass contour barrier had the highest efficiency in erosion control, followed by contour ridging and sugarcane contour barriers. Later, farmers had a group meeting and selected the management practices they wanted to test in the trials in the following year. These include:

1. the farmer's own practice of up-and-down ridging
2. sweet corn-cassava intercropping
3. squash/pumpkin-cassava intercropping
4. sugarcane contour barriers
5. vetiver grass contour barriers

Similarly, farmers in Wang Nam Yen considered that vetiver grass contour barriers had the highest efficiency in erosion control. Although the research results did not show this grass to be particularly effective in erosion control, in some trials the grass had shown its great potential in reducing soil loss due to erosion. Farmers expected this method to be the most effective in the long-term. The farmers group of Wang Nam Yen selected the following treatments for the next year's trials:

1. the farmer's own practice of up-and-down ridging
2. contour ridging
3. vetiver grass contour barriers
4. mungbean-cassava intercropping
5. dried grass mulch application between cassava rows

2. FPR Variety Trials

In Soeng Saang, the results of the variety trials in which six varieties were compared, showed that Rayong 90 produced the highest yield of 37.0 t/ha and had the highest starch content of 29.5%, followed by Kasetsart 50 with a yield of 35.7 t/ha and starch contant of 28.1% (**Table 18**).

In Wang Nam Yen, Rayong 90 produced the highest yield (32.5 t/ha). The next variety was Rayong 5 with slightly less yield (30.7 t/ha). On the other hand, Rayong 5 had the highest starch content (30.3%), while the starch content of Rayong 90 and Kasetsart 50 were equal (28.7%) (**Table 18**).

3. FPR Fertilizer Trials

Fertilizer trials were conducted only in Soeng Saang. The results (**Table 19**) indicate that the application of 25 kg N, 25 P_2O_5 and 25 K_2O/ha gave the highest yield of 31.6 t/ha and also the highest net income of 32,113 baht/ha. This treatment corresponds with an application of 166 kg/ha of 15-15-15 fertilizers, which happens to be the present fertilizer recommendation.

Constraints

The following constraints were the main cause of problems encountered in the FPR project:

1. The local extension workers, who are responsible for this project in the pilot sites, are often busy with other routine work, so they could not spend much time in this project.
2. Some participating farmers did not take good care of their trials.
3. In some erosion plots there were slopes in two directions causing problems in the collection of eroded sediments.
4. In the rainy season, the run-off is very heavy and farmers were not always able to protect their FPR erosion trials from run-off coming from fields above. This damaged some plots and resulted in excessive erosion in some plots not at all related to treatments. This reduced the reliability of the erosion data.

FUTURE PLANS

New FPR trials are already being implemented in the same districts to confirm the results of last year. Some participating farmers who showed little interest in the project have been replaced by new farmers. In addition, the project has selected some more suitable areas for the soil erosion control plots.

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Table 16. Average results of nine FPR trials on erosion control conducted by farmers in Noon Sombuun village of Soeng Saang district, Nakorn Ratchasima province of Thailand in 1995/96.

Treatments	No.of plots	Soil loss (t/ha)	Cassava yield (t/ha)	Gross income[1]	Production costs	Net income	No.of farmers[2] liking treatment
				<------------	(baht/ha)	------------>	
Up/down ridging	9	24.8	29.8	31,349	9,594	21,755	0
Vetiver grass hedgerows	7	8.5	35.2	36,999	10,219	26,780	18
Contour ridging	9	9.8	34.0	35,720	9,781	25,939	17
Sugarcane hedgerows	9	11.8	32.2	46,934	12,219	34,715	10
Peanut intercropping	8	13.3	28.9	43,409	12,719	30,690	0
Sweet corn intercropping	1	12.6	25.5	38,775	11,019	27,756	1
Mulberry hedgerows	1	16.1	40.0	43,000	10,219	32,781	0

[1] Prices: cassava fresh roots : B 1.05/kg
peanut fresh pods : 8.00/kg
sweet corn : 1.00/cob
sugarcane : 2.00/stem
mulberry leaves : 2.00/kg
1 US$ = B 25

[2]out of a total of 18 farmers.

Table 17. Average results of six FPR trials on erosion control conducted in Wang Sombuun village of Wang Nam Yen district, Sra Kaew province of Thailand in 1995/96.

Treatment	No. of plots	Cassava yield (t/ha)	Starch content (%)	Intercr. yield (t/ha)	Gross[1] income	Production[1] cost	Net income	Dry soil loss[2] (t/ha)	Farmer preferences[3]
					<----------	('000 B/ha)	--------->		
1) up/down ridging	5	28.7	26.4	-	34.44	10.75	23.69	18.1	0
2) vetiver grass hedgerows	6	23.1	26.4	-	27.74	10.62	17.12	14.6	15
3) contour ridging	6	26.8	28.1	-	32.22	10.94	21.28	8.2	0
4) intercropping with squash	3	26.4	23.9	-	31.69	10.62	21.07	12.3	0
5) intercropping with peanut	1	16.5	29.7	1.50	34.80	13.12	21.68	14.7	0
6) intercropping with mungbean	1	25.5	28.9	1.30	42.30	11.42	30.88	26.2	0
7) grass mulch	1	33.5	32.3	-	40.20	10.62	29.58	5.5	1
8) ruzie grass barriers	1	31.6	28.9	1	40.92	10.62	30.30	4.5	1
9) *Leucaena* hedgerows	1	24.2	27.6	-	29.06	10.62	18.44	7.1	0

[1]Prices:

fresh cassava roots	=	B 1.20/kg
fresh peanuts in pods	=	10.00/kg
dry mungbeans	=	9.00/kg
ruzie grass	=	3.00/kg
peanut seeds	=	16.00/kg
mungbean seeds	=	16.00/kg
contour riding	=	938/ha
up/down ridging	=	750/ha
normal cassava production costs	=	10,000/ha

[2]Only rough estimates of erosion due to some measurement problems

[3]Number of farmers selecting this as the best treatment

Table 18. Results of three FPR variety trials conducted by farmers in Noon Sombuun village of Soeng Saang district, Nakorn Ratchasima province of Thailand in 1995/96.

Farmer's name	Cassava yield (t/ha)						Starch content (%)					
	Rayong					KU	Rayong					KU
	1	3	5	60	90	50	1	3	5	60	90	50
1. Mr. Prasit	-	-	32.4	36.8	-	31.2	-	-	28.9	29.2	-	29.2
2. Mrs. Lek	22.0	9.0	20.5	15.5	20.0	20.0	26.1	25.3	25.9	19.8	29.8	27.9
3. Mrs Chuen	39.0	37.0	43.0	39.0	54.1	56.0	25.7	28.0	23.9	25.9	29.3	27.1
Average	30.5	23.0	32.0	30.4	37.0	35.7	25.9	26.6	26.2	25.0	29.5	28.1

Table 19. Average results of five FPR fertilizer trials conducted by farmers in Noon Sombuun village of Soeng Saang district, Nakorn Ratchasima province of Thailand in 1995/96.

Fertilizer rate N-P2O5-K2O (kg/ha)	Root yield (t/ha)	Gross income	Fertilizer cost	Net income
		<----------------	(baht/ha)	---------------->
0-0-0	28.6	30,030	0	30,030
50-0-0	29.2	30,660	811	29,849
50-50-0	31.0	32,550	1,755	30,795
50-0-50	30.7	32,235	1,261	30,974
25-25-25	31.6	33,180	1,067	32,113
50-50-50	30.8	32,340	2,133	30,207

Prices: cassava fresh roots : B 1.05/kg
urea : 365/50kg
triple superphosphate : 425/50kg
KCl : 270/50kg
15-15-15 : 320/50kg

FARMER PARTICIPATORY RESEARCH IN CASSAVA TECHNOLOGY TRANSFER IN INDIA

S. Ramanathan and M. Anantharaman[1]

ABSTRACT

The concept and methodology used in the transfer of technology (TOT) have undergone changes over the years corresponding to farmers' needs, and as a result, farmer participatory TOT has become more relevant, especially in complex diversified risk-prone (CDR) farming systems. The TOT in cassava, which largely belongs to the CDR farming system in India, is no exception to this.

The National Demonstration Programme (NDP) on cassava, which started in 1970, was the first organized attempt to transfer the improved cassava technologies, especially the hybrid varieties. The main objective of NDP was to convince the farmers about the production potential of the new cassava hybrids by conducting demonstrations in farmers' fields by scientists. It restricted the scope of farmers' participation in technology transfer. Their role was mainly confined to be the passive spectator of the demonstrations.

The scope of the farmers' participation was widened under the Operational Research Project (ORP) in the mid-seventies, which laid emphasis on the identification of constraints in the adoption of technologies. Though the farmers did not have much say in the technology transfer, they played a significant part in assisting the scientists in identifying the operational constraints to adopting the cassava technologies. The Lab-to-Land Programme (LLP), launched during 1979, witnessed greater participation of adopted farmers, by emphasizing direct linkages between scientists and farmers. The participation of the farmers was ensured right from the benchmark survey of farm families, the demonstration of cassava technologies, identification of potential spheres of development, and the dissemination of the impact of the program through fellow farmers and mass media. The impact assessment of the program revealed that there can not be a uniform package for transfer, and very often farmers try to blend the new technologies with their traditional practices. Hence, there is a need to evolve appropriate location-specific technologies suitable for various micro-environments.

On the realization of this fact, CTCRI has implemented a farmer participatory research program on cassava technology assessment, refinement and integration, which indicates the differential pattern of technology preferences in various farming situations.

INTRODUCTION

Cassava is a crop of small and marginal farmers operating under the complex, diversified and risk prone (CDR) system of agriculture in India. The Central Tuber Crops Research Institute (CTCRI) is spearheading the research and development of cassava in the country, together with the extension work being carried out by the Department of Agriculture/Horticulture of Kerala and Tamil Nadu, the two major cassava growing states in India. Following the changing trends in the agricultural transfer of technology (TOT) programs at the national level, the TOT programs of cassava too have undergone changes at appropriate times, facilitating more and more farmers' participation in the TOT process over the years.

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Historical Perspective of TOT in Cassava

During the early seventies (1971-74) National Demonstration (ND) on cassava was the pioneering attempt to transfer cassava technologies on a large scale, especially the hybrid varieties in India. This program, the oldest front-line extension project conceived by the Indian Council for Agricultural Research (ICAR), was implemented by various ICAR Institutes and Agricultural Universities, but with little direct participation of farmers, either in technology transfer or in their generation. The farmers' role was mainly confined to be the passive spectator of the demonstrations (**Table 1**).

Farmers' participation in cassava technology transfer was first introduced under the Operational Research Project (ORP) on cassava, implemented during 1976-81 in a suburb village near Thiruvananthapuram city of Kerala State. Although the beneficiaries of ORP did not have a say in the technologies of cassava to be transferred, they were the dominating partners in the identification of socio-economic and technological constraints in the adoption and spread of introduced cassava technologies envisaged under the ORP.

The scope of farmers' participation in cassava technology transfer was increased under the Lab-to-Land program (LLP) launched during 1979 to commemorate the Golden Jubilee celebration of ICAR. Right from the initial benchmark survey of the selected farm families up to the final impact survey of the program after withdrawal from a particular village, the beneficiary farmers enthusiastically took part in the TOT of improved cassava technologies. Occasions such as laying out the demonstration plots, group meetings, harvest festivals etc. were effectively utilized to enlist the participation of both the beneficiary as well as non-beneficiary farmers in the technology transfer process. The sharing of successful experiences in the introduced cassava technologies by the participating farmers with their fellow farmers through radio, television and the print media acted as a motivating factor in the further spread of cassava technologies (Anantharaman and Ramanathan, 1986).

Impact Implications

A study on the impact of LLP on cassava, undertaken across the implemented villages, revealed a differential pattern amongst the villages (Anantharaman and Ramanathan, 1996). It was seen that the socio-economic conditions operating at the micro-level of the farmers played a significant role in influencing the impact of the program in various villages. Moreover, a complete adoption of the entire package was not very common; rather, the farmers tended to use a blend of the introduced cassava technologies and their traditional practices, according to their socio-economic and cultural conditions. The slow rate of multiplication coupled with the time lag between the harvesting and subsequent planting continued to pose a severe constraint in the rapid spread of cassava technologies. The absence of a specialized agency for large-scale multiplication and distribution of planting material of hybrid cassava further aggravated this problem. Notwithstanding these bottlenecks, the cassava growers, if they are not innovators, they are also not laggards in adoption; they show a keen interest in the adoption of improved cassava technologies once they are exposed to those technologies and backed up with an adequate supply of critical inputs, such as planting material and fertilizers.

Table 1. Transfer of Technology Projects of cassava in India and the extent of farmers' participation.

Name of the project	Period	Impact	Nature and extent of farmers'participation
National Demonstration Program	1971-74	An awareness about hybrid cassava varieties created.	Very much limited. Only a spectator of the demonstrations
Operational Research Project	1976-81	Impressive yield performance and income generation. Constraints in TOT of cassava identified.	Participation widened. Dominating partner in identification of various constraints.
Lab-to-Land Program	1979 to today	Impressive yield performance and income generation. Spread of introduced varieties. Overall development of adopted families.	Participation from the start to the end of the program. Experience sharing between farmers for effective dissemination.
FPR Program in cassava	Since 1994	Location-specific varieties identified.	Active partners in the selection and spread of varieties.

The overall impact of the TOT efforts in cassava clearly indicated the necessity of generating location-specific technologies, particularly new varieties suitable to various micro-climatic environments of cassava production zones in the country. On realization of this fact, and taking into consideration the worldwide recognition for farmers' participation in the development of agricultural technologies and transfer, CTCRI has initiated during the mid-nineties a program of participatory research in cassava, especially for varietal evaluation and transfer. Under this program the farmers are given a basket of cassava varieties from which they can make a choice suitable to their own conditions and requirements.

FARMER PARTICIPATORY RESEARCH AND TRANSFER IN CASSAVA

Generally, agricultural technologies are developed under ideal conditions and based on various criteria they are assumed to be solving farmers' problems, as perceived by the scientists. But, quite often there exists a wide gap between what is perceived as needed by the scientists and what is actually needed by the farmers. As a result, the majority of the technologies turn out to be a mismatch and their transfer to the end-users is found difficult. In this regard, the methodology of farmer participatory research is expected not only to better identify the topics to be researched, but also to facilitate the effective transfer of improved technologies. Keeping this in mind, in 1994 a program of farmers' participation in cassava varietal evaluation and popularization was initiated at CTCRI, following the methodology developed by Anantharaman *et al.* (1994).

Methodology of FPR in Cassava

Figure 1 shows the five stages of the FPR methodology used at CTCRI.

Stage I. Selection of villages and diagnosis of the cassava crop status.

As an initial step in the conduct of on-farm trials, a suitable village has to be selected, i.e. a village where cassava plays a significant role in the economy of the village, and the selected village should have a major area under cassava. Using these criteria, Anacode village in Thiruvananthapuram district of Kerala was selected for implementing the FPR approach. A detailed study on the status of the cassava crop in this selected village was undertaken using various participatory rapid appraisal (PRA) tools and techniques. These included:

1. Village transect

The village transect of Anacode represents the cross section of the village, indicating the topography, soil type, crops grown, livestock raised, irrigation source, problems etc. (**Figure 2**). The selected village has a undulating topography like most Kerala villages, with low-lying paddy fields located at one end of the village and adjoining uplands. Though traditionally the lowland area is mainly used for paddy cultivation, of late cassava has emerged as a money-making crop under low-land conditions. A sizable proportion of the uplands in the village is under cassava, both as a monocrop and intercropped under either rubber trees during the initial period or, to a lesser extent, under coconut trees. It is clearly evident from the transect that cassava is an important crop in Anacode, raised under both upland and lowland conditions.

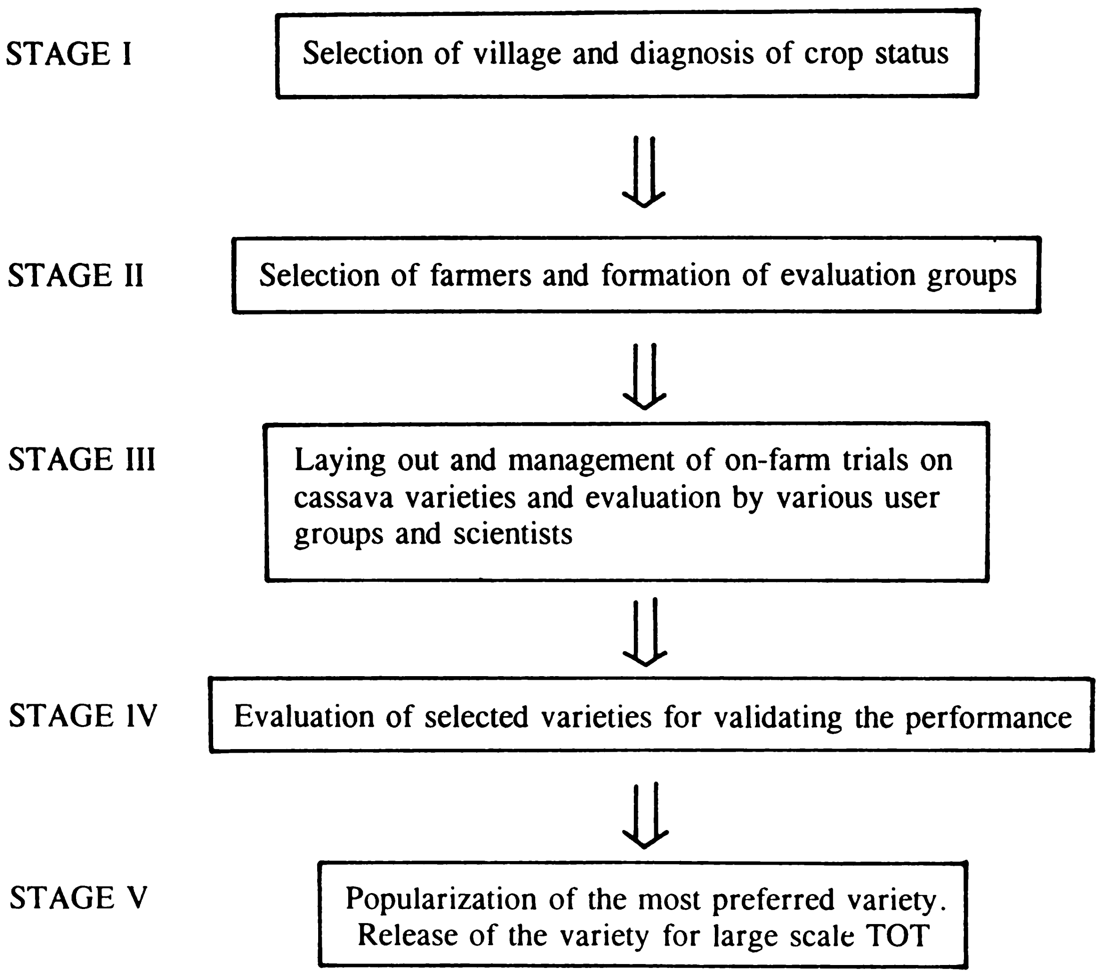
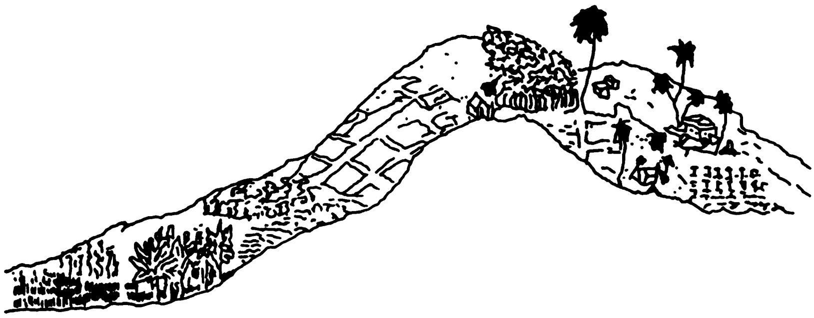


Figure 1. Schematic representation of the methodology of FPR used in cassava by CTCRI in Kerala, India.



	Lowland	Upland
Soil type	Clayey	Red and laterite
Crops	Paddy, Cassava Banana, Vegetables Aroids	Rubber, Cassava, Coconut, Yams,
Trees	-	Mango, Jackfruit Tamarind, Perumaram etc.
Irrigation	Canal	Wells and rainfed
Resources	Fodder	Fuel, Grass, Cattle and poultry manure
Livestock	-	Cow, Goat, Buffalo, Poultry
Drainage	Medium	Good
Problem	Conversion of paddy land to other crops	Lack of irrigation facilities

Figure 2. Transect of Anacode village in Trivandrum district of Kerala, India.

2. Cropping pattern and seasonality of pests and diseases

The informal interview with key informants together with a diagramming technique, cross-checked with the secondary data available at the village Agricultural Office, revealed that besides paddy, cassava is also grown to a large extent in the lowland. Normally two crops of cassava are cultivated under this condition, one during the period April/May to Sept/Oct and another one from Oct/Nov to March/April. The crop takes about 6-7 months until harvest under the lowland condition. Non-availability of mosaic-free stems and damage by rats are the two most serious problems experienced under this condition. In the upland, cassava is planted during April/May and is harvested in Feb/March. As in the case of the lowlands, cassava mosaic disease is an important constraint to increasing cassava production in the uplands too. Kariyila poriyan, Mankozhunthan and Karukannan are the popular cassava varieties grown by the farmers. The high-yielding cassava variety Sree Vishakom (H-1687) is also being cultivated.

3. Crops ranking

Farmers were also asked to compare the relative importance of the various crops they grow based on the criteria that they feel are important in choosing a crop enterprise. Using these criteria, i.e. food security, profitability, low pests and diseases incidence, tolerance to drought, low input requirement and good marketability, rubber was the most preferred crop, closely followed by cassava, owing to its drought tolerance, low pests and disease incidence, low input requirement and food security (**Table 2**). Banana and vegetables, though considered as being the most profitable, were susceptible to pests and diseases and required high inputs for their cultivation.

4. Cassava varieties ranking

A group of farmers was asked to rank their five most popular cassava varieties against the characters they considered most important, such as yield, taste, starch content, root compactness and season (**Table 3**). It is clearly evident from the ranking that none of the varieties were ranked first in all these aspects, indicating that each of the popular varieties excelled others in one character or the other. The hybrid cassava variety Sree Vishakom was ranked first in yield, taste and compactness of roots, but was preferred last with respect to starch content and season (non-bound). Similarly, the local variety Monkozhunthan rated first for starch content but was ranked last for taste. However, the overall ranking revealed that three of the varieties had quite similar scores.

5. Problem-cause relationship in cassava

Problem-cause relationships were determined with a group of farmers for both lowland and upland conditions. Low productivity of cassava was perceived as the major problem in both the upland and lowland situations (**Figures 3** and **4**). The average productivity of cassava ranged from 15-17 t/ha under upland and 20-25 t/ha under lowland conditions. The bio-physical as well as the socio-economic causes for such low yields are shown in the Figures. Of the various causes, non-availability of improved short-duration varieties was found to be the major limiting factor to cassava production under both production systems. Evaluation and identification of suitable cassava varieties with farmers' participation contemplated under the FPR program could be the possible solution to overcome this problem and increase the cassava productivity in Anacode village.

Stage II. Selection of farmers and formation of evaluation groups

1. Selection of cooperator farmers

Two farmers with long experience in cassava cultivation, who were willing and cooperative in nature and who have a high proportion of their land planted to cassava, were chosen, one each for conducting an on-farm trial (OFT) under upland and lowland conditions.

2. Formation of evaluation groups

It was not possible to establish a large number of trials to be used as replications in the on-farm research, due to the lack of mosaic-free planting material and other resources. Instead, by forming groups of various evaluator categories, such as farmers, traders and farm women, to evaluate a single trial, each member of the group was considered to be a replication/observation for the purpose of analyzing and interpreting the outcome of the trials. However, care was taken to involve the entire group in the management of OFT. Accordingly, at the village level a farmers group, a traders group and a farm women group were formed, consisting of persons with extensive experience in cassava cultivation or trade, and having the ability and inclination to participate in the evaluation and to give their assessment on the cassava varieties. In addition, a group of scientists comprising breeders, agronomists and plant protection specialists, coordinated by a social scientist, was also formed, in order to determine the degree of agreement in the evaluation of cassava varieties by the scientists with other user groups.

Stage III. Laying out, management and evaluation of OFT

In consultation between the farmers and scientists, and on the basis of character preference of cassava varieties, as indicated in the varieties' ranking (**Table 3**), it was decided to include 11 cassava varieties, comprising three released varieties, one improved variety, four pre-released varieties and three popular land races. The varieties selected for the trial were:

Released varieties:

1. Sree Vishakom (H-1687)
2. Sree Sahya (H-2304)
3. Sree Prakash (S-856)

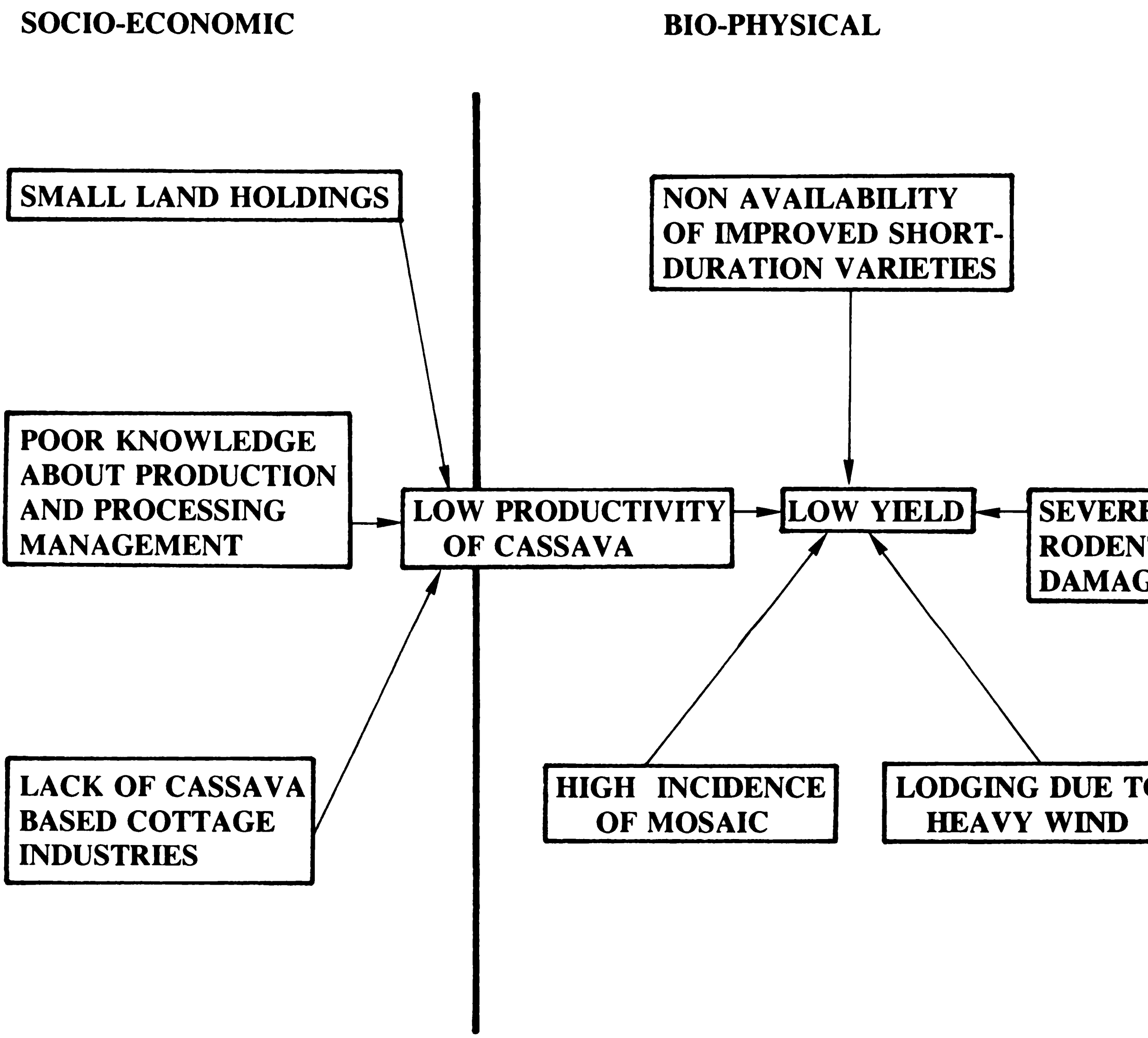


Figure 3. Problem-cause relationship for low productivity of cassava under lowland conditions in Anacode village, Trivandrum, Kerala, India.

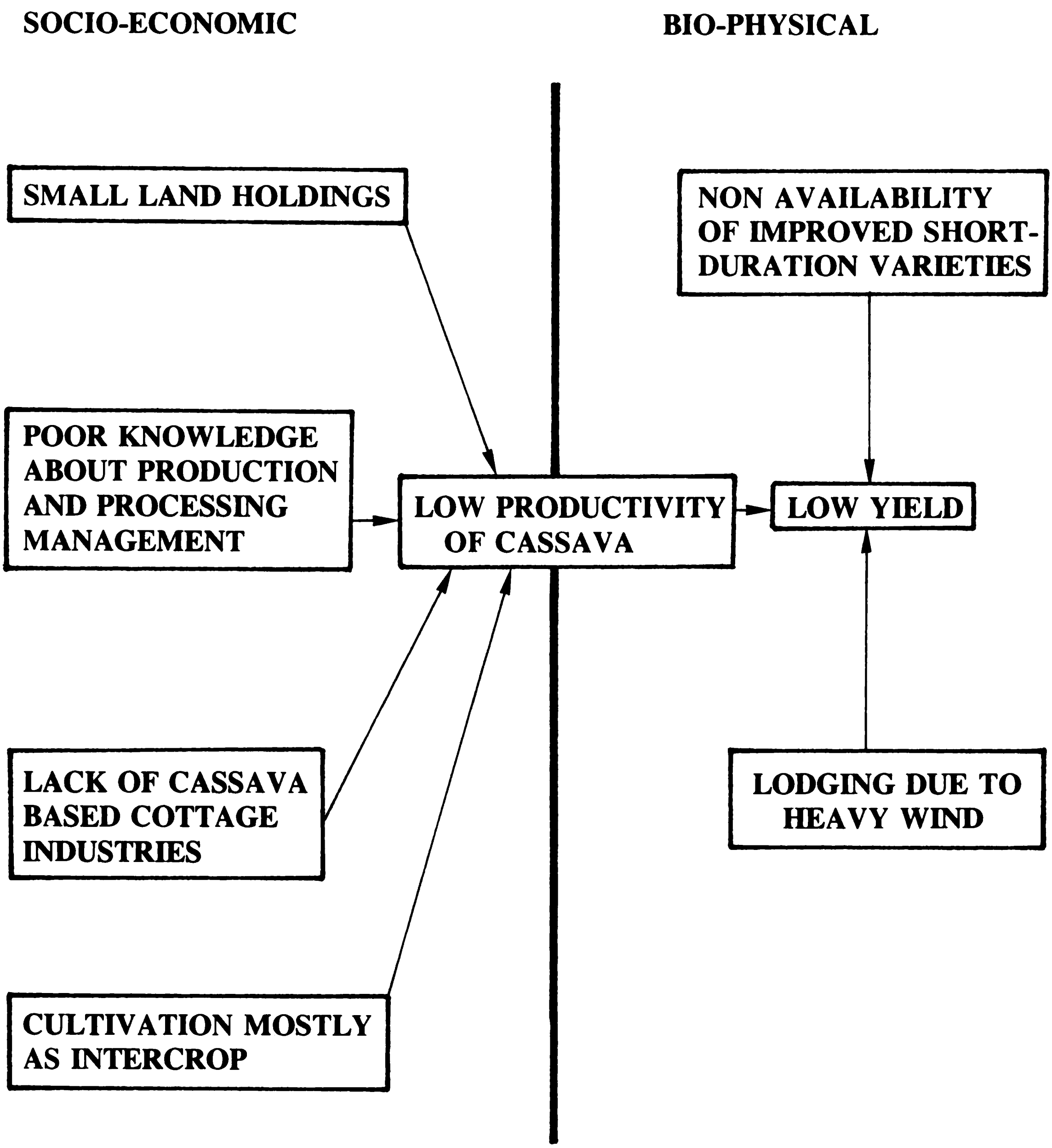


Figure 4. Problem-cause relationship for low productivity of cassava under upland conditions in Anacode village, Trivandrum, Kerala, India.

Table 2. Matrix ranking of crops by farmers in Anacode village, Trivandrum district of Kerala, India.

Characters	Paddy	Cassava	Rubber	Banana	Vegetables
Food security	1	2	5	3	4
Profitability	5	4	1	2	3
Low pest and disease incidence	4	1	2	3	5
Drought tolerance	5	1	2	4	3
Low input requirement	4	1	2	3	5
Marketability	4	5	1	3	2

Source: Anantharaman et al., 1994.

Improved variety:

4. M-4 (popular among farmers in other areas)

Pre-released varieties:

5. CI-649
6. CI-664
7. CI-731 (a selection from the local variety Kariyilaporiyan)
8. CI-732

Local varieties:

9. Karukannan
10. Monkozhunthan
11. Kariyilaporiyan

While implementing the OFT on cassava, the consultative participation of farmers, which emphasizes researcher managed and farmer-implemented trials, as outlined by Ashby (1986), was resorted to. However, researcher management was restricted to guidance provided to farmers in the management of the OFT. Considering the comprehending ability of the farmers and their unfamiliarity with experimental designs, the laying out of the OFT using a typical experimental design was found difficult under actual farm conditions. Hence, in discussion with the farmers and in consultation with a statistician, a suitable design (modified CRD with two replications) was formulated, which would facilitate the laying out of the trials and still be adequate for appropriate statistical analysis. Accordingly, two trials, one each under upland and lowland conditions, using the 11 selected cassava varieties in two replications under two types of management, namely recommended package of practices and farmers' management, were laid out. They were closely monitored through fortnightly visits to the village and with active cooperation of the participating farmers. Group meetings were also organized at the critical stages of the trials and the views and experiences of

Table 3. Matrix ranking of cassava varieties on the characters preferred by farmers in Anacode village of Trivandrum district in Kerala, India.

Character	Sree Visakham	M-4	Kariyila poriyan	Mankoz hunthan	Karu kannan
Yield	1	5	4	2	3
Taste	1	2	3	5	4
Starch content	5	4	2	1	3
Root compactness	1	5	4	3	2
Season	5	3	4	2	1

Source:* *Anantharaman et al., 1994.

the individual farmers were recorded. Group consensus was arrived at in the conduct and progress of the trials.

Cassava roots were harvested at the 7th month under the lowland condition and at the 10th month under the upland condition. The harvested roots were exhibited in a row, masking their identities, but with labels as V1, V2 etc. The selected groups of scientists, farmers, farm women and traders were guided with an open-ended questionnaire to register their opinion on positive and negative aspects of the roots. They were also requested to rate the varieties on a five point continuum and to select the best five varieties from among the 11 exhibited.

Results of FPR Cassava Varietal Selection

The most salient features of the preliminary stage of evaluation of cassava varieties are as follows:

1. Performance of cassava varieties (Phase I)

The average root yields of the tested varieties are given in **Table 4**. The analysis of the data indicate that the yield performance of the varieties under the recommended as well as the farmers' management did not show any significant difference under both production systems. However, significant differences existed amongst the varieties, with CI-649 producing a significantly higher yield than the other varieties under the lowland condition. The yields of CI-731, Mankozhunthan, H-1687 and H-2304 were not statistically different, but were higher than those of the remaining varieties. The yield performance of the cassava varieties, except H-1687 was found to be rather poor under the upland condition (Anantharaman *et al.*, 1995).

2. Evaluation of cassava varieties

Result of the evaluation by various groups on the basis of the ranks obtained by each variety in terms of root characteristics, taste and suitability of the cassava varieties for their end-use, are presented in **Table 5**. The Spearmen rank order correlation, determined between the rank order of the varieties given by the various groups, indicate that while the scientists' preferential order did not have agreement with that of other groups, there existed agreement amongst those other groups. This shows that there were differences in the preferential order of the varieties between scientists and end-users. Analysis of the criteria used by the scientists and the other user groups for evaluating the varieties, indicate that, while scientists gave importance to root weight, size, shape and compactness, farmers considered number of roots (optimum being 5-7), uniformity in size (optimum being 500-600 gm), skin and rind color, starch content, marketability, attachment of the root to the base of the plant, root shape, general appearance, absence of fibrous portion etc. as important criteria in selecting a variety. Farm women considered taste, fast cooking, bitterness/sweetness of the cooked roots important in a good cassava variety. The traders considered uniformity of roots (medium-sized), starch content and skin color as important criteria. In addition, the farmers were of the opinion that the cassava varieties suited to the lowland condition should be of medium stature and should not grow too tall. Otherwise, it might lead to lodging. Moreover, the variety should not have too much foliage, and at the same time, it should possess a higher starch content and have less rat damage. As regard to stems, these should be flexible and strong. Since there will be moisture at all times under lowland conditions, the roots should resist rotting.

On the basis of the evaluation by various groups, five cassava varieties, i.e. CI-649, CI-664, CI-731, CI-732 and H-1687 have been selected for further evaluation during the subsequent phase.

Stage IV. Evaluation of selected clones (Phase II).

The five cassava varieties selected under Stage III were grown under both upland and lowland conditions for validating the performance of these varieties for one more season, and to select one or two most preferred varieties for popularization in the selected village. The same process of evaluation of the varieties at time of harvest (excepting scientists group) conducted during the earlier stage, was repeated. The analysis of the performance under the lowland condition has been completed and the same under the upland condition is in progress. The yield performance indicate that the cassava variety CI-732 was the highest yielder (46.29 t/ha), followed by CI-649 (40.51 t/ha) and CI-731

Table 4. Yield performance of eleven cassava varieties in on-farm trials conducted under lowland and upland conditions in Anacode village of Trivandrum district in Kerala, India.

	Average root yield (t/ha)	
Variety	Lowland	Upland
H-1687	29.25	30.15
Karukannan	26.15	12.83
CI-664	19.81	12.83
S-856	26.72	14.40
CI-731	32.13	19.50
CI-649	55.00	14.18
CI-732	22.13	6.66
M-4	21.81	12.15
Mankozhunthan	30.91	8.78
Kariyilaporiyan	19.69	17.55
H-2304	28.50	16.65

Source: Anantharaman et al., 1995.

(39.72 t/ha). CI-732 also emerged as the most preferred variety by both the farmers and the farm women. Matrix ranking of varieties based on yield and other characters by farmers revealed that the preference for the varieties were in the order of CI-732, CI-731, CI-649 and CI-664. On the basis of overall performance and evaluation by various user groups, the cassava varieties CI-732, CI-649 and CI-731 were the most preferred ones, and these were taken to the next stage, popularization. Since CI-731 is a selection from the popular local variety Kariyilaporiyan, it was decided to popularize only CI-732 and CI-649 in the selected village.

Stage V. Popularization of selected cassava varieties

Under the popularization scheme, the participating farmers acted as "seed producers" for making available the disease-free planting materials of the preferred varieties, as the non-availability of planting materials of high-yielding cassava varieties was identified by Ramanathan *et al* (1987) as the most important constraint in the adoption of these varieties by the farmers. Using the stems supplied by the seed producing farmers, presently about ten farmers have grown the cassava varieties CI-732 and CI-649 in about one hectare of cassava area in the village. Efforts are underway to formally release these varieties by the State Variety Release Committee, so that large-scale TOT by the Kerala Department of Agriculture can be initiated.

The program of FPR in cassava is being continued in other villages of

Thiruvananthapuram district and is also programmed to extend to other regions of the state.

Problems Encountered in the FPR on Cassava

1. Availability of planting material

Availability of disease-free high-quality planting material of new cassava varieties at the right time and in the right quantity continues to be a serious constraint in conducting these trials in large numbers and over various regions of the state. The absence of any agency for large-scale multiplication and distribution of planting material of improved varieties of cassava in India further aggravates this problem.

2. Laying out of OFT

In spite of adopting a simplified experimental design which was discussed with the farmers, the actual conducting of the trial was found difficult, especially under lowland conditions. An area of 0.8-1.0 ha was needed for conducting the trial. Getting such a big plot in the lowlands was difficult, since channels dug in between the plots for drainage rendered them unsuitable for laying out a varietal trial with 10-12 varieties in two replications. Moreover, as bunds have to be made around each subplot to demarcate the replications, additional labor was required, which in turn increased the expenditure in the cultivation. The undulating topography of the land also at times made the laying out the trials difficult, particularly under the upland condition.

3. Organizing and conducting evaluation

Collection of various members of the evaluation groups, especially of the traders and organizing the evaluation on a particular day was found to be difficult. Often the traders go away for their business and the rest of the evaluators have to wait for hours. There were occasions, in which the evaluation had to be postponed until the subsequent day.

4. Harvesting and marketing of roots

During the initial phase of evaluation, about 50% of the plant population was harvested to get accurate yield data of the varieties. This created problems in marketing as these could only be sold a day after harvest due to the detailed evaluation on the day of harvest. Resorting to a sample harvest also had its own problems. Since the majority of the farmers preferred to market the roots on a contract basis, sample harvesting, which created vacant spots here and there in the cassava plot, always resulted in a lower price as compared to a full plot of cassava.

5. Labelling and storage of planting materials

Careful labelling of the varieties and the separate storing of the stems of each variety is very important to avoid mixing up of varieties and for conducting subsequent trials in the next season. With the stems of 11 varieties looking more or less similar, the farmers expressed difficulty in careful identification, labelling and storage of stems of each varieties at the time of harvest.

Table 5. Rank order of cassava varieties based on evaluation by user groups and scientists in Anacode village of Trivandrum district in Kerala, India.

		Ranking by user groups		
Variety	Farmers	Farm women	Traders	Scientists
H-1687	2	6	6	3
Karukannan	3	5	3	11
CI-664	5	11	8	2
S-856	9	2	6	7
CI-731	4	3	3	4
CI-649	1	1	3	1
CI-732	8	7	9	8
M-4	6	4	1	9
Mankozhunthan	7	10	9	5
Kariyilaporiyan	3	3	4	6
H-2304	11	9	10	10
Degree of agreement between user groups:				
Scientists vs Farmers		$0.39^{NS1)}$		
Scientists vs Traders		0.13^{NS}		
Scientists vs Farm women		0.20^{NS}		
Farmers vs Traders		0.65^{**}		
Farmers vs Farm women		0.49^{NS}		
Traders vs Farm women		0.80^{**}		

[1)] NS=Not significant **=Significant at 1% level

Source: Anantharaman et al., 1995.

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FARMER PARTICIPATORY RESEARCH IN CASSAVA SOIL MANAGEMENT AND VARIETAL DISSEMINATION IN VIETNAM

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ABSTRACT

Farmer Participatory Research (FPR) in Vietnam has been carried out since 1994 in collaboration with CIAT, with the objective of improving the adoption of soil conservation practices in cassava fields. Two villages in Pho Yen district, Bac Thai province; one in Thanh Hoa district, Vinh Phu province; and one in Luong Son district of Hoa Binh province were selected as pilot sites for implementing the FPR methodology.

In 1994: By using RRA and PRA methods in conducting diagnostic surveys, some main limiting factors in cassava production were identified, such as lack of suitable planting methods for soil erosion control and lack of knowledge about balanced fertilizer application and about high yielding varieties. Therefore, demonstration plot with 17 treatments on different ways to improve soil fertility and methods to control soil erosion, were established at the Agro-forestry College in Thai Ngyen, Bac Thai.

Farmers' field days were held to show the demonstration plots to farmers and extensionists from two of the selected districts in mid Nov, 1994. Based on the results and discussion, seven treatments were identified by farmers as promising treatments for 1995. Farmers also discussed how to arrange these in simple FPR trials in their own fields.

In 1995: Twenty five farmers of two villages in Pho Yen and ten farmers in Thanh Hoa districts participated in the project by conducting research on their own fields. At time of harvest, a farmers field day was held in both districts in mid Nov, 1995. Farmers and researchers joined in the harvest and in the discussion of the results. Some best treatments were identified. The treatments of cassava intercropped with peanut and contour hedgerows of vetiver grass, combined with balanced NPK application, was considered as the most promising practice at both pilot sites, as soil erosion losses were reduced by 20-40% compared to the check plot of cassava grown in monoculture and without hedgerows. In Pho Yen district, cassava yields in this treatment were about the same as the check plot, but net income increased 9-36%. In Thanh Hoa, cassava yields increased about 9% compared to the check plot, while net income increased by 23%. In this location cassava intercropped with peanut increased net income from 131 to 273% over cassava monoculture. Farmers who tested new promising clones considered KM60 and CM4995-7 as the most suitable for their conditions; these clones increased yields from 1.7 to 4.1 t/ha over the check variety Vinh Phu.

These initial results are encouraging more and more farmers to participate in the FPR trials. The number of farmers participating in 1996 increased and some of them can conduct the trials now by themselves.

INTRODUCTION

In terms of area planted, cassava (*Manihot esculenta* Crantz) is the fifth most important food crop in Vietnam, after rice, maize, sweet potato and vegetables. Cassava fresh roots are used as human food and animal feed, but most cassava is processed into dried chips or cassava starch, which are used to make monosodium glutamate, alcohol,

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candies, etc.

Cassava is grown mainly on hilly land in Vietnam. According to the literature (Howeler, 1981), to produce a yield of 15-20 ton fresh roots per ha, cassava absorbs about 75-100 kg N, 35-50 kg P_2O_5 and 105-140 kg K_2O/ha. Therefore, the crop may deplete the nutrients in the soil, especially if farmers remove from the field not only the roots but also the stems and leaves. Farmers have long experience in growing cassava, and have tried to improve their practices to maintain high cassava yields year after year, such as the making of contour ridges when growing cassava on sloping land, or intercropping cassava with peanut or black bean. But the yield of cassava was still low, because of the lack of good planting methods to control soil erosion, as well as the use of unbalanced fertilizer applications; they also lack good varieties and knowledge about how to use peanut residues as green manure for cassava.

A lot of research has been done on various aspects of agriculture including cassava, but few of these technologies have been put into practice, or they are not as efficient as the farmers' practices. One of the most limiting factors in transferring new technologies to farmers is that most research has been conducted at research stations under very good management, very different from the real farm conditions. On the other hand, for farmers to know how to apply the new technologies, they need to do them first themselves and to evaluate them according to their own criteria; or they want to observe how their neighbors apply the new technologies first. Given this fact, it is necessary to change the methods used in research and the transfer of technologies, in order to adapt to farmer's conditions.

Farmer Participatory Research (FPR) in Vietnam has been carried out since 1994 in collaboration with CIAT, with the objective of improving the adoption of soil conservation practices in cassava fields.

FPR PROJECT IN VIETNAM

Two villages in Pho Yen district of Bac Thai province, and one village in Thanh Hoa district of Vinh Phu province were pre-selected as the most suitable pilot sites for implementing the FPR methodology.

To impliment the FPR methodology the following activities were carried out:

1. Diagnostic surveys were conducted in the pilot sites using RRA and PRA methods in order to better understand the existing farming practices and to hear the farmers' opinions about how to solve their limiting factors.
2. Demonstration plots were established at the Agro-Forestry College of Thai Nguyen University in Bac Thai, in order to show farmers a large number of management options that can be used to reduce erosion.
3. Four types of FPR trials were conducted by farmers on their own fields:
    - Soils erosion control by using different soil/crop management practices
    - Cassava intercropping with peanuts, black beans etc.

- Variety testing
- Fertilization

4. Farmers field days were organized at harvesting time to discuss and evaluate the results of the FPR trials, as well as to identify the most promising treatments for next year.

Some Initial Results of the FPR Project

1. Diagnostic Surveys at Pilot Sites.

Using RRA and PRA methods, we surveyed two potential pilot sites in 1994, i.e., Pho Yen district of Bac Thai province and Thanh Hoa district of Vinh Phu province; these were selected as being most suitable for the FPR project. In 1995, another site in Luong Son district of Hoa Binh province was selected.

Table 3 shows that the climate in all three sites is subtropical with an average rainfall of 1500-2100 mm/year and considerable monthly fluctuations; the highest rainfall occurs during the summer months of June to September and almost 80% of total annual rainfall is concentrated in this period. This is one of the main causes for severe soil erosion on steep lands.

Cassava is grown mainly on sloping land in the selected areas. In Pho Yen district, cassava is grown on gentle slopes with a light textured sandy loam soil. This soil is very susceptible to erosion by water. Thus, the soil has become depleted of nutrients, especially potassium. Although cassava is grown on much steeper land in Thanh Hoa and Luong Son districts, the soil texture is a heavy clay, which is more resistent to erosion than the light soil in Pho Yen district. Another problem is that the eroded soil is deposited in the rice fields at the bottom of the hill where it causes a reduction in rice yields.

In both Thanh Hoa and Pho Yen districts, cassava occupies a rather important position among field crops in terms of the income of farm households (**Table 1**). It is usually ranked second, after rice, in terms of area and income.

The data of the RRA (**Tables 1** to **4**) have shown that cassava yields in the pilot sites are rather low (8-15 t/ha) for the following reasons:

1. Cassava is grown mainly on sloping land with such practices as contour ridging and intercropping with peanut (or black bean). Cassava has a slow initial growth and the plants do not cover the soil enough during the rainy months to prevent the direct impact of rain drops on the soil surface. The run-off water carries away both nutrients and soil. Therefore, cassava yields have decreased to only 3-4 t/ha in some plots after 10-15 years of continuous cassava production.
2. On average, fertilizers applied to cassava (**Table 3**) consists of only about 5-10 t/ha of organic (mainly pig) manure, together with 20-50 kg N, 10-50 P_2O_5 and 0-160 K_2O/ha. Farmers also lack experience about how to use fertilizers and they lack credit to purchase inputs for cassava. The number of households that use chemical fertilizers

for cassava was less than 50% of total households interviewed.
3. The local variety Vinh Phu green and a few other exotic varieties, such as Canh Ng and Du varieties, have been grown for a long time without any regeneration practices.
4. Traditionally cassava roots are mainly used for food and animal feed, while some small quantities are sold in the market when money is needed. Cassava is processed into dry chips after manual cutting with a knife; this requires a lot of labor. In Dong Rang village, however, more than 50% of cassava is sold as fresh roots.
5. The demand for cassava products, both for home consumption (mainly pig feeding) and for marketing, seems to be increasing. The greatest difficulty farmers face is the loss of productivity of the soil. This is thus a good opportunity to join with them in conducting on-farm testing of more productive and more sustainable management practices at these three pilot sites.

2. Demonstration Plots on Soil Erosion Control and Farmer's Field Days at the Agro-forestry College.

Based on previous research on soil erosion control using various soil/crop management practices, a demonstration plot with 17 treatments was established on about 20% slope in the Agro-forestry College in Thai Nguyen in 1994. These plots gave a good picture of various alternatives for growing cassava on slopes, so farmers could select the most promising treatments during the farmer's field days. The data in **Table 5** show the effect of treatments on cassava yield and soil erosion, as well as the economic returns and the farmers' preferences. Treatments with hedgerows of *Tephrosia candida*, *Flemingia congesta* and vetiver grass, or the intercropping with black bean and with *Tephrosia hedgerows* gave very good results with respect to soil eroison control; total soil erosion decreased between 47.7 and 61.9% as compared to the check plot (treatment 1). In treatment 10, with vetiver hedgerows, only 7.25 ton dry soil/ha was lossed, while cassava fresh root yield was maintained at 20.5 t/ha. In treatment 4, with balanced NPK and organic manure application, the cassava yield reached 26.6 ton fresh roots/ha, but dry soil loss was still high at 14.4 t/ha. After the results were discussed with farmers during the field day at the end of Nov, 1994, some treatments were selected for on-farm testing in 1995.

In 1995, the same demonstration plots were continued with 16 treatments: treatment 6 was replaced by NPK and intercropping with peanuts, while treatment 15 was replaced by NPK and no tillage. The results of soil loss measurements and cassava yields are given in **Table 6**. They show the same trend as in 1994. Soil losses in treatments 6, 8, 9, 10, 11 and 13 decreased between 59.8% and 81.3% as compared to the check plot. Highest cassava yields were achieved in treatments 12, 4, 5, 16, 10 and 7. Gross and net income were the highest in treatments 12, followed by treatments 4, 5, 6, 10 and 16.

Table 1. Secondary data of Luong Son district of Hoa Binh, Thanh Hoa district of Phu Tho, and Pho Yen district of Thai Nguyen provinces in north Vietnam.

Province District	Hoa Binh Luong Son	Phu Tho Thanh Hoa	Thai Nguyen Pho Yen
Latitude (°N)	20° 50'	21° 30'	21° 20'
Altitude (masl)	30-40	80	40
Soils	dark red clay typic Paleustult	red clay loam	white sandy loam
Rain fall (mm)	1600-1800		1700-2000
Temperature (°C)	23-25		22-24
Landscape	hilly	hilly	rolling
-rice	in lowlands	in lowlands	in lowlands
-cassava	on <25% slope	on <40% slope	on <20% slope
Main crops (ha)			
-rice (crop land)	4,690	3,580	7,200
-cassava	838	1,500	650
-sweet potato[1)]	402	670	1,400
-peanut	798	345	1,212
-maize	680	732	700
-mungbean	370	385	500
-tea	917	1,075	1,181
-forest	13,036	14,250	14,886
Yield (t/ha)			
-cassava	6.5-7.0	4-6	9.7
-rice	2.3-2.5	2-3	3.2
-sweet potato	5.5-6.0	4.5-5.0	5.5
-peanut	0.8-0.9	0.9-1.0	0.9
-maize	1.5-2.0	1.8-2.2	5.0
-soybean	0.5-0.7	0.6-0.8	0.7
Farm size (m^2/fam.)			
-total	9,500-10,500	2,000-15,000	7,000-11,000
-cassava	1,000-2,200	1,500-2,000	720-1,080
-rice	600-800	500-5,000	360-6,400
-garden	0-5,000	0-5,000	1,800-5,000
-tea	0-3,200	0-2,500	
-sweet potato	200-400	350-400	360-1,080
-trees	300-500	500-600	500-720

[1)]mainly as winter crop on rice land.

Table 2. Population, land classification and land use, as determined from Rapid Rural Appraisals (RRAs) conducted in four FPR pilot sites in Vietnam in 1996/97.

Province	Hoa Binh	Phu Tho	Thai Nguyen	
District	Luong Son	Thanh Hoa	Pho Yen	
Village	Dong Rang	Phuong Linh	Tien Phong	Dac Son
Population				
-no. of households (hh)	81	275		
-no. of hh. interviewed	40	158	6	35
-ethnic group	Muong (90%)/Kinh[1)]	Kinh	Kinh	Kinh
-no. of people/hh	6-7	5.2	5.3	6.1
-length of time settled (year)	>20	>25	>20	>20
Land characterization				
-lowlands (ha)	27	86		
-upland (ha)	95 (36 ha planted/yr)	29		
-cassava (ha)	30	15	50	40
-slopes (%)	<25	<40	<20	<10
-soil type, fertility	clay, medium fertile	clay, low fertility	sandy loam low fertility	sandy loam low fertility
-erosion	medium	high	medium	low
Land use				
-uplands	cassava, taro, peanut, sugarcane, fruits forestry	cassava, peanut, sweet potato tea, palm, bamboo,	cassava peanut sweet potato	cassava sweet potato peanut soybean
-lowlands	rice (2 crops) peanut, sweet potato, maize, soybean, sugarcane (chewing) fish ponds	rice (1 crop) fish in paddy fish ponds	rice (2 crops) sweet potato fish ponds	rice (2 crops) sweet potato
Area main crops (m^2/hh)				
-summer rice	2,500	3,700	4,500	3,100
-spring rice	3,100	2,160	2,460	2,063
-cassava	4,000	720	4,320	977
-sweet potato	300	500	1,080	954
-peanut	350	420	2,040	634
-soybean, mungbean etc	390	385	-	526
-tea	360	400	-	-
-garden	1,000	1,800	-	-
Total farm size	9,500	7,925	11,940	6,191
Land ownership(%)	100	100		
no. of parcels/hh	8	7		
Animals	buffalo cattle for meat (± 100 head) fish	buffalo cattle for plowing fish	buffalo fish	buffalo fish

[1)]Kinh = lowland Vietnamese

Table 3. Cropping systems, varieties and agronomic practices, as determined from RRAs conducted in four FPR pilot sites in Vietnam in 1996/97.

Province District Dong Rang	Hoa Binh Luong Son Phuong Linh	Phu Tho Thanh Hoa	Thai Nguyen Pho Yen Village Tien Phong	 Dac Son
Cropping system[1]				
-upland	tea C+T C monocult. peanut, maize	C monocult. C+P tea, peanut maize	C+P or C+B or 2 yr C rot. with 2 yr fallow sweet potato	C monocult. or C-P rotation or C-B, C-SP sweet potato
Varieties				
-rice	CR 203, hybrids from China	DT 10, DT 13, CR 203	DT 10, DT 13 CR 203	CR 203 DT 10, DT 13
-cassava	Vinh Phu, local	Vinh Phu, local	Vinh Phu Du, Canh Ng	Vinh Phu
Cassava practices				
-planting time	early March	early March	Feb/March	Feb/March
-harvest time	Nov/Dec	Nov/Dec	Nov/Dec	Nov/Dec
-plant spacing (cm)	100x80	80x80; 80x60	100x50	100x50
-planting method	horiz./inclined	horizontal	horiz./inclined	horizontal
-land preparation	buffalo/cattle	by hand/cattle	buffalo	buffalo
-weeding	2 times	2 times	2 times	2 times
-fertilization	basal	basal+side[2]	basal+side[3]	basal+side[4]
-ridging	mounding	flat	flat	flat
-mulching	rice straw	peanut residues	peanut residues	peanut residues
-root chipping	hand chipper	knife	small grater	small grater
-drying	3-5 days	3-5 days	2-4 days	2-4 days
Fertilization				
-cassava				
-pig manure (t/ha)	5	5	3-5	8-11
-urea (kg/ha)	0	50-135	83	83-110
-SSP (18% P_2O_5) (kg/ha)	50-100	0	140	0-280
-KCl (kg/ha)	0	0	55	0-280
-rice				
-pig/buffalo manure (t/ha)	5	0	-	-
-urea (kg/ha)	120-150	80	-	-
Yield (t/ha)				
-cassava	10-12	8-15	8.5	8.7
-rice (per crop)	3.3-4.2	4.2	3.0-3.1	2.7-3.0
-taro	1.9-2.2	-	-	-
-sweet potato	-	-	8.0	3.3
-peanut	0.8-1.2	0.5-1.1	1.4	1.3
pigs (kg live weight/year)	100-120	-	-	-

[1] C=cassava, P=peanut, B=black bean, T=taro, M=maize
C+P=cassava and peanut intercropped; C-P=cassava and peanut in rotation
[2] urea at 2 MAP
[3] urea when 5-10 cm tall; NPK+FYM when 20 cm tall
[4] NPK when 30 cm tall; hill up

Table 4. Labor use, crop utilization and farm income, as determined from RRAs conducted in four FPR pilot sites in Vietnam in 1996/97.

Province	Hoa Binh		Phu Tho		Thai Nguyen			
District	Luong Son		Thanh Hoa		Pho Yen Village			
Village	Dong Rang		Phuong Linh		Tien Phong		Dac Son	
Labor (mandays/ha)	cassava	rice	cassava	rice	cassava	rice	cassava	rice
-land prepartion	30	30	44	35	28	30	27	29
-planting	20	30	45	25	20	25	20	25
-weeding	45	40	35	35	30	40	30	40
-irrigation	-	10	-	35	-	10	-	10
-fertilization	10	20	20	10	17	12	16	12
-harvest	30	35	50	35	36	32	34	32
-chipping/drying	45	-	45	-				
-thrashing	-	20	-	28	50	28	48	27
Total	180	185	239	203	181	177	175	175
Prices (dong/kg)								
-fresh cassava	300-400		500				400	
-rice	1,500		1,500				1,500	
-peanut	3,500		3,300				3,500	
-urea	3,000		3,100				2,700	
-SSP	850		780				700	
-KCl	2,500		2,700				2,500	
Utilization (%)								
-rice	100% hh. use		100% hh. use		100% hh. use		100% hh. use	
-cassava -fresh roots	60% (60% to market)		15% (5% market)		20% (all home)		17% (all home)	
-dry chips	40% (pig feeding)		85% (5% market)		80 (10% market)		83 (5% market)	
-stems	firewood				firewood		firewood	
-leaves					fish or pigs		fish or pigs	
Market use of cassava								
-fresh	starch, maltose, alcohol human food, pig feed		alcohol		-		-	
-dry chips	pig feed		alcohol		pig feed		pig feed	
Income (mil. dong/hh./year)								
-crops 3.5-4.5	5.4		6.1		3.1			
-pigs, chickens, ducks	1.5-2.0		0.13				3.5	
-others 1.0-1.5	1.5-2.5				0.8			
Total 6.0-8.0	7-8				7.4			
Costs and income (mil. dong/ha/yr)								
Gross income crops	3.7		3.4		3.2			
Production costs crops	2.5		2.3		3.0			
Net income crops	1.2		1.1		0.2		0.134	

Note: 1US$ is about 11.000 dong in 1996/97

Table 5. Results of the demonstration plots on soil conservation practices in Agro-forestry College of Thai Nguyen University, Bac Thai, in 1994.

Treatment	Dry soil loss (t/ha)[1]	Yield (t/ha)		(million dong/ha)			Farmer preference[4]	
		cassava	intercrop	Gross income[2]	Costs[3]	Net income	Pho Yen	Thanh Hoa
1.No fertilizers	19.03	8.25	-	1.65	0.00	1.65	-	-
2.With NPK (60 kg N-40 P_2O_5-120 K_2O/ha	10.85	17.25	-	3.45	1.15	2.30	-	-
3.With FYM (10 t pig manure/ha)	13.53	16.86	-	3.37	1.00	2.27	-	89
4.FYM+NPK	15.44	26.63	-	5.33	2.15	3.18	77	89
5.NPK; *Tephrosia* green manure[5]	17.74	19.00	-	3.80	1.15	2.65	92	78
6.NPK; no tillage	18.40	16.25	-	3.25	1.15	2.10	-	-
7.NPK; contour ridging	11.21	18.63	-	3.73	1.15	2.62	-	-
8.NPK; vetiver grass hedgerows	8.43	18.81	-	3.76	1.15	2.61	92	-
9.NPK; *Flemingia* hedgerows	9.90	18.49	-	3.70	1.15	2.55	70	-
10.NPK; vetiver grass hedgerows	7.25	20.50	-	4.10	1.15	2.95	92	78
11.NPK; black bean intercrop., *Tephrosia* hedgerows	8.31	14.98	0.070	3.35	1.15	2.20	100	78
12.NPK; crop residues incorporated	15.27	18.50	-	3.70	1.15	2.61	85	-
13.No NPK; crop residues incorp.; *Tephrosia* hedgerows	14.49	15.41	-	3.08	0.00	3.08	-	-
14.NPK; *Tephrosia* green manure[6]	17.60	18.75	-	3.75	1.15	2.60	-	-
15.NPK; cassava intercrop[7]	20.85	20.30	-	4.06	1.15	2.91	-	-
16.NPK; closer spacing	18.14	20.06	-	4.01	1.15	2.86	-	-
17.NPK; black bean intercrop	18.75	7.88	0.055	1.86	1.15	0.71	-	-

[1]During crop cycle.

[2]Prices: cassava : 200 d/kg fresh roots; black bean : 5100 d/kg dry grain; urea(45%N) : 2500 d/kg; SSP(17%P_2O_5) : 1000 d/kg; KCl(60%K_2O) : 2500 d/kg

3)Cost of fertilizers and manure, including application (83,333 d/ha)

[4]Percentage of farmers choosing treatment

[5]Brought from outside plot

[6]From *Tephrosia* intercrop

[7]Cassava stakes planted as an intercrop at 4-5 MAP

Table 6. Results of the demonstration plots on soil conservation practices in Agro-forestry College of Thai Nguyen University, Bac Thai, in 1995.

Treatments	Dry soil loss (t/ha)[1]	Yield(t/ha)		(million dong/ha)			Farmer preference[4]
		cassava	intercrop	Gross income[2]	Costs[3]	Net income	
1.No fertiltzers	27.42	7.08	-	5.66	0.00	5.66	-
2.With NPK (60 kg N-40 P2O5-120 K2O/ha	22.94	17.25	-	13.80	1.15	12.65	-
3.With FYM (10 t pig manure/ha)	25.27	16.13	-	12.90	1.00	11.90	26
4.FYM+NPK	22.58	22.97	-	18.38	2.15	16.22	36
5.NPK; *Tephrosia* green manure	26.36	21.73	-	17.38	1.15	16.23	-
6.NPK; peanut intercrop	11.79	15.19	0.858	16.44	1.15	15.29	68
7.NPK; contour ridging	13.02	20.00	-	16.00	1.15	14.85	45
8.NPK; *Tephrosia* hedgerows	10.93	17.42	-	13.94	1.15	12.78	34
9.NPK; *Flemingea* hedgerows	5.12	17.80	-	14.24	1.15	13.09	64
10.NPK; vetiver grass hedgerows	5.62	21.52	-	17.22	1.15	16.06	68
11.NPK; black bean intercrop., *Tephrosia*+grass hedgerows	8.01	15.44	0.075	12.80	1.15	11.65	32
12.NPK; crop ressidues incorporated	17.94	23.50	-	18.80	1.15	17.65	32
13.No NPK; crop residues incorp.; *Tephrosia* hedgerows	7.99	10.88	-	8.70	0.00	8.70	-
14.NPK; *Tephrosia* green manure	14.02	17.25	-	13.80	1.15	12.65	-
15.NPK; no tillage	19.12	20.52	-	16.42	1.15	15.26	-
16.NPK; closer spacing	18.35	21.95	-	17.56	1.15	16.41	-

[1]During crop cycle.

[2]Prices:

cassava	:	800	d/kg fresh roots
peanut	:	5000	d/kg dry grain
black bean	:	6000	d/kg dry grain
urea(45%N)	:	2500	d/kg
SSP(17%P_2O_5)	:	1000	d/kg
KCl(60%K_2O)	:	2500	d/kg

[3]Cost of fertilizers and manure, including application (83,333 d/ha)

[4]Percentage of farmers from Pho Yen district choosing treatment.

During the farmers' field day, farmers from the pilot sites had the opportunity to see, discuss and select the most appropriate treatments. Most of the farmers based their choice on two main criteria: the quantity of soil lossed by erosion and cassava yield. The largest number of farmers selected treatments 9, 6 and 10. Although treatment 12 produced the highest net income, only 32.4% of farmers considered this treatment very good.

3. Farmer Participatory Research (FPR) Trials in 1995.

Four different components of technologies were tested on farmers' fields:

- erosion control
- intercropping systems
- fertilization
- varieties

As a result of the farmers' field day held at the Agro-forestry College in 1994, farmers selected the treatments that they wanted to test on their own fields.

A total of 35 farmers volunteered to conduct FPR trials: 18 in Tien Phong and seven in Dacson villages of Pho Yen district, and ten in Phuong Linh village of Thanh Hoa district.

3.1. Results of soil erosion control trials

On sandy loam soils of two villages in Pho Yen district, having slopes ranging from 10 to 25%, the results of six FPR trials show the same trends. Treatments 4 and 5 reduced soil losses between 51.1 and 59.9% as compared to the farmers' practices of growing cassava in monoculture. The reduced erosion is due to the hedgerows and the intercrops. However, the cassava yield was only 10.5 t/ha in treatment 4 and 12.1 t/ha in treatment 5, which are lower than that of the farmers' practice. But these treatments also produced between 0.15 to 0.3 t/ha of peanuts (in dry pods), so the net income of treatment 5 was among the highest while the cost was not as high as that of the farmers practice (**Table 7**).

In Phuong Linh village of Thanh Hoa district in Vinh Phu province, ten farmers participated in the project to conduct trials on their own fields with slopes ranging from 32 to 45%. The results, shown in **Table 8**, indicate that all treatments with hedgerows reduced soil erosion between 17 and 21% as compared to the check plot, while the cassava yields were between 3 and 29% higher than in the check plot (treatment 2). A simple economic analysis of the trial indicate that treatment 6 produced the highest net income of 23.57 mil. dong/ha, while the farmers practice in treatment 2 produced only 11.13 mil. dong/ha, which is less than half of that of treatment 6. After discussing the results of the FPR trials, nearly all farmers in Thanh Hoa and in Pho Yen selected the treatment of cassava intercropped with peanut, with NPK application and with vetiver grass hedgerows as the best management practice.

Table 7. Combined results of six FPR soil erosion control trials with cassava conducted in Dac Son and Tien Phong villages of Pho Yen district, Bac Thai province of Vietnam in 1995.

	Dry soil loss (t/ha)[1]	Yield(t/ha)		(million dong/ha)			
		cassava	intercrop	Gross[2] income	Costs	Net income	Farmer[3] preference
Farmer's practice[4]	29.52	14.09	-	11.27	2.99	8.28	0
C monoculture, contour ridging, NPK only[5]	32.31	11.83	-	9.46	1.29	8.17	9
C monoculture, no ridging, NPK+FYM[6]	46.54	14.68	-	11.74	1.90	9.84	0
C+black bean, *Tephrosia* hedgerows, NPK	22.76	10.49	0.153	9.31	1.25	8.06	24
C+peanut, vetiver grass hedgerows, NPK	18.65	12.06	0.312	11.52	1.71	9.81	100

[1]Soil loss during crop cycle.

[2]Cost of manure, fertilizers, intercrop seeds and ridging.

Prices:			
	fresh cassava roots	:	800 d/kg
	black bean or peanut	:	6,000 d/kg
	urea(45%N)	:	2,500 d/kg
	SSP(17%P_2O_5)	:	1,000 d/kg
	KCl(60%K_2O)	:	2,500 d/kg
	pig manure	:	100,000 d/t
	black bean seeds	:	6,000 d/kg
	peanut bean seeds	:	7,000 d/kg
	ridging	:	280,000 d/ha

[3]Percentage of farmers choosing treatment.

[4]Cassava monoculture fertilized with on average 47.3 kg N+29.5 P_2O_5+53.6 K_2O+21.6 t pig manure/ha.

[5]NPK=80 kg N+40 P_2O_5+80 K_2O/ha.

[6]NPK+FYM=60kg N+40 P_2O_5+80 K_2O+10 t pig manure/ha.

Table 8. Results of an FPR soil erosion control trial with cassava conducted in Phuong Linh village, Thanh Hoa district of Vinh Phu province of Vietnam in 1995. Data are average of two replications.

Treatments[1]	Slope (%)	Dry soil loss (t/ha)	Yield(t/ha)		Income (mil.dong/ha)[3]		Farmer preference[4]
			cassava	peanut	gross	net	
1)Cassava+peanut, no fertilizers, no hedgerows	40.5	53.7	19.6	1.200	14.82	10.13	-
2)Cassava monoculture, with fert.[2],no hedgerows	45.0	54.5	16.5	-	7.42	2.40	-
3)C+peanut, with fert., no hedgerows	42.7	50.1	16.9	1.471	13.46	7.70	30
4)C+peanut, with fert., *Tephrosia* hedgerows	39.7	45.3	17.0	1.288	14.09	8.33	-
5)C+peanut, with fert., *Desmodium* hedgerows	32.2	43.4	18.7	1.133	14.08	8.33	40
6)C+peanut, with fert., vetiver grass hedgerows	37.7	42.9	21.3	1.720	18.18	12.42	100
7)Cassava monoculture, with fert., *Tephrosia* hedgerows	40.0	45.3	20.6	-	9.27	4.25	-

[1]All treatments received 10 t pig manure/ha.
[2]Fertilizers = 60 kg N+40 P_2O_5+120 K_2O/ha = 1.069 million dong/ha.
[3]Prices:

fresh cassava roots	:	450	d/kg
peanut in shell	:	5,000	d/kg
urea(45%N)	:	2,500	d/kg
SSP(17%P_2O_5)	:	1,000	d/kg
KCl(60%K_2O)	:	2,500	d/kg
pig manure	:	100,000	d/t

[4]Percentage of farmers choosing treatment.

3.2. Results of intercropping trials

The survey conducted in 1994 identified some commonly used systems of cassava intercropping with peanut or black bean. Cassava was usually planted with 1.4 m between rows and 0.6 between plants. The intercrops were planted along two sides of the cassava rows. So, it was decided to compare these two systems with the traditional system of growing cassava in monoculture. In 1995, seven farmers in Tien Phong village conducted these intercropping trials, each with three treatments. Cassava and intercropped plants were distributed as follows: cassava was planted at 0.9x0.7 m with two rows of intercrops between cassava rows. Results of these trials (**Table 9**) show that net incomes from intercropping were higher than from cassava monoculture. Cassava intercropped with peanut increased net income by 45% over cassava monoculture, because this treatment produced 12.3% higher cassava fresh root yields than the check, as well as 0.711 ton dry pods of peanut/ha. Since, all stems and leaves of intercropped peanuts were incorporated as green manure after the peanut harvest this may have increased cassava yields. Cassava intercropping with black bean seems less promising as the black bean variety used is a climbing bean, which climbs around cassava plants. Cassava yields were affected by competition from these beans.

Cassava intercropping with peanut seems a very promising system, both for increasing farmers' income and for soil conservation. Most farmers want to apply this method as 100% of farmers selected this treatment as the best practice.

3.3. Results of fertilizer trials

Some FPR fertilizer trials, each with various combinations of N, P and K, together with pig manure, were conducted in the two villages of Pho Yen district in 1995. The results of these trials, shown in **Table 10**, gave farmers some idea about the economic effects of fertilizer application. The farmers' own practice produced an average cassava yield of only 10.9 t/ha, while the application of 10 t/ha of pig or buffalo manure produced a yield of only 7.13 t/ha. The results indicate that potassium plays a very important role for cassava (comparing cassava yields in treatments 5 and 6) in sandy loam soils like those in Pho Yen district. It is very important to apply K to cassava if farmers want to get higher cassava yields. On the other hand, when we compare cassava yields in treatments 4 and 6, it is clear that cassava did not respond to phosphorus application. So, farmers should apply P probably only once every three years. Treatment 4 also produced the highest net income among these six treatments. It is very important to know that cassava yields in this area can be maintained with the application of organic manure combined with some chemical fertilizers, as shown in these trials.

Table 9. Average results of seven FPR intercropping trials with cassava conducted in Tien Phong village of Pho Yen district in Bac Thai province of Vietnam in 1995.

Treatments	Yield (t/ha)		(million dong/ha)			
	cassava	intercrop	Gross income	Costs[1)]	Net income	Farmer preference[2)]
Cassava monoculture	17.07	-	13.66	2.01	11.65	14
Cassava + black bean	16.62	0.263	14.87	2.25	12.62	57
Cassava + peanut	19.17	0.711	19.60	2.71	16.89	100

[1)]Cost of fertilizers, manure and intercrop seeds:
80 kg N + 40 P_2O_5 + 80 K_2O/ha = 1.01 million dong/ha
10 t pig manure/ha = 1.00 million dong/ha
40 kg black bean seeds/ha = 0.24 million dong/ha
100 kg peanut seeds/ha = 0.70 million dong/ha
[2)]Percentage of farmers choosing treatment.

Table 10. Average results of two FPR fertilizer trials with cassava conducted in Dac Son and Tien Phong villages of Pho Yen district, Bac Thai province of Vietnam in 1995.

Treatments	Cassava yield (t/ha)	Gross[1)] income	(million dong/ha)		
			Costs[1)]	Net income	Farmer preference[2)]
Farmer's practice[3)]	10.92	8.74	2.87	5.87	-
$N_0P_0K_0$ + 10 t FYM	7.13	5.70	1.00	4.70	-
$N_0P_{40}K_{80}$ + 10 t FYM	14.15	11.32	1.57	9.75	-
$N_{80}P_0K_{80}$ + 10 t FYM	15.65	12.52	1.78	10.74	100
$N_{80}P_{40}K_0$ + 10 t FYM	13.87	11.10	1.68	9.42	-
$N_{80}P_{40}K_{80}$ + 10 t FYM	15.65	12.52	2.01	10.51	81

[1)]Prices :
fresh cassava roots : 800 d/kg
urea (45% N) : 2,500 d/kg
SSP (17% P_2O_5) : 1,000 d/kg
KCl (60% K_2O) : 2,500 d/kg
pig manure : 100,000 d/t
[2)]Percentage of farmers choosing treatment.
[3)]On average applied 20.8 t pig manure, 37.1 kg P_2O_5 and 137.5 K_2O/ha

3.4. Results of variety trials

In 1995, two promising clones, i.e. KM60 and CM4955-7, were evaluated on farmers' fields. **Table 11** shows that these clones had fresh root yields between 11.6 and 28.5% higher than the local check variety, Vinh Phu. Among 18 farmers who evaluated these trials, 61.1% selected KM60 and 77.8% selected CM4955-7 for planting next year.

Table 11. Average results of three FPR cassava variety trials conducted in Tien Phong village of Pho Yen district, Bac Thai province of Vietnam in 1995.

Variety	Cassava yield (t/ha)	(million dong/ha) Gross income	Net income[1)]	Farmer preference[2)]
Vinh Phu	14.30	11.44	9.43	11
CM4995-7	18.37	14.70	12.69	78
KM-60	15.96	12.77	10.76	61

[1)]Cost of fertilizers+manure = 2.01 million dong/ha.
[2)]Percentage of farmers preferring the variety.

4. Farmers' Field Days

The first farmers' field day was held for farmers from both pilot sites at the Agro-forestry College in Thai Nguyen, to evaluate the demonstration plots and to discuss the technology components to be tested on their own fields in 1995.

The second farmers' field days were held both at the pilot sites and at the Agro-forestry College, one day in each location. A very important aspect of FPR is that farmers, researchers and extensionists work together in conducting the trials. Thus, all of us joined and worked together during harvest, evaluation and the discussion to select the best options and to decide on the most appropriate technologies to be included in the design of the work plan for the next season.

Farmers' preferences are presented in the last column of **Tables 7, 8, 9, 10** and **11**. Based on this, the following technologies were considered as best adapted to the farmers' conditions (Tran Ngoc Ngoan *et al.*, 1995):

1. Cassava intercropped with peanut, with application of 60 kg N + 40 P_2O_5 + 120 K_2O + 10 ton pig manure/ha, and with vetiver grass hedgerows to reduce soil erosion and increase net income.
2. Cassava intercropped with peanut with a basic fertilization of 10 ton pig manure, 80 kg N + 40 P_2O_5 + 80 K_2O/ha for soil conservation and increasing net income.
3. Both KM60 and CM4955-7 were selected for the next evaluation.

5. On-going Work in 1996.

These initial results are encouraging more and more farmers to participate in the FPR trials. The number of farmers participating in 1996 increased to 57 households, of which 37 in Pho Yen district, 13 in Thanh Hoa district and 7 in Luong Son district.

Also, some treatments have been adjusted in accordance with the farmers' own ideas, such as the use of the new variety KM60 in combination with treatments on soil erosion control. In 1996, the variety trials increased both in number of farmers participating (20 farmers) and in the number of promising clones tested (5 promising clones/trial).

CONCLUSIONS

After two years of work and some initial results, we have learned a lot about the use of the FPR approach, and farmers also know why we need to work more closely together with them; they are encouraged to contribute their local experiences while working together as a group. FPR is very useful for us, because by conducting this type of research together with farmers on their own fields, other problems can be identified. We can get feedback information about what farmers want to do and what they don't want to do. A strong linkage between researchers, farmers and extentionists in the technology development process was established. The learning from each other, while working closely with farmers, will increase the adoption of new technologies by farmers and will also improve the relevance of the research conducted by us. It is also encouraging the process of farmers learning from farmers. However, while working with farmers we need to learn more about the FPR methodology and improve our skill in working with different groups of farmers.

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FARMER PARTICIPATORY RESEARCH IN SOIL MANAGEMENT IN INDONESIA

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ABSTRACT

Soil degradation, both due to soil erosion and nutrient removal, is a major problem in cassava fields. Most of the existing management technologies that have been developed have had little success in adoption. Some of the reasons are that the technology developed is technically oriented, based on experiment station research with very little farmer involvement.

Research on "Farmer's participation in developing management technologies for cassava-based cropping systems" was carried out in farmers' fields in Wates and Dampit subdistricts of Blitar and Malang districts of East Java, respectively. The research is planned for five years, with the first year activities of : (a) Rapid Rural Appraisal (RRA) and diagnostic surveys for identification of the problems encountered by cassava farmers, and (b) establishment of demonstration plots to test and to show to farmers the management technologies that have been identified and selected by the collaborating farmers. Activities planned for the second and following years include the testing of the most attractive technology options on farmers' fields by farmers themselves.

In general, most farmers had already been aware of the problem of soil degradation in their fields, and had tried some management technologies for overcoming this problem. However, since the technology is too complicated, laborious and costly, they were unwilling to adopt. In fact, most farmers were very keen to adopt any attractive new technology, if the technology is simple, does not imply a lot of extra costs, and is easy to be adopted. This was indicated by the number of farmers willing to participate in the second year to test some technologies in their own fields.

INTRODUCTION

Soil deteriotation and land degradation are common and serious problems in Indonesian cassava fields. Therefore, a lot of people believe that these problems arose from cassava cropping. With its high dry matter yield, cassava removes a lot of plant nutrients from the soil. In addition, a high erosion rate, especially during the early growth phase, is often observed from cassava fields.

It is true that the soil in most cassava fields is in very poor condition. However, the soil deterioration is not only due to cassava. In fact, the soil has become in such a critical condition, that cassava is the only crop that can grow and produce a reasonable yield. For example, of the 300,000 ha planted to cassava in East Java more than 80% is in critical condition.

Realizing the problem, many soil management technologies have been developed, both to control soil degradation and to improve soil productivity. However, cassava

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farmers have hardly adopted these technologies. If they apply the technology, the adoption process takes a very long time, and the application of the technology is only temporary. This is not due to the lack of understanding of soil erosion and soil management. A lot of studies have indicated that in most areas of marginal land, farmers are already well aware of the problems of soil erosion, soil degradation and of ways to overcome these problems (Utomo *et al*, 1994). However, technology adoption is another matter. In most cases, farmers are reluctant to adopt the technology developed by researchers, because the technology is too costly, too complicated or does not give direct benefits. It seems that most researchers developed the technologies based on their own ideas, without considering the farmers conditions and requirements. In addition, most of the technologies are technically oriented and developed under experimental station conditions. Thus, as stated by Henry (1994), researchers used a top-down approach.

Some sociologists and anthropologists (Fujisaka, 1989; Saragih and Tampubolon, 1991) have suggested that to develop a more adoptable technology, we should take into account the farmers' conditions and farmers' requirements. Thus, the technology should be more farmer-oriented. The methodologies used include what are called "On Farm Research" and "Farmer Participatory Research" (FPR). Henry and Hernandez (1994) have shown that FPR is very effective for the dissemination of new cassava varieties in Colombia. The potential of FPR in soil management technology transfer has been discussed extensively by Fujisaka (1991).

The work reported here aims to study the effectiveness of FPR for soil management and varietal dissemination to cassava farmers in East Java, Indonesia. The research was carried out at Ringinrejo village, Wates subdistrict of Blitar district, and in Sumbersuko village, Dampit subdistrict of Malang district, and was planned for five years. The report describes the first and second year's results.

FARMER PARTICIPATORY RESEARCH

The research started with a Rapid Rural Appraisal (RRA) to identify the problems of cassava farmers, and to learn about the farmers' ideas on soil management. Based on this discussion, demonstration plots were established to show a wide range of prospective soil management technologies, after which farmers selected and tried some soil management technologies in their own fields. The project staff helped farmers to conduct this research.

Rapid Rural Appraisal (RRA)

A Rapid Rural Appraisal was carried out in August 1994 in Blitar and in Sept 1994 in Malang district. A team consisting of two soil scientists, one agronomist, one agricultural socio-economist and one soil conservation extensionist (from Brawijaya University, RILET and the Institute for Soil Conservation and Land Rehabilitation, respectively), interviewed key farmers in the two villages covering the following topics:

a. Soil and land conditions
b. Agricultural practices (crops and varieties used, spacing, cropping systems, fertilization, etc.)
c. Soil conservation and management practices
d. Socio-economic conditions

The main purpose of the RRA is to learn about the awareness and the perception of the target farmers concerning soil degradation problems, and their understanding and ideas about soil conservation and management practices.

To obtain more detailed baseline data, a diagnostic survey was conducted in Sept 1995 in Blitar and in Nov 1995 in Malang.

The results of the Rapid Rural Appraisal (**Table 1**) indicate that most farmers in the study area are aware of the problems they encounter. The farmers know well that their soil is in a very poor condition and a lot of work needs to be done to get a reasonable yield. They are also well aware that soil degradation due to soil erosion is occuring very rapidly. Hence, soil conservation, both the preventing of soil erosion and the improving of soil fertility is essential.

The problems are that the land area owned by individual farmers is very small, about 0.40-1.0 ha/household (also notice the results of the detailed survey given in **Table 2**). Hence, the income from farming activities is very low (around Rp 600,000/year/household). With this low income it is imposible for farmers to worry about erosion and to manage the soil more effectively. Actually, the farmers are very eager to practice better soil management in their fields. However, most of the recommended soil management technologies are very expensive and require constant maintenance. In addition, some soil management techniques (such as alley cropping) are complicated and require a lot of time and labor for the technology to work well. At certain times during the year, especially during the dry season and after planting, many people go to the city to earn additional income. Therefore, there is often not enough labor available to look after the soil management technology they want to practice.

Although a lot of farmers raise livestock (**Table 2**), they do not like to include elephant grass barriers in their crop area. It seems this is due to strong competition between the main crop and the elephant grass. Some farmers use leaves of *Gliricidia sepium* which is planted as a fence, for livestock feeding, especially during the dry season.

Demonstration Plots

Based on the information obtained through the RRA, a set of soil management technologies was tested in the demonstration plots established both in Ringinrejo village, Wates subdistrict of Blitar district, and in Sumbersuko village, Dampit subdistrict of Malang district, both in East Java.

The soil management technologies tested in Blitar and Malang are given in **Tables 3** and **4**, respectively.

All experimental activities, including land preparation, planting and the taking of measurements, were done by the farmers, which were coordinated in a farmers' group in each site. These farmers' groups consisted of 33 farmers in Ringinrejo and 23 farmers in Sumbersuko.

The data given in **Tables 3** and **4** show that some introduced soil management technologies produced better results, both in terms of increasing farmer's income and decreasing soil loss, than the traditional farmer's practice. Even though the alley trees were still small in both sites, the practice of alley cropping was already able to decrease soil losses due to erosion.

To obtain the perception of the farmers' group and of their neighbors to the soil management technologies tested, field days were organized on April 28 and Sept 3, 1995, for the Ringinrejo site, and on Oct 24, 1995 for the Sumbersuko site. In addition, to broaden the view of the participating farmers, another field day was held at Jatikerto Experimental Station of Brawijaya University in Jatikerto, Malang. Farmers evaluated and discussed the soil management technologies that have been tested for many years at this experimental station.

The opinion and selection priorities of farmers to the soil management technologies are given in Table 5. It seems that the opinion and preference of farmers to any technology is based mainly on what they see. They did not yet know the cassava yield at Jatikerto, but the field showed that cassava planted with *Gliricidia* contour strips grew very well. Hence, they choose this technology.

Although there was clear competition between the elephant grass and cassava, as indicated by poor cassava growth close to the elephant grass strips, this technology is still preferred by some farmers. These farmers argued that they need elephant grass to feed their livestock. Crop competition could be decreased by the application of manure. They also saw that the soil loss in the treatment with elephant grass strips at Jatikerto was very low.

Some farmers in Ringinrejo still preferred planting cassava intercropped with maize using the farmer's traditional wide spacing of cassava rows because they can use more space to plant maize and other crops after maize. These farmers use maize as the main family food.

Table 1. Results the of Rapid Rural Appraisal (RRA) conducted at Ringinrejo village, Wates subdistrict of Blitar district in East Java, Indonesia, in Aug 1994.

Key issues	Conditions	Farmer perception	Limiting factors
Soil	- Thin top soil with underlying limestone - Low nutrient content (esp. N, P, K and some micronutrients)	- They understand that soil should be improved	- Lack of capital - Difficult to obtain manure
Cropping			
a.Species	- Maize as the main crop, cassava as intercrop	- Maize is the main food, cassava is only a security food or for cash	- High fluctuation of cassava prices
b. Variety	- Maize: local, Arjuno or Hybrids - Cassava : local or Faroka	- Farmers plant the variety available	- Lack of information about new varieties
c. Spacing	- Maize: 100x20 cm - Cassava: 100x200 cm	- Farmers are able to grow a second intercrop after maize	
d. Planting date	- Start of rainy season		- Beginning of rainy season is unpredictable
e. Fertilizer	- Urea	- Do not apply enough	- Lack of capital
f. Yield	- Maize: 2-3 t/ha - Cassava: 5-8 t/ha	- Yields are extremely low	
Soil and Land Conservation			
a. Tree crops	- Very few tree crops	- Farmers understood well the importance of soil conservation	- Lack of capital - Lack of labor for maintenance of terraces
b. Terracing	- Improper terracing	- Technology for soil conservation is too costly and too complicated	
c. Contouring	- Some farmers practice contour ridging		
d. Strip cropping /alley cropping	- Gliricidea is used as a fence	- Gliricidea and elephant grass used as animal feed	
Farm size	- 0.60 ha/household	- Too small to obtain enough income	
Land distribution	- Unequal land area - Fragmented land holdings	- Need a lot of time and labor	
Farmers income	- Rp 600.000/household/year[1)]		
Mobility	- Many people move to the nearest city temporarily to earn additional income		- Limited work opportunity at at the village

[1)]1US$ = Rp 2100,-

Table 2. Characteristics of the two project sites.

Characteristic	Ringinrejo(Blitar)	Sumbersuko(Malang)
1. Altitude (m above the sea)	420	500
2. Rainfall (mm/year)	~1500	>2000
3. Soil	Lithosol (Entisol)	Latosol (Oxisol)
4. Topography	undulating to hilly	undulating to hilly
5. Total area (ha)	2,232	1,057
a. Upland (tegal)	552	835
b. Plantation crops	857	-
c. Forest	159	-
d. Others	664	222
6. Crops (ha)		
a. Upland rice	115	36
b. Maize	292	425.
c. Cassava	145	725.
d. Soybean	60	-
e. Peanut	30	-
7. Total Population	3,420	1,191
a. Farmers	3,283	641
b. Others	137	550
8. Livestock ownership		
a. Cow/household	1.36	0.6
9. Income (US $/h.h./year)		
a. Farming	250	550
b. Others	500	300

Table 3. Total dry soil loss[1] due to erosion and yield[1] of cassava and maize in the demonstration plots planted on 10-25% slope in Ringinrejo village, Wates subdistrict of Blitar district in East Java, Indonesia in 1994/95.

Treatments	Total dry soil loss (t/ha)	Yield (t/ha) Cassava	Yield (t/ha) Maize[4]	Total crop value[5] <----('000Rp/ha)	Fertilizer cost ('000Rp/ha)	Net income ('000Rp/ha)---->
1. Monoculture cassava (Ketela ijo), farmer fertilization[2], farmer spacing[3]	27.45	7.75	-	697.5	225.5	472.0
2. Monoculture cassava (Ketela ijo), recommended fertilization, farmer spacing	59.32	12.50	-	1,125.0	117.0	1,008.0
3. Monoculture cassava (Faroka), recommended fertilization, recommended spacing	42.78	7.17	-	645.3	117.0	528.3
4. Monoculture cassava (SM-4772), recommended fertilization, recommended spacing	45.54	6.45	-	580.5	117.0	463.5
5. C(Ketela ijo)+M-S, farmer fertilization, farmer spacing	41.06	4.64	3.04	949.6	225.5	724.1
6. C(Faroka)+M-S, recommended fertilization, recommended spacing	35.93	5.11	5.43	1,410.1	175.5	1,234.6
7. C(Faroka)+M-S+cowpea strip, recommended fertilization, recommended spacing	37.98	3.44	4.53	1,102.3	175.5	926.8
8. C(Faroka)+M-S+*Gliricidia sepium* hedgerows, recom. fertilization, recom. spacing	27.59	4.17	5.36	1,313.3	175.5	1,137.8
9. C(Faroka)+M-S+*Flemingia congesta* hedgerows, recom. fertilization, recom. spacing	25.30	3.91	3.65	990.6	175.5	815.1
10. C(Faroka)+M-S+*Leucaena leucocephala* hedgerows, recom. fertilization, recom. spacing	36.85	3.37	3.74	957.8	175.5	782.3
11. C(Faroka)+M-S+*Calliandra* hedgerows, recom. fertilization, recom. spacing	22.41	3.66	5.22	1,242.9	175.5	1,067.4
12. C(Faroka)+M-S+elephant grass hedgerows, recom. fertilization, recom. spacing	37.37	6.38	4.89	1,429.9	175.5	1,254.4

[1]Yield and soil loss data are average of three replications, even though yield of cassava in the third replication was zero in all plots.

[2]Fertilization: a) farmer practice: 6t/ha FYM; 100 kg urea, 100 TSP, 50 KCl/ha.
b) recommended: monoculture: 5t/ha FYM, 200 kg urea, 100 TSP, 100 KCl/ha.
intercropping: 300 kg urea, 150 TSP, 150 KCl/ha.

[3]Spacing: a) farmer practice: monoculture: cassava 100x100 cm.
intercropping: cassava 80x80 cm, maize 20x100 cm.
b) recommended: monoculture: cassava 80x80 cm.
intercropping: cassava 80x80 cm, maize 40x40 cm.

[4]Maize variety: CPI-1 Hybrid.

[5]Prices: fresh cassava roots: Rp 90/kg; maize dry grain: Rp 175/kg.

Table 4. Total dry soil loss[1] due to erosion and yield[1] of cassava and intercrops in the demonstration plots planted on 15-30% slope in Sumbersuko village, Dampit subdistrict of Malang district in East Java, Indonesia in 1994/95.

Treatments[2]	Total dry soil loss (t/ha)	Yield (t/ha) Cassava	Maize	Peanut	Cowpea	Total crop value[3]	Fertilizer cost[3]	Net income
						<---------('000Rp/ha		-------->
1. Monoculture cassava, farmer practices, up/down ridging, cv. Menyok	72.33	19.89	-	-	-	1,293	73.50	1,219
2. Monoculture cassava, recom. practices, up/down ridging, cv. Menyok	65.86	18.67	-	-	-	1,213	229.75	983
3. Monoculture cassava, recom. practices, up/down ridging, cv. Malang-1	72.69	21.14	-	-	-	1,374	229.75	1,144
4. Monoculture cassava, recom. practices, contour ridging, cv. Malang-1	57.06	25.83	-	-	-	1,679	229.75	1,449
5. As treatment 4, with silt pit and application of FYM, cv. Malang-1	58.19	19.75	-	-	-	1,284	229.75	1,054
6. C+M+Cp-P, double row cassava (400x100x80 cm), no ridging, cv. Malang-1	49.97	15.47	0.26	1.00	1.17	2,801	217.00	2,584
7. C+M+Cp-P, single row cassava (100x80 cm), no ridging, cv. Malang-1	46.75	14.60	0.46	0.83	1.21	2,687	217.00	2,470
8. C+M+*Gliricidia sepium* hedgerows every 4m, no ridging, cv. Malang-1	51.62	18.61	4.58	-	-	2,263	170.75	2,092
9. C+M+*Flemingia congesta* hedgerows every 4m, no ridging, cv. Malang-1	55.39	18.29	4.65	-	-	2,258	170.75	2,088
10. C+M+*Leucaena leucocephala* hedgerows every 4m, no ridging, cv. Malang-1	58.00	18.21	4.79	-	-	2,285	170.75	2,115
11. C+M+*Calliandra* hedgerows, every 4m, no ridging, cv. Malang-1	54.73	17.50	4.85	-	-	2,253	170.75	2,082
12. C+M+elephant grass hedgerows every 4m, no ridging, cv. Malang-1	48.50	20.47	4.61	-	-	2,391	170.70	2,220

[1]Yield and soil loss data are average of three replications; maize yields estimated from weight of fresh cobs x 0.3

[2]Fertilization: farmer practice: 300 kg urea/ha.;
recommended: ymonoculture: 5t FYM, 150kg urea, 100 TSP, 100 KCl/ha.
intercropping: cassava: 150 kg urea, 50 TSP, 50 KCl/ha.
maize: 150 kg urea, 50 TSP, 50 KCl/ha.
peanut or cowpea: 50 kg urea, 50 TSP, 50 KCl/ha.
treatments 8-12: cassava: 200 kg urea, 100 TSP, 100 KCl/ha.
maize: 150 kg urea, 50 TSP/ha.

Varieties: Cassava: Menyok in treatments 1-2; Malang-1 in treatments 3-12
Maize: Arjuna
Peanut: Gajah

[3]Prices:

Cassava fresh roots	: Rp	65/kg.	urea	: Rp	245/kg.
Maize dry grain	:	230/kg.	TSP	:	340/kg.
Peanut dry pods	:	800/kg.	KCl	:	340/kg.
Cowpea dry grain	:	800/kg.	FYM	:	25/kg.

Table 5. Farmer preference and opinion on soil management technologies demonstrated in Ringinrejo (Blitar) and Sumbersuko (Malang) as well as at Jatikerto Experimen Station in Malang, E. Java, Indonesia.

Farmer preference	Soil management treatment	Net income ('000 Rp/ha)	Soil loss (t/ha/year)	Farmers' opinions
1.	*Gliricidia* contour strip	1,509[1)]	39.6[1)] a little[4)]	- Cassava grows very well[5)] - Soil loss is low - *Gliricidia* leaves can be used for livestock feed
2.	*Flemingia* contour strip	1,451[1)]	40.3[1)] a little[4)]	- Cassava grows very well[5)] - No competition - *Flemingia* leaves are good for feeding goats
3.	Elephant grass contour strip	1,737[1)]	42.9[1)] none[4)]	- Altough there was strong crop competition, the soil loss is rather low - Elephant grass used as livestock feed
4.	*Calliandra* contour strip	1,574[1)]	38.6[1)]	- *Calliandra* leaves are good for livestock feed - Soil loss is low
5.	Cassava + Maize (farmers' practice)	724[2)]	41.1[2)]	- Need a wide cassava spacing to plant more maize
6.	Farmers' practice	472[2)]	47.4[2)]	-
7.	Farmers' practice	1,219[3)]	72.3[3)]	-

[1)]Date are average values of Ringinrejo and Sumbersuko demonstration plots
[2)]Ringinrejo demonstration plots
[3)]Sumbersuko demonstration plots
[4)]Soil loss observed at Jatikerto Experiment Station
[5)]The opinions on cassava growth were based on observations made in Jatikerto Experiment Station

Participating Farmers' Experiments

After evaluating the soil management technologies tested at Ringinrejo and at the Jatikerto Experiment Station, 15 farmers in Ringinrejo participated in the FPR project by testing some selected technologies in their own fields. The technologies tested in the farmers' fields are given in **Table 6**. Nine farmers conducted erosion control trials and six farmers participated in variety trials. In Sumbersuko, experimental activities in the second year still focussed mainly on the improvement of the demonstration plots.

Table 6. Soil management technologies tested by farmers in Ringinrejo in nine erosion control and six variety trials in 1995/96.

Soil management technologies	Number of farmers[1]
1. Erosion control trials:	
- *Gliricidia* contour strips	7
- *Calliandra* contour strips	3
- *Flemingia* contour strips	2
- *Leucaena* contour strips	1
- Elephant grass contour strips	2
- Intercropped with cowpea	2
- Control without strips	7
2. Variety trials:	
- Faroka	6(+6)[2]
- 15/10	5(+1)
- SM-4772	6(+1)
- Local(Ketela ijo)	1(+4)

[1] Number of farmers including the treatment in their FPR trials

[2] The number in brackets shows the number of farmers doing erosion trials in which the variety is included

As in the first year all experimental activities were done by the participating farmers. Project staff acted as coordinators and provided materials for the experiments. In Ringinrejo all participating farmers used 5000 kg manure/ha and applied 300-375 kg urea, 150-200 kg TSP and 100 KCl/ha in all treatments.

The yield and income of each treatment tested by participating farmers are given in **Table 7**. Due to high variability between farmers' fields in the eroison trials, a valid comparison between treatments is difficult. From the variety trials it can be concluded (**Table 7**) that the two introduced varieties, 15/10 and SM-4772, have a good prospect.

To discuss the results and obtain the views of the participating farmers, field days were held on August 15, 1996 in Sumbersuko and on September 19, 1996 in Renginrejo. In addition to the participating farmers, some neighbor farmers were also invited and participated in these field days. Farmers discussed the experimental results as well as the future of the project. For the third year, there will be 22 farmers in Ringinrejo and 15 farmers in Sumbersuko participating in the project, testing some selected technologies in their own fields.

Table 7. Average yields of cassava and maize as well as farmers' net income in nine FPR erosion and six variety trials conducted by farmers in Ringinrejo in 1995/96.

Treatment	Yield(t/ha)		Net income (Rp/ha/year)
	Cassava	Maize	
1. Erosion control trials:			
a. *Gliricidia* strips(Faroka)[1)]	5.6	1.1	1,387
b. *Gliricidia* strips(15/10)	8.9	0.6	868
c. *Gliricidia* strips(SM-4772)	9.0	0.7	731
d. *Calliandra* strips(Faroka)	6.3	2.2	2,453
e. *Calliandra* strips(15/10)	8.2	1.5	791
f. *Flemingia* strips(Faroka)	5.6	0.9	1,191
g. *Leucaena* strips(Faroka)	2.2	0.8	707
h. Elephant grass strips(Faroka)	3.4	0.9	1,052
i. Cowpea intercrop(Faroka)	1.5	0.6	520
J. No strips(Faroka)	4.9	1.2	1,778
k. No strips (Local/Ketela ijo)	5.5	1.0	1,307
2. Variety trials:			
a. Faroka	4.2	1.1	1,075
b. 15/10	9.4	1.0	1,238
c. SM-4772	5.1	0.8	1,084
d. Local/Ketela ijo	5.2	1.2	581

[1)]Cassava variety used in treatment

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FARMERS' PARTICIPATION IN CASSAVA TECHNOLOGY TRANSFER IN THE PHILIPPINES

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ABSTRACT

Experiences gained from past root crop extension activities made PRCRTC realize the importance of clienteles' participation in technology development and transfer. PRCRTC is now trying to adopt a participatory approach in all cassava technology transfer activities. Results of some of these extension activities shows that farmers' involvement in technology testing and modification and in the over-all decision making process of a project, led to the development of technologies that are better suited to the needs of the clienteles and helps to build up their capacity to manage the project on their own.

In 1996 a project was initiated that employs farmer participatory research (FPR) methodologies to transfer soil and water conservation technologies to cassava farmers in Bontoc, south Leyte. This is a cassava growing area where cassava production is increasing due to the establishment of a cassava-based feedmill, as well as the entry of San Miguel Corporation, which buys large volumes of dried cassava chips for export. A preliminary survey about the farmers' knowledge, attitude and practices concerning soil conservation has already been conducted with 91 cassava farmers as respondents. The majority (75%) of the farmers realized the damage that would occur on continuously cultivating hilly areas, but only less than 50% are actually trying to control erosion using various methods they learned from different sources. Around 65% of the respondents, however, expressed their interest in learning soil conservation methods that would be more effective than the methods presently used. The information given by the farmers is now used as the basis for conducting other FPR activities in Bontoc.

INTRODUCTION

The increasing interest in cassava by the business sector offers opportunities to further the development of the cassava industry in the Philippines. At present, the crop is used not only as food by many Filipinos, but also as raw material in the manufacture of several commercial and industrial products, like chips for export, starch, adhesives, binders, feed and various food products. Some private companies are also looking into the possibility of using cassava as raw material in the massive production of alcohol, glucose and sorbitol.

Despite these opportunities, the cassava industry in the country has been growing slower than what is desired, because it has been hindered by several problems. These problems include low crop yield, poor processing facilities, low product quality, low product price and lack of domestic markets.

The Philippine Root Crops Research and Training Center (PRCRTC) has been supporting the cassava industry in the country through the development and transfer of cassava technologies, such as high-yielding cassava varieties, improved cultural

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management practices, cassava storage technologies, processing machines, feeds and different food products. However, the Center's past extension activities had limited impact on the cassava industry, especially on farmers. Acceptance of the technologies introduced was rather low and sustainability of technology adoption, especially among farmers and small processors, was hardly obtained.

Several factors caused these problems. One is too much focus on the technology itself, disregarding other factors that greatly influence technology adoption, such as market, the entrepreneurial and organizational capabilities of the technology users and others. Another constraint was the farmers' lack of participation in the technology development and transfer process. Farmers' participation was limited to being mere recipients of the technologies developed by the research institutions, respondents in some baseline surveys, participants in some formal consultation meetings, or cooperators of some on-farm trials, which were basically designed by the researchers. According to Werner (1993), nobody has a better understanding of his different needs and the opportunities his farm offers than the farmer himself. Thus, the farmers' lack of participation in the technology development and transfer process often resulted in technologies that did not correspond with their needs and conditions.

With these realizations, PRCRTC is now trying to improve its technology transfer approaches. Efforts are geared towards improving farmers' participation in the technology development and transfer process. PRCRTC is also trying to incorporate market development, organizational/entrepreneurial build-up, linkage establishment and other neccessary components in the Center's technology transfer efforts. All these are being considered in the PRCRTC's current cassava technology tranfer program (funded by PCARRD-DOST), which focus on the expansion of cassava markets through the establishment of integrated cassava projects.

This paper will discuss how the farmers are being involved in the implementation of PRCRTC's cassava technology transfer projects in northern Mindanao and in Bontoc, southern Leyte. This will also present the problems encountered and the possible ways of increasing farmers' participation and/or improving the efficiency of project implementation. Moreover, this paper will present the status of the FPR project on soil and water conservation, which PRCRTC has started to conduct late this year as part of its integrated cassava project in Bontoc, southern Leyte.

Direction of PRCRTC's Current Cassava Technology Transfer Activities

Considering the present status of the cassava industry in the country, PRCRTC's cassava extension activities are geared towards: 1. improving the farmers' cassava production level and processing efficiency in areas with existing cassava markets; and 2. promoting cassava commercialization/market expansion in cassava growing areas which are far from the existing cassava industries to encourage farmers to improve their cassava production level and enable them to increase their incomes.

PRCRTC's Ongoing Cassava Technology Transfer Activities

The Center currently focuses its technology transfer activities in northern Mindanao and the Visayas. The work in northern Mindanao is done to help the cassava farmers improve their cassava production level and chips processing efficiency. The project in the Visayas, on the other hand, are intended to expand the market for cassava through the establishment of integrated cassava projects that can create sustainable livelihood opportunities for the people. PRCRTC is currently assisting three integrated cassava projects in the Visayas. Of these three projects, the Integrated Cassava-Feedmill-Livestock Project in Bontoc, southern Leyte, was established first and is already operational. Thus, the discussion of PRCRTC's experience in involving farmers in technology transfer in the Visayas will be based on the Bontoc experience.

Farmers' Participation of the PRCRTC's Cassava Technology Transfer Activities

The cassava technology transfer projects in northern Mindano and in Bontoc, southern Leyte, are implemented by multidisciplinary action teams and in coordination with several agencies, i.e. the Department of Agriculture, Land Bank of the Philippines, Department of Science and Technology, etc. Phasing of activities for each area differed due to the differences in the nature of their problems and concerns. However, the activities followed the same pattern of: 1. micro-level diagnostics (analysis of problems and identification of possible solutions); 2. identification of project intervention and technologies to be introduced; 3. identification of technology transfer strategies to be used; 4. drawing up of detailed implementation plans; 5. actual project implementation/technology transfer; and 6. monitoring and evaluation.

In the first four stages, farmers' participation was made possible through joint visits and appraisals of the project sites, consultation meetings, and formal and informal group discussions.

In the actual project implementation/technology transfer, the farmers were asked to participate in the following activities: 1. establishment of demonstration farms; 2. trainings; 3. consultation meetings; 4. evaluation of the chipping machines; and 5. the conduct of simple experiments.

The farmers participation in the different technology transfer activities are further explained based on the experiences in the implementation of the projects in northern Mindanao and in Bontoc.

I. Cassava Technology Transfer in Northern Mindanao

Background information

Northern Mindanao is one of the most important cassava producing regions in the country. It is presently the site of rapid expansion of cassava production area due to the presence of a number of starch mills and the increasing chip export activities by some big companies, like San Miguel Corporation (SMC), CAPICAOR and GUANI

Marketing. In fact, financial assistance for the growing of cassava has been made available by CAPICOR, the Land Bank of the Philippines, and recently by the SMC Agribusiness Division.

Results of the diagnostic surveys revealed that despite these developments many farmers are still complaining about having low income from cassava because of the low yield of their native varieties and the low price offered by the chips exporters. They also complain about the absence of processing machines that can improve their processing efficiency and the quality of their chips. The exporters, on the other hand, are also complaining that the dried cassava chips produced by the small cassava farmers/ processors do not meet the required quality of the importing firms in Europe, resulting in high price discounts imposed on a number of their deliveries.

The above situation led PRCRTC to implement an action project that would deliver the needed package of assistance/technology to the people in the area to make cassava production and processing profitable for the farmers and at the same time improve the quality and acceptability of dried chips. The technologies introduced to the farmers include high yielding cassava varieties, improved cultural management practices and chipping machines.

In the conduct of the different technology transfer activities, PRCRTC worked with San Miguel Corporation, which had earlier sought the Center's assistance in looking for cassava suppliers, and with other support agencies.

During the consultation meetings with the different agencies concerned, it was agreed that SMC would do the legworking and the organization of farmers, Land Bank of the Philippines (LBP) would be tapped to finance the cassava production activities of the farmers, while PRCRTC would provide the needed technical assistance in the propagation of planting materials of the recommended high-yielding cassava varieties, training farmers on the improved cassava cultural practices and chips processing, and in the fabrication of the needed chipping machines.

The farmers, on the other hand, were asked to participate in the establishment and management of demonstration/model farms, technical training activities on cassava production and processing, and in the testing/evaluation and possible modifications of the chipping machines.

Establishment of model farms

To enable the farmers to actually observe the advantages of the high yielding varieties and the improved cultural practices, and to have propagation areas for the recommended high yielding cassava varieties, ten model farms (1.0 ha/site) were established in strategic sites in Misamis Oriental, Bukidnon and Lanao provinces. These model farms were managed by farmers; PRCRTC only provided the needed technical supervision. Lakan, Golden Yellow, VC varieties (1 to 5) and other high-yielding lines were planted in the model farms. The farmers' native varieties and their usual cassava cultural management practices were used as the control treatment. Selection of the best performing varieties were later conducted jointly by the farmers, the PRCRTC staff and San Miguel technicians. Other cassava farmers were also asked to participate in the selection process.

Farmers liked all the recommended varieties as these gave yields which were higher than those of their native varieties. Considering chips recovery, Lakan and Golden Yellow were choosen by the farmers because of their high dry matter content and high chips recovery.

Training on cassava production and chips processing

To reinforce the knowledge gained by the farmers from the demonstration farms, training on cassava production and chips processing was also conducted by technical experts from VISCA.

Fabrication and testing of chipping machines

To support the chips processing activities of the farmers, SMC is currently fabricating 15 units of pedal-operated chippers using the PRCRTC design. These machines will be distributed to the farmers for field evaluation and for actual use by farmers if found acceptable. SMC also plans to produce motorized chippers using the PRCRTC design.

Project status

As of 1996, the total cassava expansion area in the three sites already reached 3,000 ha. Although all farmers liked the recommended varieties included in the model farms, Lakan, Golden Yellow and VC-5 were used in the initial cassava production expansion because planting material of these varieties was more readily available.

In the farms that use the recommended varieties and the management practices recommended by PRCRTC, the average cassava yield ranged from 24 - 40 t/ha. Before the introduction of the PRCRTC technology, the farmers were planting native varieties which only gave them an average yield of 6-8 t/ha. Moreover, the chips processing efficiency of the farmers is already improving with the use of the chippers provided by SMC. However, a farmers' evaluation of the field performance and life span of the machines still needs to be done.

II. Cassava Technology Transfer in Bontoc, Southern Leyte

Background information

Results of the micro-level diagnostics conducted in Bontoc revealed that the municipality had a big unutilized hilly area suited for cassava production. Upland farmers were growing cassava because it was one of the few food crops that could thrive under the marginal conditions of the hilly area. However, the crop was grown only in small patches not exceeding 0.25 ha. This was because cassava utilization in the area was limited to food as a supplement for rice or maize, as animal feed, or was sold as fresh roots to the markets in the neighboring towns. The farmers did not process the crop into chips or other products.

The average yield of cassava in the area was low (3-5 t/ha). Many farmers were using native varieties like Imelda, Pulutan, Makan and others.

Regarding livestock raising activities, it was found that the animals raised by the farmers include carabao and native pigs and chicken. Only very few farmers raised cattle and hybrid pigs. The other farmers said piglets of hybrid pigs were expensive and not readily available in the area. The meat demand in Bontoc and the neighboring towns, however, was high. This demand was satisfied by importing pigs from Davao.

The overall situation of the cassava production and animal raising activities in Bontoc offered some opportunities for the development of integrated projects involving the improvement of cassava production, establishment of cassava processing projects to expand utilization and markets for the crop, and the development of the swine industry. The technologies and expertise needed for the establishment of these projects were available at PRCRTC-ViSCA.

A series of consultation meetings with the cooperator, a big cooperative known as the Bontoc Multipurpose Cooperative (BCCI), were conducted to identify the specific projects to be implemented in Bontoc. The BCCI and PRCRTC representatives later decided to initiate an integrated project having the following components: 1. cassava production and chips processing; 2. cassava-based feedmill; and 3. pig (100-sow level) and poultry raising.

The general concept of the project was that the farmer-members of BCCI would be taught to improve their production level by planting high-yielding cassava varieties recommended by PRCRTC. They would also be taught how to process cassava into dried chips using the PRCRTC-developed chippers. To serve as the main market of the farmers' chips, a cassava-based feedmill would be established. The piggery and poultry projects would serve as sure markets for the feeds produced by the feedmill. The piggery and poultry projects were also envisioned to satisfy the demand for meat by the people in Bontoc and the neighboring towns in southern Leyte. The cassava farmers would be encouraged to regularly supply dried chips to the feedmill to keep it operating. In short, the integrated project had been conceived to generate employment and increase the farmers' income from cassava production.

Cassava production and processing

These components of the integrated project were established first to assure that the feedmill would have a continuous supply of cassava chips once it started operation. The introduction/transfer of the high yielding varieties, the improved cassava cultural practices and the chipping machines was done through the establishment of demonstration farms, training, and fabrication and evaluation of the chipping machines.

Demonstration farms

To showcase the cassava production technology developed by PRCRTC, a demonstration farm containing the PRCRTC recommended varieties (Golden Yellow, Lakan and the edible VC varieties) was set up in Bontoc. The demo farm, which was managed by a farmer, was intended not only to show the farmers the advantages of using the new varieties and the improved cultural practices, but also to propagate cassava planting materials, which would be used by the farmers in their cassava production activities.

Evaluation of the advantages of the improved cassava production practices were later conducted by the farmers together with the PRCRTC and BCCI staff. The performance of cassava in the demo farm was compared with cassava in the farmer's field (using native varieties and traditional practices). The farmers observed that the high-yielding varieties grown using the recommended practices had yields which were more than twice the yield of the native varieties.

Training

To reinforce the knowlege gained by the farmers from the demo farm, PRCRTC also conducted training activities on "Cassava Production" and "Chips Processing" Farmers and technicians participated in these training activities. During the training, the farmers were taught about the high-yielding cassava varieties, the improved cultural practices for cassava, and the procedures in processing dried cassava chips, including the use of the PRCRTC-developed chippers. The farmers expressed their apprehension about the profitability of processing dried chips from cassava. After the discussion on the cost and returns of chips processing, most participants were convinced to produce and process cassava into chips for the BCCI feedmill.

Cassava Production

To identify farmer-cooperators for the cassava production and processing project, the BCCI officials together with the PRCRTC staff met with the BCCI farmer-members to inform them about the integrated cassava project. Several farmers expressed their interest in participating in the cassava production and processing components of the integrated project. The farmers, however, expressed their concern about the lack of capital to expand their cassava production areas. Thus, BCCI decided to extend cassava production loans to their members. The loanable amount was set at P6,000 per hectare.

Fabrication and Testing of Chipping Machines

To facilitate the cassava chipping operations, PRCRTC introduced to BCCI the pedal-operated chipper which could chip 400-500 kg of cassava roots per hour. BCCI ordered eight of these machines from PRCRTC. Construction expenses were shouldered by BCCI. The machines were stationed in strategic places in the cassava-growing village in Bontoc. The farmers took turns in using the machines at a minimal fee for maintenance purposes. Farmers' initial feedback about the machines was positive. They said the machines were many times more efficient than the bolo or knife. However, some problems regarding the machines may occur later. Thus, long-term evaluation of the machines' field performance and life span will have to be conducted by the project staff together with the farmer-processors.

Feedmill establishment

Building construction and equipment acquisition

The feedmill was established after the farmers assured BCCI of their full support through a constant supply of cassava chips. The building, which cost P800,000 was constructed using BCCI's own money. The feedmill equipment, on the other hand, was acquired by BCCI through DOST's financial support (loan grant).

Training on feed formulation

BCCI members who were identified to manage the feedmill component of the integrated project were trained by PRCRTC-ViSCA on the formulation of cassava-based feeds and on feedmill management. Hands-on training was done at the ViSCA Feedmill.

Piggery establishment

Construction of the BCCI' piggery was also done simultaneously with the construction of the feedmill building. Financing came from the Development Bank of the Philippines (P 2.5 million) and from the Land Bank of the Philippines-Maasin branch (P 1.2 million).

Status of the Bontoc Project

Cassava Production

The status of BCCI's cassava production project as of the 1995/96 cropping season is summarized in **Table 1**. There were 52 farmers who participated in the BCCI's cassava production program. All availed themselves of the loan extended by the cooperative. These farmers planted cassava before, but only in an area of less than 0.25 ha. When BCCI started its integrated cassava program, these farmers increased the size of the area planted to cassava to not less than one ha. The total area planted to cassava by the BCCI farmer-members who availed themselves of the cassava loan was 64 ha. The varieties used were Golden Yellow and Lakan because according to them, these varieties had high chips recovery and dried at a shorter period of time.

Yield sampling from different farmers' fields were conducted by the farmers and the PRCRTC staff to determine the average yield of the cassava planted using the recommended cultural practices. The average yield of the Golden Yellow and Lakan varieties was 20 t/ha. This is already a very big improvement over the yields of the native varieties (3-5 t/ha).

Chips Processing

A total of eight pedal chippers are currently used by the farmers to process chips for the feedmill. According to the farmers, these units are not enough, especially during the peak harvest season when many of them would like to use the machines. They also reported that the chipper blades will not last long if used to process big and over-mature roots. BCCI ordered chipper blades from PRCRTC to replace the destroyed ones. The PRCRTC project staff delivered the needed blades but they plan to train some BCCI staff on the repair and maintenance of the processing machines so that they would not have to rely anymore on the Center if repairs are needed.

Another problem reported by the farmers in relation to their chipping operations is the difficulty of drying the chips due to unpredictable weather and the lack of drying areas. Solution to this problem still needs to be discussed among the project participants.

Table 1. Cassava production status before and during the implementation of the BCCI cassava project in Bontoc, southern Leyte, Philippines.

Parameter	Before BCCI Project	When Project was implemented (1995/96 cropping season)
Number of participating farmers (BCCI members)	-	52
Total area planted to cassava (ha) under the BCCI cassava program	-	64
Varieties used	Imelda, Makan, Pulutan	Golden Yellow Lakan
Average area planted per farmer (ha)	0.25	1.0
Average yield (t/ha)	3-5	20

Chips Marketing

The chips processed by the BCCI members were bought by BCCI at P3.00/kg (farm gate price) for the cassava-based feedmill. From Feb 1996 (when the BCCI feedmill started operating) to Sept 1996, BCCI was able to buy a total of approximately 200 tons of chips from its farmer members. About 61% of these chips have been used by BCCI for the formulation of cassava-based feeds, while the remaining 39% have been sold at P4.00/kg to other chip users, like the ViSCA Feedmill, Biliran Feedmill, Placer Feedmill and the San Miguel Corporation.

Forty one farmer-cooperators have already sold cassava chips to BCCI (at P3.00/kg). During a survey conducted in the middle of 1996, 38 farmer-cooperators claimed to have benefitted from the venture, while 13 did not mention any specific benefit (**Table 2**). Among the benefits mentioned were higher profit and the availability of money to buy better food (rice and others), pay debts, pay children's school fees and buy medicine. However, when asked about the specific amount of the profit, only 19 farmers were able to give figures, the other 22 said they did not keep records of their expenses and profits. The profits reported ranged from P1,000 to P10,000 per hectare (**Table 3**). It was observed, however, that those who reported higher profit were those who maintained the cleanliness of their farms and followed most of the recommended cassava cultural practices.

Table 2. Benefits derived by BCCI farmer cooperators from processing and selling of dried cassava chips to BCCI (n=41) in Bontoc, southern Leyte, Philippines.

Benefits	Frequency
Big profit	4
Helped to buy better food	11
Helped during hardships (buy medicine, pay debts pay children's school fees)	13
No response	13

Feedmill operation

Feedmill operations formally started in Feb 1996. The cassava-based feed formulations produced include pig starter, pig grower and pig finisher feeds. The feedmill is currently supplying cassava-based feeds not only to the BCCI's piggery but also to the other swine raisers in the municipality and the other neighboring towns. The

BCCI's major feed markets, aside from its own piggery, are its members in Bontoc, Liloan, Malitbog and Sogod. These people can buy feed at cheaper prices (8% mark-up) than non-members (10% mark-up).

Per suggestion of the PRCRTC staff, the coop management is currently hiring new staff to take charge of the marketing of feeds. This staff will be responsible for planning the appropriate marketing strategies to increase the sales of the cassava-based feeds. PRCRTC-ViSCA, will assist in market development through the production of promotional materials, i.e. brochures/leaflets and posters on the proper use and advantages of cassava-based feeds.

Table 3. Amount of profit derived from chips processing and selling activities (n=41) in Bontoc, Southern Leyte, Philippines.

Profit Range[1)]	Frequency
P 1,000 - P 5,000	16
P 6,000 - P 10,000	3
Cannot estimate/no record	22
Total	**41**

[1)] 1 US$ is approx. 25 pesos

BCCI Piggery

The piggery building was completed in Jan 1996. At present it has four boars (Duroc and Large White) and 60 sows (Large White and Hypor) most of which are pregnant. Additional animals will be procured early next year.

Evaluation of the cassava-based feeds' effect on the performance of the animals i.e. weight gain, carcass quality, etc., still needs to be done.

III. FPR on Soil and Water Conservation in Bontoc

Background information

With the ongoing processing and marketing activities in northen Mindanao and Bontoc, there is a great possibility that the cassava production areas in the two sites will expand. In Bontoc, BCCI has been urged by SMC to become one of its cassava chips suppliers. The BCCI staff who manages the cassava project, however, said that at this time, they are apprehensive to enter into an agreement with San Miguel because even at the present scale of the integrated project, BCCI has already encountered some difficulties in the project. But even if SMC will not enter into the picture, there is still a great possiblity for area expansion because the farmers are opening more hilly areas to plant cassava for the BCCI feedmill.

A positive development which would promote the expansion of cassava production in Bontoc is the DA-LGU's grant of a tractor to BCCI to support cassava production. The tractor is now ready for use. The Department of Agriculture (DA) and BCCI will make a memorandum of agreement regarding the use of the tractor by the BCCI members (especially on rentals).

In anticipation of the opening of so much hilly areas for cassava production, the PRCRTC and DA staff and the BCCI officers and members, during the consultative meeting held in June 1996, agreed on the importance of introducing soil and water conservation (SWC) technologies to the cassava farmers.

Preliminary survey.

A survey with 91 farmer-respondents was conducted in the cassava-growing villages in Bontoc to monitor the initial results of the integrated cassava project and to gather initial information about SWC practices among the farmers in the area. Of the 91 farmers respondents, 75% realized the damage that would occur in continuously cultivating hilly areas due to soil erosion. However, only 50% were trying to control soil erosion using their own methods, i.e. plowing deep along the contours or fallowing. Nevertheless, 60% of the respondents were interested to learn SWC techniques that are more effective than their present practice.

In line with PRCRTC's current efforts to encourage farmers' participation in technology development and transfer, the project staff will be transfering soil and water conservation technologies to the farmers in Bontoc using the FPR approach. A formal survey will still need to be conducted to gather more information needed for the planning and implementation of the FPR activities.

Establishment of demonstration farms.

An erosion control trial established earlier by PRCRTC in a village near ViSCA does not exist anymore because the owner need the land back for other purposes. Thus, PRCRTC is now planning to set up demo plots showing the different SWC techniques in Bontoc. However, several arrangements have to be made before these demo plots can be established.

In the meantime, two one-hectare cassava demo farms using vetiver grass as contour hedgerows have been established in Feb 1996. One demo farm was set up in a moderately sloping cassava farm in Pamahawan village, while the other was set up in a steeper farm in Mahayahay village. As of Oct 1996, the vetiver grass hedgerows in the two demo farms had 100% survival.

CONCLUSIONS

In general, the cassava-based projects in northern Mindanao and Bontoc still need to be strengthened. A lot of activities, like the expansion of area planted to cassava, protecting the cassava area from destruction through appropriate soil and water conservation techniques, strengthening market linkages for chips, promotion of the cassava-based feeds (in the case of Bontoc), and other related activities have to be continued. However, preliminary results show that the projects have already provided some benefits to the intended clienteles. In northern Mindanao, the use of high-yielding varieties and the improved cultural practices increased the yield of cassava from 6-8 t/ha to 24-40 t/ha. Also, the introduction of the chipping machines improved the chips processing efficiency of the farmers.

For the upland cassava farmers in Bontoc, the cassava production and chips processing activities enabled them to earn considerable profits, which they used to buy better food and medicine and to pay some of their financial obligations. The cassava chips trading activity of BCCI added income to the cooperative. Some of the swine raisers in the area were also able to buy cheaper but good quality feeds from the BCCI feedmill.

Several factors contributed to the initial success of these projects. One is the farmers' involvement in all phases of project implementation.

Some Observable Results of Farmers Participation in Technology Transfer Activities

As a result of the increased farmers' participation in the technology transfer process, the following happened:

1. Identification of real farmers' problems, i.e. lack of cassava markets for the farmers in Bontoc; and low yield, low chip prices and lack of processing machines for the farmers in northern Mindanao.
2. Identification of solutions/project interventions that would likely fit their conditions, i.e. implementation of an integrated project that created additional markets for cassava in Bontoc; and the introduction of high-yielding varieties and chips processing machines acceptable to farmers in northen Mindanao.
3. Awareness of the opportunities offered by cassava, i.e. other uses aside from food.
4. Farmers' increasing participation in project activities, i.e. as suppliers of cassava chips to the feedmill and buyers of feeds from the same feedmill.
5. Feeling of "ownership" by the farmers for their project, i.e. the BCCI feedmill and piggery.
6. Identification of other activities/technology modifications that need to be done, such as FPR in soil and water conservation in Bontoc.

Problems in the Implementation of Integrated/Participatory Cassava Projects

Despite the positive results of farmers' participation in the cassava technology transfer projects, the following problems were encountered:

1. *Coordination among support agencies.* The Center, being the lead agency in the conduct of integrated cassava projects, was not able to form a cassava council to oversee the different project activities before project implementation. As a result, the Center staff found it difficult to obtain maximum participation among the different agencies involved in the project. Some targets were not reached because the other agencies were not able to do their parts owing to conflicts with their other responsibilities and priorities.

2. *Scale of integrated project is too big for the cooperators.* This is true in the Bontoc project. The people in charge of the different project components found the scope of the project too big. They said they could not manage the project if they have to go into cassava area expansion to serve the needs of San Miguel for cassava chips. They said they have to concentrate on solving the problems of the feedmill and livestock projects before they can expand their cassava production to serve the needs of SMC.

3. *Lack of capability of the cooperator to handle integrated projects.* This could be the reason why the people in charge claimed that the integrated project is too big. The project manager is afraid to take business risks, especially if one has to talk about project expansion. He said he lacks the capability to manage the complexities of the integrated project.

4. *Lack of staff to closely monitor the projects.* The Center's extension division is generally understaffed. This is the reason why it could not always monitor the activities and solve the problems of the projects. Some technical problems are not addressed right away, such as the problem of lack of dryers.

Possible Ways to Improve PRCRTC's Implementation of the Cassava Technology Transfer Activities

The following suggestions made by Perez-Crespo (1991) can be used to improve the implementation of the cassava technology transfer projects undertaken by PRCRTC:

1. Formal organization of a council to support the implementation of the integrated cassava project in Bontoc. The council should be composed of technology generators from PRCRTC-ViSCA, extension workers from PRCRTC-ViSCA and other government agencies offering support to the project, rural development program administrators (LGU officials) and farmers.

2. Keep the integrated project small and simple at first to avoid confusion and to allow the cooperators to learn first about the details of the project before expanding into other ventures.

3. The project should concentrate on giving those aspects direct benefits to farmers. This means that the project should be able to increase the income of the farmers and improve their living conditions. In the case of Bontoc, the project should make sure that the farmers can gain from their cassava production and chips processing venture.

4. Involve farmers in the conduct of small experiments such as FPR on soil and water

conservation. This will increase the farmers understanding of the technologies introduced and the likelihood that the technologies will fit the conditions of the farmers, and thus, be adopted on a sustainable basis.

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FARMER PARTICIPATORY RESEARCH FOR CASSAVA TECHNOLOGY TRANSFER IN ASIA - CONSTRAINTS AND OPPORTUNITIES

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ABSTRACT

Since 1994 a farmer participatory research (FPR) methodology has been used with the objective of enhancing the development and adoption of efficient cassava production practices that will reduce erosion, maintain soil productivity and increase the income of cassava farmers in Asia. This 5-year FPR project, funded by the Nippon Foundation in Japan and coordinated by CIAT, is being executed by national research and extension organizations in Thailand, Indonesia, China and Vietnam. Members of the FPR teams in each of these countries participated in a Workshop in July 1994 in Thailand to become familiar with the FPR philosophy and methodologies. Upon return, they conducted Rapid Rural Appraisals (RRA) in cassava growing regions in their country to select two suitable pilot sites for the project. In addition, they established demonstration plots to show the farmers of the pilot sites a range of management practices to control erosion and increase yield or income. During a field day farmers looked at and discussed the various options and selected 4-5 that were considered most useful for their own conditions in order to try these on their own farms.

In 1995 the first FPR trials were set out by farmers on their own fields with help from FPR team members. In erosion control trials they established 2-5 treatments on a uniform slope and constructed sedimentation channels along the lower side of each plot to collect the eroded sediments and measure soil losses due to erosion. In addition, other technology components such as improved varieties, alternative intercrop systems and fertilizer treatments were offered and experimented with by farmers. At the end of the first year, farmers and FPR team members jointly harvested all the plots and calculated cassava and intercrop yields, as well as the amount of soil loss in each treatment. These results were discussed with the participating farmers in order to select the best treatments for the second year of testing in 1996.

From the experiences obtained so far we have learned that farmers in the selected sites are interested in the trials, and are adapting and adopting several component technologies. However, the success rate has been varied, especially between different sites and countries. A number of limitations have been identified, both technical, financial, organizational and institutional.

This paper assesses the results of the project and identifies and analyzes the various constraints that are currently limiting the project. In addition, new opportunities are proposed that may alleviate the constraints. The analysis is conducted within a framework of how to move the project from the pilot phase to an implementation phase in order to reach a wider audience and obtain greater adoption of the developed technologies.

INTRODUCTION

Since 1987 the CIAT Cassava Agronomy Program in Asia has coordinated a network of cassava agronomists in various countries in Asia. These national program

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scientists have conducted agronomy and soil management experiments in collaboration with CIAT, with major emphasis on soil fertility maintenance and erosion control. Results of these experiments are reported in this and in previous Workshop Proceedings. From these experiments it was concluded that cassava can indeed cause soil nutrient depletion if the crop is grown continuously without application of adequate amounts of nutrients in the form of organic or chemical fertilizers, and that cassava cultivation on slopes may cause serious erosion if the crop is not properly managed. However, research has shown that erosion can be markedly reduced either by common agronomic practices, such as minimum tillage, planting on contour ridges and at relatively close spacing, fertilizer application and intercropping, or by special soil conservation measures, such as application of mulch or the planting of contour barriers of grasses or legumes to reduce raindrop impact on the soil and to slow water run-off down the slope. While most of these practices were found to be effective in controlling erosion, very few cassava farmers are actually using these practices, either because they are unaware of the seriousness of soil erosion, or because they don't know which practice is most effective or most suitable for their own conditions. Since most of these practices require some additional labor or financial inputs, while the benefits tend to be long-term, farmers are seldom interested in practicing soil conservation. From these and other experiences it was concluded that cassava farmers will not adopt more sustainable management practices unless they first become aware of the extent and long-term effect of soil erosion on soil productivity; and secondly, they themselves test and select the most suitable practices under their own conditions.

To enhance the adoption of more sustainable practices by cassava farmers in Asia, a new special project, funded by the Nippon Foundation in Japan and executed by CIAT in collaboration with national scientists, was initiated in 1994. The strategy to achieve the objectives was to develop a Farmer Participatory Research (FPR) methodology for testing soil management practices together with farmers in pilot sites in some important cassava growing countries in Asia. Thus, two or more pilot sites were selected in Thailand, Vietnam, Indonesia and China. Research and extension institutions dealing with cassava were invited to join the project and to name an "FPR team" of agronomists and social scientists to collaborate in its execution. In addition to the FPR project, the same or other institutions continued the conducting of collaborative strategic or applied research on cassava agronomic practices in order to identify still more effective technology components to enhance productivity and reduce soil degradation.

FPR PROJECT

The various activities of the project include the following:

1. Organize a consortium of collaborating research and extension institutions in each of the four participating countries, and identify the persons that will be directly involved in the project.

2. Conduct a one-week Workshop on FPR Methodologies with participation of the four FPR teams.
3. Select potential pilot sites and conduct Rapid Rural Appraisals (RRA) in each site to select at least two appropriate pilot sites in each country.
4. Establish in each country or site Demonstration Plots with a large range of management options.
5. Organize a Farmers' Field Day at the Demonstration Plots to let farmers evaluate and select the best technological options for their own conditions.
6. Select participating farmers and let them choose the type of FPR trials to be conducted at each site and the treatments to be used in each type of trial.
7. Test, evaluate and select the most attractive options with farmers in their own fields. This includes experimentation with practices to control erosion as well as with, varieties, cropping systems and fertilization.
8. Through a reiterative process of trying out, discussing, selecting etc., develop the best package of practices for sustainable cassava production in each site.
9. Try out the best practices in commercial fields.
10. Enhance the testing and adoption of these practices in nearby villages.

1. Collaborating Institutions

Table 1 list the various research and extension institutions collaborating in the project. Beside agronomists or soil scientists, attempts were made to include economists or other social scientists in the project. Local extensionists also played an important role in Vietnam and China.

2. Training Workshop on FPR Methodologies

In order to become familiar with the FPR approach, FPR team members of the collaborating institutes participated in a one-week Workshop, held in Rayong, Thailand, from July 24 to 30, 1994. Besides lectures on the principles of FPR and some of the methodologies used, participants developed a workplan for the project in each country and also practiced interviewing cassava farmers, both in groups and individually.

3. Rapid Rural Appraisals (RRA)

Each FPR team conducted RRAs in potential pilot sites by interviewing farmers about general farming conditions in the area, cassava production practices, problems and constraints (including erosion), utilization and marketing. Based on these data, each team selected two sites considered most suitable based on the following criteria

- cassava is and will most likely remain an important crop in the area
- cassava is grown on slopes
- erosion is a serious problem and is perceived as such by the farmers
- farmers are interested in participating in the project

Table 1. Institutions collaborating with CIAT in the Nippon Foundation Project on Improving Agricultural Sustainability in Asia.

Country/Province	Institution	FPR project	Research
China-Hainan	Chinese Acad. Tropical Agric. Sciences (CATAS)	/	/
China-Guangxi	Guangxi Subtropical Crops Research Institute (GSCRI)		/
China-Guangdong	Upland Crops Research Institute (UCRI)		/
Indonesia-E.Java	Brawijaya University (UNIBRAW)	/	/
Indonesia-E.Java	Research Institute for Legumes and Tuber Crops (RILET)	/	/
Indonesia-W.Java	Bogor Research Institute for Food Crops (BORIF)		/
Philippines-Leyte	Phil. Root Crops Research and Training Center (PRCRTC)		/
Philippines-Bohol	Bohol Experiment Station (BES)		/
Thailand-Bangkok	Field Crops Research Institute (FCRI) of Dept. of Agriculture	/	/
Tahiland-Bangkok	Field Crops Promotion Division of Dept. Agric. Extension	/	
Thailand-Bangkok	Kasetsart University		/
Thailand-Korat	Thai Tapioca Development Institute	/	
Vietnam-Thai Nguyen	Agro-Forestry College of Thai Nguyen University	/	/
Vietnam-Hanoi	National Soil and Fertilizer Institute (NSFI)	/	
Vietnam-Ho Chi Minh	Institute of Agric. Sciences (IAS) of South Vietnam		/

Detailed information obtained in each site have already been presented in earlier papers (Zhang Weite *et al.*, Wilawan Vongkasem *et al.*, Nguyen The Dang *et al.*, and Wani Hadi Utomo *et al.*) in this Proceedings. **Table 2** shows a comparative summary of the RRA data collected in the pilot sites selected for the project. This shows that cassava is an important crop in all sites, but is the most important crop in only two of the eight sites. The cassava planted area per household is rather large in Thailand and in Baisha county of Hainan, but very small in most other sites. Farm size is an important determinant in the selection of suitable crops, cropping systems and production practices. The relatively large farm size in Thailand, for example, necessitates partial mechanization and almost precludes the use of intercropping systems.

4. Demonstration Plots

In each country FPR team members established demonstration plots with a large number of treatments to be able to show farmers many technological options and their effect on yield, total income, and erosion. Plots were laid out on a uniform slope; along the lower end of each plot a ditch was dug and covered with plastic (**Figure 1**). Eroded sediments and runoff water would collect in these sedimentation channels. Water was allowed to seep away through small holes made in the plastic, and sediments were collected and weighed several times during the cassava growth cycle. Samples of wet sediments were taken to be dried and weighed in order to calculate soil losses per ha on a dry weight basis. Results of cassava and intercrop yields, gross and net income, as well as soil losses due to erosion in these demonstration plots are presented in earlier papers (Zhang Weite *et al.*, Wilawan Vongkasem *et al.*, Nguyen The Dang *et al.*, and Wani Hadi Utomo *et al.*) in this Proceedings.

5. Farmers' Field Day

Shortly before or during the harvest of cassava, farmers from the selected pilot sites were invited to visit the demonstration plots, with the objective of discussing the *pros* and *cons* of each treatment and then to score the treatments in terms of general usefulness, i.e. effectiveness in reducing erosion while maintaining or increasing farmers' income. The occasion was also used to explain clearly the objectives of the project and to inform farmers about new varieties and other new technologies.

Table 3 shows the ranking of management practices considered most useful by farmers from seven pilot sites. The treatments in the demonstration plots varied from country to country, but even within the same country farmers' preference varied from site to site. However, in both Thailand and Vietnam, farmers liked the treatment of vetiver grass barriers and decided to try this as one of their treatments in the FPR erosion control trials. In Indonesia, farmers generally preferred intercropping cassava with maize (their traditional practice) and planting *Gliricidia sepium* or elephant grass as contour barriers, as both can be used as animal feed.

6. Selection of Participating Farmers and Treatments for FPR Trials

In most cases there was no particular selection of farmers to participate in the project, i.e. those farmers that were interested could participate. Farmers that had sloping land suitable for erosion control trials were encouraged to do those trials, while those with flat land participated in variety, fertilization or intercropping trials. **Table 4** shows the types and number of trials conducted in each pilot site in 1995/96 and 1996/97.

In Baisha county of Hainan about 37 farmers participated in the first year. They generally had only two treatments per trial, comparing an "improved" practice or variety *versus* their traditional practice or variety. The large number of farmers participating was difficult to manage, while having only two treatments per trial made it difficult to compare among "improved" treatments. Thus, in the second year, the number of trials in China was reduced while the number of treatments per trial was increased. Moreover, farmers within one site were encouraged to all test the same 4-5 "improved" practices or varieties *versus* their traditional practice or variety. This way, trial results could be averaged over farms and more reliable results could be obtained to draw conclusions and select the best treatments. In Vietnam the number of participating farmers increased in the second year (1996/97) as farmers saw the benefits of participating in this community effort, especially in obtaining planting material of new varieties.

Before starting the trials, participating farmers met in the village with the FPR team members to discuss the type of trials to be conducted and the treatments to be tested. For the erosion control trials farmers discussed the results of the scores given to each treatment during the field day at the demonstration plots. They generally selected 3-4 treatments with high scores, but sometimes they themselves suggested new treatments that seemed of greater benefit for their own particular circumstances. Thus, in Soeng Saang district in Thailand, farmers wanted to test contour barriers of sugarcane (for chewing) as a more useful alternative to king grass, which they had observed in the demonstration plots. Also, some farmers raising silkworms wanted to test hedgerows of mulberry bushes as a means to control erosion while also obtaining benefit from the barrier. In Thailand farmers decided to test 3-4 common treatments as well as one preferred individual treatment, all in comparison with their traditional practice. When farmers test one individually selected treatment, They are encouraged to think for themselves about effective ways to control erosion while at the same time providing additional benefits or income. These farmer innovations can sometimes lead to better and more practical management practices, and also enhances farmers' feelings of empowerment to find their own solutions. This is a fundamental element for success (Ashby *et al.*, 1997).

To compensate for the additional cost of doing the trials, farmers were paid for digging the sedimentation channels and received the plastic for covering the channels. They also received planting material of vetiver grass and new cassava varieties for the trials, as well as seed for intercropping treatments. In Thailand farmers also received one bag of 15-15-15 fertilizers, while in one site in Indonesia the participating farmers as a group received 15 goats. These incentives were kept to a minimum to enhance the feeling that farmers were conducting the trials for their own rather than for the researchers' benefit.

7. Testing, Evaluation and Selection of Best Options

Once the types of trials as well as the treatments were selected, FPR team members helped the farmers to select the most suitable site for each trial, to set out contour lines (for the erosion control trials) and stake out the trials. Especially the first year, team members had to help farmers establish the various treatments. But once established, farmers managed their own trials similar to their other commercial fields. Team members would visit regularly to discuss the progress and try to solve any problems. They would also collect and weigh the eroded sediments in the sedimentation channels, usually once during the cassava growth cycle and again at time of harvest.

A very common problem in the erosion control trials was that some trials were not laid out well along contour lines, as most farmers would prefer their trials laid out parallel to roads or the edge of fields. In that case, run-off water would sometimes enter or leave plots through side borders, resulting in unreliable soil loss data. Moreover, if the erosion trials were situated halfway or near the bottom of a slope, run-off water from fields above would enter plots if the diversion ditches along the upper side of plots (**Figure 1**) were unable to divert all the run-off away from the plots. In that case, large amounts of run-off would enter the plots, causing excessive erosion that was not related to the treatment. As such, the eroded sediments in the ditches did not accurately reflect the effectiveness of the treatment in controlling erosion.

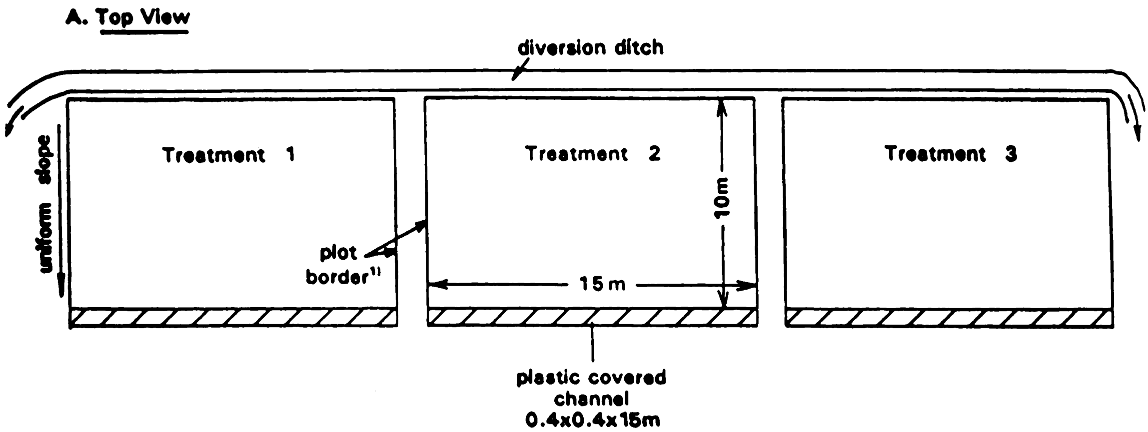
At time of harvest, participating farmers and FPR team members would jointly harvest all or part (usually 16-20m^2) of each plot to determine cassava root yield. In Thailand, where farmers receive a differential price according to root starch content, the starch content was also determined. In case of intercropping treatments, the yield of the intercrops had been determined earlier at their time of harvest. During the cassava harvest farmers also noted and discussed the amount of sediments in the ditch of each treatment, before those sediments were collected and weighed.

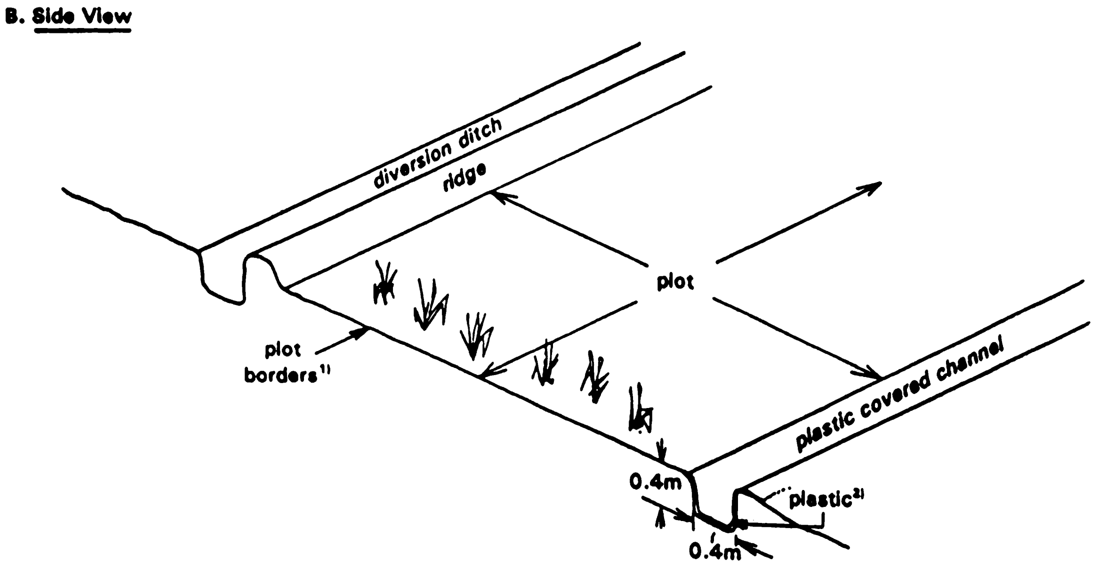
One problem observed during the harvest in the first year was that farmers had often planted at irregular spacings, making it very difficult to accurately determine effective plot size and compare yields; in subsequent years farmers were encouraged to use a standard planting distance, usually 1.0x1.0 m, 0.1x0.8 m or 0.8x0.8 m. Another commonly observed problem in estimating yield in plots with contour hedgerows, was that researchers often excluded from their harvested plot any rows bordering those

Table 2. Characteristics of eight pilot sites for the Farmer Participatory Research (FPR) trials in Asia.

	Thailand		Vietnam			China	Indonesia	
	Soeng Saang	Wang Nam Yen	Pho Yen	Thanh Hoa	Luong Son	Kongba	Malang	Blitar
Mean temp. (°C)	26-28	26-28	16-29	15-28	16-29	17-27	25-27	25-27
Rainfall (mm)	950	1400	2000	~1800	~1700	~1800	>2000	~1500
Rainy season	Apr-Oct	Apr-Nov	Apr-Oct	Apr-Nov	May-Oct	May-Oct	Oct-Aug	Oct-June
Slope (%)	5-10	10-20	3-10	30-40	10-40	10-30	20-30	10-30
Soil	± fertile	± fertile	infertile	very infert.	± fertile	± fertile	infertile	infertile
	loamy	clayey	sandy loam	clayey	clayey	sandycl.l.	clay loam	clay loam
	Paleustult	Haplustult	Ultisol	Ultisol	Paleustult	Paleudult	Mollisol	Alfisol
Main crops	cassava	maize	rice	rice	rice	rubber	cassava	maize
	rice	soybean	sweet pot.	cassava	cassava	cassava	maize	cassava
	fruit trees	cassava	maize	tea	taro	sugarcane		ricerice
Cropping system[1]	C monocrop	C monocrop	C monocrop	C+P	C+T	C monocrop		C+MC+M
Cassava yield (t/ha)	17	17	10	4-6	15-20	20-21	12	11
Farm size (ha)	4-24	3-22	0.7-1.1	0.2-1.5	0.5-1.5	2.7-3.3	0.2-0.5	0.3-0.6
Cassava (ha/hh)	2.4-3.2	1.6-9.6	0.07-0.1	0.15-0.2	0.3-0.5	2.0-2.7	0.1-0.2	0.1-0.2

[1] C = cassava, M = maize, P = peanut, T = taro





1) plot border of sheet metal, wood or soil ridge to prevent water entering or leaving plots.

2) polyethylene or PVC plastic sheet with small holes in bottom to catch eroded soil sediments but allow run-off water to seep away. Sediments are collected and weighed once a month.

Figure 1. Experimental lay-out of simple trials to determine the effect of soil/crop management practices on soil erosion.

Table 3. Ranking of conservation farming practices considered most useful by cassava farmers from several locations in Asia.

Practice	Thailand		Vietnam		China	Indonesia	
	Soeng Saang	Wang Nam Yen	Pho Yen	Thanh Hoa	Baisha	Blitar	Dampit
Farm yard manure (FYM)				2			
Medium NPK	5						
High NPK					2		
FYM+NPK				1			
Cassava residues incorporated			5				
Reduced tillage	4						
Contour ridging		2					
Up-and-down ridging					5		
Maize intercropping	2					1	1
Peanut intercropping		5			4		2
Mungbean intercropping					3		
Black bean intercrop+*Tephrosia* hedgerows			1	4			
Tephrosia green manure			3	5			
Tephrosia hedgerows			4				
Gliricidia sepium hedgerows						2	4
Vetiver grass barriers	1	1	2	3			
Brachiaria ruziziensis barriers	3	4					
Elephant grass barriers						3	3
Lemon grass barriers		3					
Stylosanthes barriers					1		

Table 4. Types and number of Farmer Participatory Research (FPR) trials with cassava conducted in four countries in Asia in 1995/96 and 1996/97.

	Thailand		Vietnam			China		Indonesia	
1995/96 Type of trial	Soeng Saang Nakorn Ratchasima	Wang Nam Yen Sra Kaew	Pho Yen Thai	Thanh Hoa Phu Tho	Luong Son Hoa Binh	Baisha Hainan	Tunchang Hainan	Dampit Malang	Wates Blitar
Erosion control	9	6	6	7	3	12	-	10	7
Varieties	5	7	6	-	1	15	-	-	8
Fertilization	5	-	4	-	1	10	-	-	-
Intercropping	-	-	8	-	-	-	-	-	-
Total	19	13	24	7	5	37	-	10	15
1996/97									
Erosion control	8	7	5	7	3	4	1	10	9
Varieties	3	6	11	3	3	4	1	1	5
Fertilization	8	-	6	4	3	4	1	1	-
Intercropping	-	-	11	-	-	-	-	-	-
Total	19	13	33	14	9	12	3	12	14

hedgerows. As such, they ignored the fact that hedgerows occupy part of the land and may either increase (mulching effect, trapping of water and fertilizer) or decrease (competition effect) the yield of bordering cassava plants. To correct this problem, harvested plots should include the hedgerows approximately in the same proportion they might be found in commercial fields (usually about 10-20% of crop area, depending on slope). On the other hand, if experimental plots have more than the necessary number of hedgerows (usually spaced at 1 m vertical distance between hedges), crop yields are likely to be reduced more than necessary, and farmers may unduly reject such treatments for that reason. Finally, another common problem is that the "farmers' traditional practice" treatment, used as comparison with other "improved" practices, does not reflect actual farming practices. If this treatment is not "real", farmers may reject the results of the whole trial as not accurate.

After all trials had been harvested and all data (including yields of intercrops and hedgerows, eroded sediments, etc) collected, FPR team members quickly calculated and tabulated the results, including the gross and net incomes obtained in each treatment, expressed in local currency and units of measurement. These were then presented to and discussed with the farmers. Farmers were asked to score treatments or raise hands for those treatments they preferred, considering both the effectiveness in controlling erosion and producing benefits (higher income or other benefits) to the farmers. In the same meeting farmers were usually asked whether they liked to continue the FPR trials, which types, and which treatments. Farmers usually selected the "best" treatments from the previous cycle, sometimes combined with newly proposed treatments. Thus, "best-bet" treatments were again tested against farmers' traditional practices in a reiterative process to develop a package of management practices, including new varieties, optimum fertilization, productive intercropping systems and possibly hedgerows or other special measures to reduce erosion, that would optimize yields or income while reducing erosion and soil nutrient depletion.

8. Trying out in Practice

Usually, after 2-3 years of experimentation in relatively small plots, farmers would be convinced of the usefulness of certain practices, and would be ready to try "their" recommended practices on their own production fields. These practices should be tried for 1-2 years on a relatively small scale, such as 0.1-0.2 ha, to determine whether these practices are truly practical and meeting farmers expectations. If not, they may need to be tested again in a modified version that better corresponds with the conditions in the field. Especially in Thailand, where commercial fields tend to be large, some further modification may be necessary to facilitate mechanized land preparation and harvesting.

CONSTRAINTS AND OPPORTUNITIES: WHAT HAVE WE LEARNED?

Table 5 shows a comparative summary of the conditions of the FPR trials conducted in the eight pilot sites as well as some of the problem encountered. Specific conditions at the site, the relation between the institutions involved in the project, as well as their relation with local extensionists and village leaders, often have a strong bearing on the success or failure of the project.

1. Conditions at the Pilot Sites

Table 5 summarizes some of the pertinent biophysical and socio-economic conditions at the sites. Travel time from the participating institute to the sites varied from less than one to more than five hours by car. Less time required to go to Pho Yen, Luong Son or south Malang facilitated more frequent visits of FPR team members to these sites. The longer distances in Thailand made frequent visits or long stays at the sites impractical. To get the work done quickly and efficiently, the Thai FPR team often brought their own laborers. While certainly efficient, this eliminated the need to involve farmers directly in the work and thus reduced farmers' participation and interest. Although in China the pilot site in Baisha county is only 1 1/2 hours from CATAS, the lack of transport facilities as well as the lack of personnel at CATAS prevented regular visits to that site. For the same reasons, attempts to expand to a second site in Quongzhong county and later in Tunchang county were unsuccessful. Thus, distance to and accessibility of the sites is another important criterion in selecting pilot sites.

Cassava was the principal crop only in Soeng Saang and in Malang, and an important secondary crop in the other locations. The more important cassava is in the whole cropping system, the more farmers will be interested in developing practices that will optimize cassava yields and protect the soil's productivity. Similarly, the smaller farm sizes (**Table 2**) in Vietnam and Indonesia result in more intensive land use management and greater concern for maintaining soil productivity. Also, slopes were quite steep in Thanh Hoa and Luong Son districts in Vietnam, in some areas of Baisha county of China and in Malang district in Indonesia, resulting in serious soil losses due to erosion. This enhanced farmers' concern about the problem. These three aspects influence the degree of farmers' interest and participation in the project.

In most sites both men and women participated in the project, but for cultural or religious reasons only men participated in Baisha county in China and in the two sites in Indonesia. This did not seem to have any direct bearing on the interest of farmers or their degree of participation. Of greater importance is the interest of the leaders in the village or of local extensionists. In both sites in Thailand the village leaders were supportive of and actively involved in the project; in Pho Yen in Vietnam and in Blitar in Indonesia this was also the case, while in Baisha county in China a local extensionist was providing good leadership to the project.

2. Institutional Relations

In Thailand the project was executed jointly by the Dept. of Agriculture (DOA) and the Dept. of Agricultural Extension (DOAE). Teams from both institutions worked together very effectively in both sites, the DOA providing research expertise and planting material of new varieties, while DOAE provided expertise in extension activities as well as access to a nationwide network of extension offices, which participated in various degrees in the selection of sites, in the conducting of RRAs, and in the execution of the FPR trials. In other countries each site was the responsibility of only one institute. This facilitated decision making and management, but each institution did not benefit much from the expertise or the experience obtained by the other institutes in the country. A sharing of experiences and mutual participation in at least the final field day at harvest, would probably have improved the project execution at some of the sites.

In Pho Yen district of Vietnam much of the responsibility for helping farmers establish the trials and the taking of data rested with the local extension office, as well as with 4th-year students from Agro-forestry College of Thai Nguyen University. These students would live, or spend a considerably amount of time, with farmers in the village, which stimulated mutual learning and contributed to a close relationship between farmers and FPR team members. In Blitar district in Indonesia the project was similarly executed by an MSc student who spent a lot of time in the village and build a good relationship with the participating farmers. Where possible, this seems an effective way to improve the quality of the trials and build trust between villagers and government officials.

3. Technical Problems

Technical problems in executing the FPR erosion control trials concerned mainly the laying out of the trial along contour lines, preventing water from entering or leaving the plots from fields above or through side borders, and the correct measurement of yields, which should include the effect of contour hedgerows if present. These have already been discussed above. An additional problem is that some plastics used in the sedimentation channels deteriorated very quickly or were stolen. Attempts to substitute plastic sheet with bamboo matting or opened-up plastic fertilizer bags were not very successful. Lining sedimentation channels with split-open bamboo has been successful in the Philippines, but this material is not readily available in other countries. Other technical problems encountered include the poor germination of cassava stakes if they had been stored for too long, and poor germination of some hedgerow or intercrop species due to poor quality seed or unfavorable weather. Furthermore, results of FPR trials were sometimes unreliable due to poor marking of plots, difficulty in calculating effective plot size due to irregular cassava planting distances, varietal mixtures, poor weed control, stealing of crops, and damage of cassava or intercrops by water buffaloes or rats.

Table 5. Conditions of FPR trials conducted in eight pilot sites in Asia.

Conditions/	Thailand		Vietnam			China	Indonesia	
problems	Soeng Saang	Wang Nam Yen	Pho Yen	Thanh Hoa	Luong Son	Baisha	Malang	Blitar
Instit. responsible	DOA+DOAE	DOA+DOAE	AC#3	NISF	NISF	CATAS	RILET	UNIBRAW
Local project responsibility	village head	village head	students extensionist	agronomist	model farmer	extentionist	model farmer	model farmer
Distance (hrs)	4-5	4-5	1	3	1	1 1/2	1 1 1/2	
Principal crop	cassava	maize	rice	rice	rice	rubber	cassava	maize
Slope (%)	<10	<20	<15	<40	<30	<30	<30	<20
Erosion (t/ha)[1]	4-25	18-48	8-29	28-54	10-43	47-125	12-145	28-55
Particip. farmers	19	13	29	13	9	15	10 14	
-gender	♀♂	♂♀	♂♀	♂♀	♂♀	♂	♂ ♂	
Type of trials	erosion varieties fertilizer	erosion varieties	erosion varieties fertilizer intercrop	erosion varieties fertilizer	erosion varieties	erosion varieties fertilizer	erosion varieties fertilizer	erosion varieties
Farmer interest	++	+	+++	+	+	++	+ +	
Farmer particip.	+	+	+++	+	+	++	+ ++	
Local leadership	++	++	+++	+	+	++	+ ++	
Preferred treatm.	vetiver sugarcane	vetiver	vetiver C+P	vetiver C+P	*Tephrosia* C+P	C+P[2]	? *Gliricidia*	
Techn. adopted	new var. vetiver/sugarcane	new var. vetiver	C+P	C+P	C+P	new var.	not yet	not yet
Problems	very far	very far		very far		transport	<–few good alternative options–>	
	<-------------------------	erosion	measurements	------------------------->				

4. Availability of Attractive Options

One of the most important requirements for obtaining farmers' interest in the project is the availability of new and attractive technological options. In most pilot sites farmers were interested in participating not because of their concern for soil erosion, but because of the possibility of obtaining planting material of new higher-yielding varieties. Farmers were primarily interested in testing new varieties, new intercropping systems or fertilizers, because all of these can directly increase their net income. Fortunately, in all participating countries cassava breeders had already developed higher-yielding varieties, which were ready for on-farm testing and distribution. In Indonesia, however, these varieties were only marginally better than the local varieties, while in Vietnam and China the lack of sufficient planting material of new varieties initially limited their use. Once farmers saw the benefits of these new varieties, of better intercropping practices and of correct fertilizer use, they became more enthusiastic about the project, including the development of practices to control erosion.

To be acceptable to farmers, erosion control measures must be effective, not require too much additional labor or money, and maintain or increase yield or income. Farmers in Thailand and Vietnam generally selected vetiver grass as the most effective way to reduce erosion, but its adoption on a large scale may still be limited because of unavailability of planting material, high cost of transport and planting, and lack of direct use of the grass except as mulch. For that reason, many farmers in Vietnam prefer contour barriers of *Tephrosia candida*, which is less effective in controlling erosion, but easier to establish and more useful as a green manure. In Indonesia vetiver grass was not included in the demonstration plots until the second year; once included farmers seem to appreciate its effectiveness in controlling erosion, but adoption will be slow because of lack of planting material and its unsuitability as an animal feed.

Intercropping cassava with peanut is a new and very useful technology for farmers in the three sites in Vietnam as well as in Baisha county of China. In some parts of China, intercropping with peanut, however, is impossible due to serious damage caused by rats. In Thailand, plowing with tractor is usually done up-and-down the slope and/or parallel to roads or field borders. Contour hedgerows of any species will interfere with this practice, while curved hedgerows will also interfere with the planting of cassava in straight lines using tight ropes as a guide. These practical problems are likely to limit adoption of contour hedgerows. In fields with uniform and unidirectional slopes, the planting of straight hedgerows or barrier strips across the slope, however, may be acceptable. Intercropping with sweetcorn or pumpkin is rather new in Thailand, but the susceptibility of these crops to drought or excessive moisture will limit their adoption.

In Indonesia cassava farmers already use many soil conserving practices, such as terracing (especially in Java), agro-forestry, intercropping, and manure or fertilizer application. Fields tend to be very small and often bordered by hedgerows of grass (mainly elephant grass) or tree legumes (mainly *Gliricidia sepium, Leucaena leucocephala*, or *Calliandra*). Some of these essentially function as contour barriers. Farmers have shown little spontaneous interest in the project because of lack of attractive new options, alternatives that are either more effective or more beneficial than what farmers are already doing. The inclusion of vetiver grass in the demonstration plots in Malang showed farmers a highly effective erosion control option, but this technology may still find little adoption because of other limitations, as discussed above. The challenge for Indonesian team members is to find truly superior alternatives to what farmers are already doing now.

5. Institutionalization of a Participatory Approach in Research and Extension

Traditionally, governments in Asia, whether communist or democratic, have all used a top-down approach in the research-extension continuum, i.e. researchers do research, usually at experiment stations, and based on their results make recommendations, which are then extended by extensionists to farmers. Farmers have no input in setting research priorities and they either accept or reject the recommendations of the extensionists. This system works reasonably well for those technologies, like new varieties, that are readily accepted anyway because they increase farmers benefits at little additional cost. Fertilizer practices are also easily accepted if the benefits clearly outway the costs, and if farmers have the resources to buy the fertilizers. However, for knowledge-intensive technologies, like erosion control practices, which are often highly site-specific, the practices recommended in this top-down approach are either not the best for the specific location or require too much additional inputs in comparison to the perceived benefits. The participatory approach used in this FPR project assures that the technologies are better tailored to farmers' needs and to the specific conditions in the pilot sites. Moreover, as farmers are directly involved in the testing and selection of the best practices they are more likely to develop practices that are acceptable and adoptable, thus eventually leading to greater use of sustainable production practices. However, to reach a much wider audience of farmers beyond the pilot sites, either involving them directly in FPR, or at least convincing them of the usefulness of those practices developed by fellow farmers in the same area, it is necessary to involve many more researchers and extensionists in the process. This can only be done if local administrators and policy makers are convinced that FPR is an efficient and effective methodology for the development and transfer of site-specific technologies, and are willing to adopt a more participatory and bottom-up approach within their own institutions. This FPR project on enhancing the sustainability of cassava production in Asia, is a rather insignificant endeavor in the whole realm of things, but can become significant if we can convince policy makers of the effectiveness of the methodologies used, and contribute to the institutionalization of a more participatory approach in national research and extension organizations.

Moreover, as evidenced in cassava processing projects in Colombia and Ecuador (Ospina *et al.*, 1996), collaborating farmers themselves, once trained and experienced in FPR in their own sites, are excellent transfer specialists to other farmers, especially when technologies are more complicated, as is the case for processing and erosion control. As is already pointed out, it will take significant human resources to transfer the FPR approach as well as the technologies developed to other villages and regions. Hence, the collaboration of farmers as alternative transfer agents (farmer-to-farmer extension) could be a viable option for the future.

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CASSAVA BIOTECHNOLOGY NETWORK

Ann Marie Thro[1]

INTRODUCTION

The objective of this session is to provide all participants in the Asian Cassava Research Network, regardless of specialization, with a common background for evaluating the usefulness of biotechnology tools for Asian cassava research and development.

Specific Objectives

-Briefly describe biotechnology tools available for cassava

-Review types of research objectives for which each biotechnology tool is appropriate

-Consider other factors important for using each tool effectively (time to output, relative costs to be measured, etc)

Target Outcomes for Participants and CBN

-A common understanding of biotechnology tools and their functions

-A shared basis for evaluating whether or not biotechnology tools offer an advantage for developing technical solutions to problems encountered in Asia for cassava

-Based on discussions and information during the Cassava Regional Workshop to obtain a information assessment by Workshop participants of the following:

- * Does biotechnology have any advantages to offer for cassava in Asia?
- * How? What? Where?
- * Is biotechnology being used effectively in those situations? What are the elements of practical success?
- * Where biotechnology could offer advantages but is not being used, what is available and what is missing for effective action? Institutional linkages, information, human resources, financial resources, research policies..etc?

BIOTECHNOLOGY TOOLS FOR CASSAVA

I. Micropropagation (cell and tissue culture)

Genetic Biotechnologies ("gene technologies"):

II. Genetic engineering, or genetic transformation

III. Molecular markers

Microbial Biotechnology:

IV. Fermentation biotechnology

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Each Biotechnology Tool Does Something Different

-Molecular markers are a form of information technology; used to enhance breeders' ability to assess and select genetic diversity.

-Genetic engineering is a way to extract and insert genes; used to enhance breeders' access to genetic variations or to create new variation.

-Tissue culture is a method of vegetative propagation (cleaner, faster,...)

-Fermentation biotechnology is a way of changing a substrate; used to give cassava greater value and/or new properties.

The nature of the technology determines how it is useful.

I. Micropropagation (Cell and Tissue Culture)

Used in at least 20 countries for conservation and sharing of cassava genetic diversity Considered "conventional" for cassava by some. Widely used for cassava because:

-Cassava varieties must be propagated by cuttings, which can transmit pests and diseases.

-Production of disease-free cuttings in tissue culture permits:

1. Conservation of cassava genetic diversity without long-term build-up of pests and diseases which may occur in field collections.

   This requires a long-term funding commitment, which is often more problematic than the technology itself.

   Cryopreservation (freezing): Lower cost, long-term. Has been experimentally successful, but requires pilot testing to assess genetic stability and operating costs.

2. Improved international access to cassava genetic diversity via clean propagules to meet quarantine regulations.

3. Similarly, international sharing of experimental varieties, so breeding programs can use varieties developed in similar environments.

   This can be managed as shorter-term commitments. Tissue culture facilities can be shared with other crops.

4. Renovation of infested important cultivars

   Thermotherapy: virus/pest elimination.

   Effective for yield increases over several years if rate of re-infection is slow.

   If rate of re-infection is high (rapid), resistant cultivars are required.

   Careful agronomic management is necesary: Loss of associated beneficial microorganisms, or unusual infection of succulent plantlets just out of tissue culture, can lead to disappointing yield "crashes".

5. Faster multiplication of desired cassava varieties ("*in-vitro* rapid micropropagation")

   Potential (biologically-achievable) rates per year:

Field multiplication: tens of plants from one plant

Single-or two-node cutting multiplication: thousands from one
Tissue culture: millions from one

Some of the factors affecting success:
-Selection of plant materials for tissue culture multiplication. Clones must be well-tested with target users.
-Health status of source material.
-Post-flask management (hardening, "weaning")
Requires investment of experienced supervision, labor, water, materials (screening...).
Succulent tissue more susceptible than usual to pests and diseases.
-Integration with existing program of field multiplication and distribution
Links with agricultural extension, NGOs, private sector.
Distribution logistics.

Pilot projects
-Information on costs and benefits
In emergencies when cassava varieties in a region must be changed or restored rapidly due to abrupt social, economic, or biological events.
For normal progress in more stable situations

Facilities can be shared with other crops
-Requires management skills
For delivering plantlets on time
For efficient use of facilities

"Low tech biotech"
-A need to develop lower-cost methods for tissue culture
In-vitro culture protocols
Post-flask management
Plantlet distribution

Energy-efficient, use more local materials
General principals, site-specific aspects

Micro-propagation also permits regeneration of plants from single cells, an essential step in genetic engineering.

II. Genetic Transformation ("Transgenesis")

"Transfer of a piece of DNA into a plant cell, followed by stable integration in the genome".

Used for traits that can be altered by a single-gene, or single-gene steps in multigenic pathways.
Increase genetic diversity by inserting new genes into otherwise superior varieties, or,
Alter the level of expression of existing genes above or below naturally-occurring levels.
Promoters to enhance enzyme activity.
Anti-sense forms of existing genes, to inhibit gene action.

Examples of types of genes used in genetic transformation:
Resistances to viruses and other disease organisms.
Enzymes to transform the cassava root into a "biofactory" for biodegradable plastics-polymers or other totally new products.

Genetic engineering can be used to create specific mutations, useful for studying complex physiological traits, e.g. could permit the first definitive studies of the ecology and biochemistry of cyanogens in cassava, to permit more effective and better-targeted genetic manipulation of this trait (whether by plant breeding or genetic engineering).

Biological requirements

1. Efficient systems(s) for plantlet regeneration from single cells.
2. Efficient system (s) for transformation.
3. Efficient system for selection of transformed from non-transformed cells immediately after transformation.
4. Transformation, selection, and regeration systems must be compatible, i.e.
   -Transformable cells must be regerable.
   -Transformation and selection systems must not have too negative an effect on regeneration.
5. Isolated (cloned) genes available:
   Marker genes.
   Genes for desired agronomic or quality characteristics.

Types of transformation systems either through vectors or by direct gene transfer

1. Vectors: usually Agrobacterium

Agrobacteria can transfer a piece of DNA from a region of an extra-chromosomal part of their DNA (the tumor-inducing Ti plasmid) to a plant cell. The Ti plasmid contains important regions necessary for successful transfer of DNA to the plant.
Transfer DNA (T-DNA), the region actually transferred to the plant cell. The gene to be transferred is inserted into the T-DNA region.

Virulence or Vir-region, containing genes which determine whether and how efficiently the T-DNA is transferred to the plant cell.
In nature: Several other genes involved in formation and breakdown of opines (sugar amino acids) and so-called *onc*-genes
Agrobacterium "breeding" has created strains with additional and more effective Vir genes, capable of transforming additional species, more effciently.

Integration of DNA in the genome of the plant by the bacterium occurs at random, although there seems to be preference for certain transcriptionally-active regions.
Advantages of *Agrobacterium* methods
More suitable for simple laboratory conditions, require only the equipment and supplies of a normal microbiology and tissue culture laboratory.
Possibly fewer stuctural changes or amplifications in the genes inserted, low number of copies inserted compared to direct gene transfer methods.
Tend to give more normal gene expression and inheritance

2. Direct gene transfer

Examples:
- Micro-injection of individual cells with DNA.
- Micro-projectile bombardment (biolistics). Gold "bullets" coated with DNA are transferred into plant tissue (intact cells) by high velocity force using a "gene gun".
- Electroporation of DNA into protoplasts.

Frequencies of success using direct gene transfer range from 0.1% to 10% depending on the plant species and the procedure used. Generally less efficient than *Agrobacterium*, for which success ranges from 1% to 90%.

More costly (specialized equipment and maintenance).
However: The only alternative for many monocot species not susceptible to *Agrobacterium*.
Less genotype-dependent than *Agrobacterium* methods.

Factors influencing expression of transgenic traits

So-called "position effects", the actual position on the chromosome (hard to influence)

Environmental factors (GxE)

Structure of gene to be integrated (codon composition, borders, regulatory elements such as promoters, enhancers, introns, etc...) (can be manipulated)

Type of gene to be integrated:

Genomic sequence from same species:

60-90% of transformants have desired expression

Anti-sense sequence (e.g., "turning off" a gene): 0-50%

Heterologous sequence (gene from another species): 1-40%

When to select and evaluate products of genetic transformation

-Before or during regeneration of transformed cells

-During tissue-culture growth of transformed plantlets

-Based on greenhouse growth and performance

-Based on field characteristics and performance

-Based on inheritance of traits by offspring (gene can remain present but become silenced, or expression level can change)

Field selection and inheritance are the ultimate test; also most expensive; eliminate as much material as possible in earlier stages

Genetic engineering of cassava:update

Cassava genetic engineering research began in 1987.

The only systems successful for regeneration of cassava cells are adversely effected by transformation and selection.

Result: progress has been slow and difficult.

Breakthroughs in 1996; dramatic progress since last biennial report in 1994.

Regeneration of transgenic plants using microbombardment of embryogenic suspension cell cultures (Agri. Univ. Wageningen, Netherlands; ILTAB/ORSTOM, USA/France)

Agrobacterium transformation of somatic embryo-derived cotyledons with subsequent regeneration via organogenesis (ETH, Zurich).

Wild *Agrobacterium* strain to infect somatic embryo-derived cotyledons and regeneration through somatic embryogenesis (CIAT).

New gene promoters

From cassava vein mosaic virus: potential to replace the commonly-used CaMV 35S promoter in cassava transformation (ILTAB); available on request to researchers in cassava growing countries.

Possible root-specific promoter (Univ. Newcastle, UK).

Next steps

1. Introduction of genes of agronomic interest
a. Genes available:
    Resistance to viral diseases (CasCMV, ACMV)(Africa)
    Starch concentration, quality (S.America, Asia)
    Modification of cyanogen metabolism (Africa, S. America)
b. Genes not yet available for:
    Reduced postharvest perishability of cassava (global)
    Other...
c. Genetic transformation as a basic research tool (global)
    Mechanisms of insect and disease resistance
    Nutrient use efficiency
    Drought tolerance
    Photosynthesis
    Cyanogenesis
2. Simplify and improve the new experimental protocols for cassava genetic engineering (repeatability, efficiency).
3. Extend genetic tranformation protocols to a range of important cultivars
4. Continue to identify tissue-specific gene promoters

Outlook for the next few years:
Improved protocols ready for technology transfer to cassava-growing countries (3 to 5 years)
Transgenic cassava with genes of interest, ready for field trials (5 years?)
Therefore, planning phase should start now for:
-Transfer of improved protocols to additional laboratories
-Biosafety
-Design of evaluation of transgenic prototypes with applied researchers and cassava users

III. Molecular Markers
Genetic variation is:
The basis of plant taxonomy, classification, germplasm evaluation
The basis of crop improvement.
What plant breeders do:
Detect and measure the genetic variation available and combine it into new varieties by using cycles of crossing, selection, crossing again,...to combine and

recombine genes.

How plant breeders detect and measure genetic variation:

Inferred from the phenotype: measurements of morphology, performance, analyzed via quantitative genetics ("organized ignorance").

or, Direct from the genotype via molecular markers (also requires quantitative analysis!).

Molecular marker types

Isozymes: limited amount of variation; inexpensive; recommended when sufficiently informative.

DNA sequence markers

DNA sequence marker types: RFLPs, RAPDs, Microsatellites, AFLPs, etc.

....a rapidly-evolving technology....

Characteristics of different DNA marker types:

1. *RFLPs* (Restriction fragment length polymorphisms)

Uses "restriction" enzymes which cut DNA at specific bases sequences.

Resulting fragments separated on a gel by electrophoresis.

Genetic variation detected as differences in the size of fragments.

Advantage: Very reproducible (reliable) from lab to lab and species to species

Specific to particular sequences

Disadvantage: Expensive

Require radioactive labels (research to develop non-radioactive methods)

2. *RAPDs* (Random amplified polymorphic DNA)

Uses polymerase chain reaction (PCR) which polymerizes nucleotides into polynucleotide chains) and a single small primer (starter sequence), which is likely to occur at random in a genome.

Advantage: Easy and quick.

Disadvantage: Not always reliable.

Not easy to target a specific area of the genome.

Can not distinguish heterozygotes from homozygous dominant (less genetic information than RFLPs).

3. *Microsatellites*

Uses PCR with long (and therefore more specific) primers.

Identifies areas with long tandem (one-after-the-other) repeats of a short DNA sequence.

Name refers to appearance of this type of DNA after centrifuging a fragmented sample of total DNA: a microsatellite apart from the rest of the DNA.

Advantage: Can target a specific area of the genome.

More variability than any other market type--can detect variation among more closely related genotypes than can be distinguished by other marker types.

Disadvantage: Expensive.

Requires DNA sequence analysis to create the primers.

4. *AFLPs* (Amplified fragment length polymorphisms)

A combination of RFLP and PCR technology:

Cut DNA with restriction enzymes.

Attach short DNA "adapters" (known primers) to the ends of the fragments.

Amplify the fragments using the primers.

Advantage: Reproducible (reliable), easy.

Disadvantage: Can not easily target a specific area of the genome.

Usually does not distinguish heterozygote from homozygous dominant.

Basically...differences between molecular marker types are related to how much they cost vs. amount of information and reliability

Uses of molecular markers

1. Germplasm screening

   Measure differences and assay relationships. Easiest with AFLPs or RAPDs.

2. Construction of genetic maps

   General-purpose tools for gene tagging, quantitative trait analysis, and map-based cloning.

3. Tagging of genes for indirect selection
   - To find molecular markers closely linked to the gene of interest, especially for difficult- or expensive-to-measure traits (e.g. insect resistance, traits with high GxE), or traits that can be measured only late in the life cycle (e.g. post-harvest perishability).
   - Then pre-select based on the marker (and select against undesirable linked genes), confirm field phenotype with smaller number.
   - Increases efficiency of field testing.
   - Less expensive? depends on the situation and the trait!

4. Quantitative trait analysis
   - Follow segregation of a large number of RFLP markers in a single cross.
   - Correlate presence of a certain marker (e.g., chromosome segment) with the quantitative trait.
   - Assemble genotypes containing multiple favorable chromosome segments (markers) for the quantitative trait (QTLs).

5. Map-based cloning of genes

A method of isolating genes for genetic engineering, when there is little information about the gene.

6. Analysis of introgression

   Increased speed of gene transfer via backcrossing.

   Select against unfavorable linked genes from donor parent.

IV. Traditional and Contemporary Fermentation Biotechnology

Used for centuries to preserve and detoxify cassava

- Improved starter cultures can enhance safety, nutritional value, and consumer appeal of traditional cassava foods.
- Contemporary fermentation technology: a growth industry that uses cassava substrate to produce a range of products, from animal feeds to industrial enzymes and pharmaceuticals.

Need for consumer-oriented market research and product development activity.

Microbial biotechnology for waste management

- Treatment of cassava processing waste water and solids
- Environmental protection, clean water conservation
  - Detoxification
  - Reduction of biological oxygen demand
  - Value added?

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APPENDIX

Results of Soil Analyses in Asia 1994-1997

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 and in FPR trials in farmers fields. To facilitate interpretation of the results, **Table 1** indicates the approximate classification of soil chemical characteristic 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	Quongzhong county, Changzhang - area cleared for cassava	Nov 95	S498
	-2	Baisha county, Kongba village - black soil	Nov 95	S498
	-3	Baisha county, Kongba village - black soil in fertilizer trial	Nov 95	S498
	-4	Kongba village - Mr. Pu Yong Chuan, FPR fert. trial check	Jan 95	S498
	-5	Kongba village - Mr. Tan Jing Zhou, FPR fert. trial check	Jan 95	S498
	-6	Kongba village - Mr. Tan Jia Chai, FPR fert. trial check	Jan 95	S498
	-7	Kongba village - Mr. Tan Yin Zhui FPR fert. trial check	Jan 95	S498
	-8	Kongba village - Mr. Tan Ya Zhui, FPR fert. trial check	Jan 95	S498
	-9	Kongba village - Mr. Zhou Shao Xiong, FPR fert. trial check	Jan 95	S498
	-10	Kongba village - Mr. Tan Ming Lei, poor eroded soil	Jan 97	S782
	-11	Kongba village - Mr. Tan Yen Chai, FPR erosion trial	Jan 97	S782
	-12	Kongba village - Mr. Zhou Ya Nin, FPR fert. trial check	Jan 97	S782
	-13	Kongba village - Mr. Tan Ya Tian, FPR fert. trial check	Jan 97	S782
	-14	Kongba village - Mr. Ma Guo Rong, FPR fert. trial check	Jan 97	S782
	-15	Kongba village - Mr. Fu Yong Chuan, FPR fert. trial check	Jan 97	S782
	-16	CATAS - NPK trial, 1995, 4th year, $N_0P_0K_0$	Mar 95	S498
	-17	CATAS - NPK trial, 1995, 4th year, $N_3P_3K_3$	Mar 95	S498
	-18	CATAS - NPK trial, 1996, 5th year, $N_0P_0K_0$	Mar 95	S782
	-19	CATAS - NPK trial, 1996, 5th year, $N_3P_3K_3$	Mar 96	S782
Guangxi	-1	Nanning, NPK trial, 1994, 6th year, $N_0P_0K_0$	Feb 94	S891
	-2	Nanning, NPK trial, 1994, 6th year, $N_3P_3K_3$	Feb 94	S891
	-4	Nanning, NPK trial, 1995, 7th year, $N_0P_0K_0$	Mar 95	S498
	-5	Nanning, NPK trial, 1995, 7th year, $N_3P_3K_3$	Mar 95	S498
	-6	Nanning, NPK trial, 1996, 8th year, $N_0P_0K_0$	Mar 96	S782
	-7	Nanning, NPK trial, 1996, 8th year, $N_3P_3K_3$	Mar 96	S782
Guangdong	-1	Huayji, on-farm NPK trial, before planting	Mar 96	S782
	-2	Gaozhou Agric. College, NPK trial, before planting	Mar 96	S782
	-3	Yunnan, on-farm NPK trial, before planting	Mar 96	S782

Table 3. Chemical and physical characteristics of cassava soils in China.

		Chemical characteristics													Physical characteristics			
			%	ppm-	me/100g				%	ppm					%			
		pH	OM	P	Al	Ca	Mg	K	Al	B	Zn	Mn	Cu	Fe	Sand	Silt	Clay	Texture[1]
Hainan	-1	4.4	4.6	4.0	2.07	0.68	0.46	0.21	60	0.30	0.69	13.0	0.27	25.6	51.1	17.1	31.8	s.c.l.[1]
	-2	5.5	4.8	23.5	0.10	3.59	1.25	0.40	2	0.35	6.09	78.5	0.29	9.4	48.9	17.5	33.6	s.c.l.
	-3	4.8	4.7	6.0	0.47	2.24	0.90	0.18	12	0.33	1.90	67.0	0.24	12.9	50.4	16.2	33.4	s.c.l.
	-4	4.1	3.8	13.7	1.57	0.80	0.37	0.18	54	0.29	0.89	63.0	0.20	18.6	52.8	11.0	36.2	sandy clay
	-5	4.3	6.5	6.6	2.39	1.10	0.69	0.32	53	0.36	1.49	54.1	0.22	14.2	44.6	16.2	39.2	clay loam
	-6	4.7	5.9	35.0	0.83	1.87	0.85	0.38	21	0.36	1.64	41.9	0.25	12.9	42.1	23.9	34.0	clay loam
	-7	4.6	4.0	7.9	1.26	1.39	0.80	0.44	32	0.37	1.87	44.4	0.34	17.0	45.1	16.8	38.1	sandy clay
	-8	4.8	4.6	16.1	0.70	1.88	0.72	0.17	20	0.28	1.50	62.3	0.21	14.1	50.9	15.0	34.1	s.c.l.
	-9	4.8	4.2	26.5	0.60	1.58	0.86	0.16	19	0.33	1.65	49.3	0.19	17.2	63.6	5.0	31.4	s.c.l.
	-10	4.7	2.9	3.7	1.35	0.83	0.44	0.21	48	0.33	1.02	33.6	0.14	22.8	51.2	15.9	32.9	s.c.l.
	-11	3.9	3.3	11.3	3.12	0.26	0.15	0.18	84	0.47	0.67	12.5	0.17	66.4	30.6	17.2	52.2	clay
	-12	4.4	3.0	4.8	2.18	0.63	0.32	0.18	66	0.44	0.76	33.6	0.12	32.7	49.0	14.5	36.5	sandy clay
	-13	4.8	2.4	3.0	0.83	1.34	0.59	0.18	28	0.59	1.20	68.6	0.09	25.0	51.4	14.5	34.1	s.c.l.
	-14	4.8	2.2	24.8	0.94	1.52	0.30	0.07	33	0.57	1.17	83.3	0.14	19.6	52.7	12.0	35.3	sandy clay
	-15	4.3	2.3	9.0	2.61	0.36	0.17	0.12	80	0.57	0.84	57.8	0.19	34.7	48.1	12.3	39.6	sandy clay
	-16	4.5	1.8	17.6	0.76	0.67	0.10	0.06	48	-	-	-	-	-	-	-	-	-
	-17	4.4	1.9	41.2	0.73	0.66	0.10	0.11	46	0.23	0.58	14.5	0.18	15.6	58.2	17.4	24.4	s.c.l.
	-18	4.6	0.7	16.1	0.83	0.57	0.13	0.06	52	-	-	-	-	-	-	-	-	-
	-19	4.7	0.8	88.9	0.73	0.78	0.12	0.10	42	0.39	0.44	17.6	0.19	22.1	58.7	17.0	24.2	s.c.l.
Guangxi	-1	5.1	3.0	19.5	1.38	2.41	0.48	0.15	31	-	-	-	-	-	-	-	-	-
	-2	5.2	2.8	100.0	1.20	2.29	0.89	0.29	26	-	0.46	8.8	0.64	49.5	25.3	36.0	38.7	clay loam
	-4	4.5	2.4	14.0	2.27	2.13	0.39	0.14	46	-	-	-	-	-	-	-	-	-
	-5	4.5	2.8	28.2	2.38	2.04	0.67	0.24	45	0.75	0.70	8.5	0.54	34.1	21.9	35.5	42.6	clay
	-6	4.7	1.5	13.8	1.77	2.02	0.51	0.17	40	-	-	-	-	-	-	-	-	-
	-7	4.8	1.5	34.5	1.14	2.61	0.84	0.17	24	0.43	0.45	6.9	0.55	56.7	28.1	34.9	37.0	sandy clay
Guangdong	-1	6.1	1.1	7.5	0	3.82	0.75	0.15	0	0.78	0.90	26.0	0.41	18.9	53.4	15.3	31.3	s.c.l.
	-2	5.0	1.2	169.1	0.62	0.95	0.18	0.22	31	0.32	3.21	23.7	2.87	161.2	60.0	15.8	24.2	s.c.l.
	-3	5.1	2.6	73.3	0.10	3.51	0.87	0.92	2	0.50	5.31	27.8	1.48	26.9	33.5	17.8	48.7	clay

[1] s.c.l. = sandy clay loam.

Table 4. Soil samples taken in Indonesia.

Sample no.		Sample location and description	Date	Lab Series
E-Java	-1	Malang, Jatikerto, NPK trial, 1995, 8th year, $N_0P_0K_0$	Oct 95	S498
	-2	Malang, Jatikerto, NPK trial, 1995, 8th year, $N_3P_3K_3$	Oct 95	S498
	-3	Blitar, Ringinrejo, Demonstration plots, black soil+lime	Febr 96	S498
	-4	Blitar, Ringinrejo, Mr. Ponirin - erosion trial, red clay	Febr 96	S498
	-5	Blitar, Ringinrejo, Mr. Hardi - variety trial, black soil	Febr 96	S498
	-6	Blitar, Ringinrejo, Mr. Katimin - erosion trial	July 96	S782
	-7	Blitar, Ringinrejo, white purple clay in road cut	July 96	S782
	-8	Malang, Dampit, demonstration plots - T_2, severe K def.	July 96	S782
	-9	Malang, Dampit, demonstration plots - T_{12}, no K deficiency	July 96	S782
	-10	Malang, Dampit, Ir. Noviar erosion trial, severe K def.	July 96	S782
	-11	Malang, Dampit, K trial before planting	Sept 96	S782
Yogyakarta	-1	Playen, farmer's field - Fert x soybean trial	Febr 96	S498
Lampung	-1	Umas Jaya, NPK trial, 1996, 9th year, Av. $N_0P_0K_0$	Febr 96	S498
	-2	Umas Jaya, NPK trial, 1996, 9th year, Av. $N_3P_3K_3$	Febr 96	S498
	-3	Tamanbogo, erosion trial, 1994/95, 5th year, T_1	Dec 94	S782
	-4	Tamanbogo, NPK trial, 1994/95, 4th year, $N_0P_0K_0$	Dec 94	S782
	-5	Tamanbogo, NPK trial, 1994/95, 4th year, $N_3P_3K_3$	Dec 94	S782
	-6	Tamanbogo, NPK trial, 1995/96, 5th year, $N_0P_0K_0$	Sept 95	S782
	-7	Tamanbogo, NPK trial, 1995/96, 5th year, $N_3P_3K_3$	Sept 95	S782

Table 5. Chemical and physical characteristics of cassava soils in Indonesia.

		Chemical characteristics													Physical characteristics			
			%	ppm	me/100g				%	ppm					%			
Sample no.		pH	OM	P	Al	Ca	Mg	K	Al	B	Zn	Mn	Cu	Fe	Sand	Silt	Clay	Texture
E-Java	-1	5.7	1.6	9.0	0.06	6.24	3.03	0.99	0	-	-	-	-	-	-	-	-	-
	-2	5.6	1.2	21.4	0.16	7.98	3.12	1.62	1	0.17	1.17	40.0	3.46	44.4	25.3	25.1	49.6	clay
	-3	7.5	2.9	4.6	0.07	40.14	1.12	0.27	0	0.44	0.17	3.1	0.12	0.3	12.5	18.7	68.8	clay
	-4	5.0	2.2	1.5	0.21	11.05	5.10	0.29	1	0.41	0.67	76.7	1.90	16.9	12.9	19.6	67.5	clay
	-5	7.5	2.4	20.7	0.07	33.82	1.30	0.14	0	0.33	0.07	2.9	0.10	0.2	12.3	18.1	69.6	clay
	-6	5.3	1.0	2.6	0.16	34.00	8.35	0.18	0	0.69	19.47	23.0	1.26	9.0	19.9	22.6	57.5	clay
	-7	6.2	0	1.2	0	31.66	0.80	0.05	0	0.30	0.69	4.3	0.71	8.9	7.5	29.0	63.5	clay
	-8	5.4	1.7	1.9	0.42	8.95	2.49	0.07	4	0.44	1.48	121.8	1.66	19.4	38.7	19.9	41.4	clay
	-9	5.3	1.8	1.4	0.52	8.42	2.11	0.11	5	0.77	3.22	116.2	1.89	22.8	36.9	22.3	40.8	clay
	-10	5.3	1.4	1.4	0.42	8.23	4.19	0.08	3	0.57	1.20	91.3	3.81	38.8	21.4	23.5	55.1	clay
	-11	5.2	1.1	1.6	0.52	9.70	2.60	0.07	4	0.38	1.48	57.0	2.74	29.6	32.0	23.5	44.5	clay
Yogya	-1	6.3	2.6	24.3	0.04	49.56	2.43	0.17	0	0.30	0.40	28.0	0.33	0.5	4.3	10.4	85.2	clay
Lampung	-1	4.4	3.5	6.2	1.65	1.77	0.38	0.07	43	0.25	0.78	7.2	0.33	52.9	45.3	15.8	38.9	sandy clay
	-2	4.4	3.6	36.6	1.71	1.05	0.20	0.20	54	0.30	0.78	5.6	0.24	59.6	47.3	16.4	36.3	sandy clay
	-3	4.3	2.0	3.4	1.56	0.71	0.37	0.09	57	-	-	-	-	-	-	-	-	-
	-4	4.2	2.6	4.3	1.66	0.91	0.49	0.09	53	-	-	-	-	-	-	-	-	-
	-5	4.4	2.6	11.5	1.56	0.92	0.46	0.20	50	0.51	1.36	32.6	0.74	26.1	-	-	-	-
	-6	4.1	2.2	6.0	1.66	0.88	0.45	0.10	54	-	-	-	-	-	-	-	-	-
	-7	4.4	2.3	12.3	1.25	0.86	0.43	0.19	46	0.39	0.67	32.2	0.51	30.5	45.3	12.4	42.3	sandy clay

Table 6. Soil samples taken in the Philippines.

Sample no.		Sample location and description	Date	Lab series
Leyte	-1	Bontoc, Pamahawa village - cassava field with vetiver grass barriers	Oct 96	S-782
	-2	Bontoc, Pamahawa village - young cassava with vetiver grass barriers, red clay soil	Oct 96	S-782
	-3	Bontoc, Pamahawa village - cassava field, P deficiency, red clay soil	Oct 96	S-782
	-4	Matalom, San Salvador - FSP trials, K deficiency in pasture species	Oct 96	S-782
Behol	-1	San Miguel, Corazon, Mr. Rauel Cambangay, on-farm fertilizer trial, grey clay loam	Oct 96	S-782

Table 7. Chemical and physical characteristics of cassava soils in the Philippines.

		Chemical characteristics													Physical characteristics			
			%	ppm	me/100g				%	ppm					%			
Sample no.		pH	OM	P	Al	Ca	Mg	K	Al	B	Zn	Mn	Cu	Fe	Sand	Silt	Clay	Texture
Leyte	-1	4.9	2.9	2.2	1.14	9.23	4.14	0.37	8	0.37	1.97	274.1	1.68	25.8	25.0	24.9	50.1	clay
	-2	4.7	2.2	2.3	2.60	4.61	3.26	0.26	24	0.62	1.26	122.7	1.53	44.0	37.8	16.7	45.4	clay
	-3	4.7	1.8	1.2	3.43	1.68	1.30	0.19	52	0.44	1.56	166.3	1.46	51.1	38.2	19.2	42.6	clay
	-4	4.6	2.0	2.0	0.83	1.54	1.10	0.06	23	0.58	2.57	397.5	1.66	29.6	-	-	-	-
Bohol	-1	5.3	1.5	2.1	0.42	1.57	1.80	0.14	11	0.44	0.69	69.3	1.15	29.8	57.4	20.5	22.1	s.c.l.[1]

[1] s.c.l. = sandy clay loam

Table 8. Soil samples taken in Thailand.

Sample no.		Sample location and deseription	Date	Lab series
N.Ratchasima	-1	Soeng Saeng, Mr. Nonglak - FPR erosion trial	July 95	S-498
	-2	Soeng Saeng, Mr. Saway - FPR erosion trial	July 95	S-498
	-3	Soeng Saeng, Mrs. Kaew - FPR erosion trial	July 95	S-498
	-4	Soeng Saeng, Mrs. Thong - FPR erosion trial	July 95	S-498
	-5	Soeng Saeng, Mrs. Lamun - FPR erosion trial	July 95	S-498
	-6	Soeng Saeng, Mrs. Nuukaan - FPR erosion trial	July 95	S-498
	-7	Soeng Saeng, Mrs. Kong - FPR erosion trial	July 95	S-498
	-8	Soeng Saeng, Mrs. Wongduean - FPR variety trial	July 95	S-498
	-9	Soeng Saeng, Mr. Thongchan - FPR fert. trial check.	Mar 96	S-498
	-10	Banmai Samrong NPK trial, 21st year, 0-0-0	July 95	S-498
	-11	Banmai Samrong NPK trial, tops incorp + 8-8-8	July 95	S-498
	-12	Huay Bong, Daan Khun Thot - TTDI - demonstr. plots	July 95	S-498
	-13	Huay Bong, Daan Khun Thot - TTDI-long-term trial I-1	July 96	S-782
	-14	Huay Bong, Daan Khun Thot - TTDI-long-term trial II-1	July 96	S-782
	-15	Highway Paakchong-Huay Bong-Field with Fe/Zn def.	July 96	S-782
Sra Kaew	-1	Wang Nam Yen, Mr. Sawong - FPR erosion trial	July 95	S-498
	-2	Wang Nam Yen, Mr. Bunlue - FPR erosion trial	July 95	S-498
	-3	Wang Nam Yen, Mr. Udom - FPR erosion trial	July 95	S-498
	-4	Wang Nam Yen, Mr. Prichaa - FPR erosion trial	July 95	S-498
	-5	Wang Nam Yen, Mr. Lek - FPR variety trial	July 95	S-498
	-6	Wang Nam Yen, Mr. Bunlue - FPR erosion trial	Dec 95	S-498
Prachin Buri	-1	Khaw Hin Sorn-grass barrier trial	July 96	S-782

Table 9. Chemical and physical characteristics of cassava soils in Thailand.

	Chemical characteristics													Physical characteristics			
		%	ppm	me/100g				%	ppm					%			
Sample no.	pH	OM	P	Al	Ca	Mg	K	Al	B	Zn	Mn	Cu	Fe	Sand	Silt	Clay	Texture
N. Ratchasima -1	5.1	2.9	2.7	0.11	2.85	3.06	0.16	2	0.36	0.78	31.1	0.93	23.3	47.6	15.7	36.6	sandy clay
-2	6.2	4.4	12.2	0.14	14.00	6.20	0.56	1	0.47	1.59	22.7	0.58	6.4	20.1	24.8	55.1	clay
-3	6.2	4.1	15.5	0.06	7.90	2.38	0.65	1	0.25	4.13	34.3	1.15	8.7	13.2	25.0	61.7	clay
-4	7.0	1.8	7.0	0.05	4.76	0.60	0.25	1	0.28	0.69	35.5	0.27	9.5	58.3	15.4	26.3	s.c.l.[1]
-5	6.1	1.9	4.3	0.04	3.16	0.75	0.24	1	0.31	0.56	16.7	0.35	17.9	57.1	17.9	25.0	s.c.l.
-6	5.4	4.3	7.7	0.07	3.10	1.21	0.58	1	1.05	1.70	58.8	1.02	9.9	17.2	18.6	64.2	clay
-7	5.6	1.7	5.5	0.04	1.72	0.49	0.11	2	0.40	0.48	46.1	0.14	4.5	65.2	12.3	22.4	s.c.l.
-8	5.6	1.2	9.5	0.03	1.35	0.38	0.09	2	0.27	0.46	13.3	0.15	4.9	62.5	18.5	19.0	sandy loam
-9	4.4	3.0	14.8	1.29	1.32	0.42	0.22	40	0.85	1.34	128.1	1.56	18.4	-	-	-	-
-10	7.1	1.5	41.4	0.03	5.40	0.80	0.32	0	0.23	2.15	34.9	0.59	6.0	52.4	20.7	26.8	s.c.l.
-11	7.0	1.6	49.3	0.02	4.52	0.79	0.35	0	0.32	2.21	33.0	0.57	6.9	56.5	19.6	23.9	s.c.l.
-12	7.3	1.7	9.4	0.02	7.60	0.44	0.32	0	0.80	0.56	35.5	0.24	3.9	54.3	21.2	24.5	s.c.l.
-13	7.0	0.9	14.1	0	4.84	0.96	0.30	0	0.65	0.69	42.2	0.27	8.6	57.3	15.2	27.5	s.c.l.
-14	7.5	1.0	24.6	0	14.20	1.08	0.42	0	0.50	0.90	52.3	0.38	13.9	49.5	20.9	29.6	s.c.l.
-15	7.6	4.7	7.5	0	58.20	4.51	0.98	0	0.64	0.07	0.3	0.12	0.4	11.9	25.9	62.2	clay
Sra Kaew -1	6.3	4.7	3.0	0.04	24.70	8.55	0.10	0	0.38	1.60	28.8	0.54	3.9	29.4	18.1	52.5	clay
-2	6.5	5.1	11.2	0.03	33.10	9.74	0.24	0	0.53	1.26	32.1	0.30	1.7	25.8	24.4	49.8	clay
-3	6.7	5.4	7.6	0.04	29.40	4.89	0.40	0	0.46	1.47	38.3	0.72	2.6	-	-	-	-
-4	6.3	4.0	3.2	0.04	17.20	4.47	0.18	0	0.39	1.73	44.5	0.45	4.1	-	-	-	-
-5	6.5	4.0	4.0	0.01	26.90	6.86	0.18	0	0.59	1.16	34.4	0.34	1.7	32.9	19.5	47.6	clay
-6	6.2	5.0	11.0	0.04	36.41	10.50	0.20	0	0.55	1.36	42.7	0.30	3.1	25.7	28.1	46.3	clay
Prachin Buri -1	5.9	0.5	9.5	0	1.12	0.18	0.14	0	0.50	0.52	24.7	0.17	22.3	72.7	8.8	18.6	sandy loam

[1]s.c.l. = sandy clay loam.

Table 10. Soil samples taken in Vietnam.

Sample no.		Sample location and description	Date	Lab series
Dong Nai	-1	Hung Loc Center, Soil Improvement trial, 1994/95, 3d year, T_1	Apr 94	S-498
	-2	Hung Loc Center, Soil Improvement trial, 1995/96, 4th year, T_1	May 95	S-498
	-3	Hung Loc Center, Soil Improvement trial, 1996/97, 5th year, T_1	May 96	S-782
	-4	Hung Loc Center, Soil Improvement trial, 1996/97, 5th year, T_8	May 96	S-782
	-5	Hung Loc Center, NPK trial, 1994/95, 5th tear, $N_0P_0K_0$	Apr 94	S-498
	-6	Hung Loc Center, NPK trial, 1995/96, 6th year, $N_0P_0K_0$	Apr 95	S-498
	-7	Hung Loc Center, NPK trial, 1996/97, 7th year, $N_0P_0K_0$	May 96	S-782
	-8	Hung Loc Center, NPK trial, 1996/97, 7th year, $N_3P_3K_3$	May 96	S-782
	-9	Thong Nhat, Traco village, NPK trial, 1995/96, $N_0P_0K_0$	June 95	S-498
	-10	Thong Nhat, Traco village, new NPK trial before planting	May 96	S-782
Thai Ninh	-1	Farmers' field	June 95	S-498
Bac Thai	-1	Agro-forestry College, NPK trial, 1996, 7th year, $N_0P_0K_0$	Jan 96	S-498
	-2	Agro-forestry College, NPK trial, 1996, 7th year, $N_3P_3K_3$	Jan 96	S-498
	-3	Agro-forestry College, erosion trial, 1996, T_1	Jan 96	S-498
	-4	Agro-forestry College, Mg trial, 1996, before 1st year planting	Jan 96	S-498
	-5	Agro-forestry College, FPR demonstration plots, 1996	Jan 96	S-498
	-6	Pho Yen, Tien Phong, Mr. Nguyen Van Dung, erosion trial	Oct 95	S-498
	-7	Pho Yen, Tien Phong, Mr. Ngo Dinh Thuong, variety trial, Mg def.	Oct 95	S-498
	-8	Pho Yen, Dac Son, Mr. Nguyen Van Du, K and Mg deficiency	July 96	S-782
Vinh Phu	-1	Thanh Hoa, Kieu Tung, FPR fertilizer trial check plot	Oct 95	S-498
Hoa Binh	-1	Luong Son, Dong Rang, farmer's field, FPR variety trial	Apr 96	S-498
	-2	Luong Son, Dong Rang, erosion trial, T_1 (no fertilizers)	July 96	S-782

Table 11. Chemical and physical characteristics of cassava soils in Vietnam.

		Chemical characteristics													Physical characteristics			
			%	ppm	me/100g				%	ppm					%			
Sample no.		pH	OM	P	Al	Ca	Mg	K	Al	B	Zn	Mn	Cu	Fe	Sand	Silt	Clay	Texture
Dong Nai	-1	4.4	3.1	9.4	1.00	1.66	0.57	0.32	28	0.29	1.20	56.8	0.80	12.6	-	-	-	-
	-2	4.6	3.3	11.9	0.94	1.90	0.61	0.28	25	0.25	1.38	90.2	0.90	13.2	-	-	-	-
	-3	4.6	2.5	11.5	1.04	1.71	0.52	0.28	29	0.32	1.43	74.0	1.08	15.2	7.1	10.9	82.0	clay
	-4	4.6	2.5	12.2	0.73	2.19	0.67	0.37	18	0.56	1.21	79.0	1.01	15.0	10.2	9.7	80.1	clay
	-5	4.0	3.3	20.0	2.32	1.24	0.48	0.15	55	0.31	0.97	69.6	0.58	11.0	-	-	-	-
	-6	4.2	2.5	17.9	2.19	0.91	0.41	0.18	59	0.32	1.11	72.6	0.72	14.9	-	-	-	-
	-7	4.5	2.5	23.0	1.87	1.01	0.52	0.19	52	0.39	1.11	85.6	0.83	13.6	10.9	8.3	80.8	clay
	-8	4.3	2.6	34.8	1.87	1.19	0.37	0.23	51	0.54	1.14	94.5	0.86	6.7	8.2	9.6	82.2	clay
	-9	4.0	1.8	7.1	0.78	0.32	0.14	0.06	60	0.29	0.74	3.0	0.17	37.8	63.0	11.6	25.4	s.c.l.
	-10	4.6	0.6	6.7	0.83	0.40	0.13	0.05	59	0.30	0.62	6.2	0.27	41.7	69.6	5.6	24.8	s.c.l.
Thai Ninh	-1	4.0	3.0	2.8	5.72	0.42	0.12	0.06	90	0.07	1.72	6.1	0.67	28.0	27.5	19.99	52.6	clay
Bac Tahi	-1	4.2	2.6	7.5	1.91	0.78	0.13	0.05	66	0.16	0.72	3.1	0.42	96.6	57.3	17.4	25.3	s.c.l
	-2	4.1	2.4	25.7	2.22	0.64	0.20	0.09	70	-	-	-	-	-	-	-	-	-
	-3	4.4	3.4	34.2	2.38	1.28	0.23	0.05	60	0.11	0.44	2.9	0.26	57.1	52.7	20.3	27.0	s.c.l.
	-4	5.3	2.4	26.2	0.10	2.55	0.13	0.13	3	0.27	0.62	6.2	0.37	34.1	55.5	19.5	25.0	s.c.l.
	-5	4.3	3.8	14.5	2.65	0.66	0.10	0.07	76	0.27	-	2.5	-	78.7	52.3	20.8	26.9	s.c.l.
	-6	4.2	0.8	9.9	0.99	0.22	0.05	0.05	76	0.20	0.37	3.9	0.15	28.3	66.4	15.4	18.2	sandy loam
	-7	4.3	1.1	13.7	0.53	0.23	0.05	0.03	63	0.18	0.36	2.8	0.16	21.0	70.9	13.6	15.5	sandy loam
Vinh Phu	-1	3.9	3.3	6.0	6.50	0.54	0.14	0.06	90	0.17	0.84	6.8	0.46	42.2	22.0	21.4	56.6	clay
Hoa Binh	-1	4.3	6.1	4.3	1.42	0.72	0.40	0.29	50	0.34	2.04	140.5	6.90	17.5	24.9	21.5	53.6	clay
	-2	4.7	4.7	2.6	1.25	0.59	0.35	0.07	55	0.95	2.08	330.2	8.88	20.9	22.7	21.4	55.9	clay

[1]s.c.l. = sandy clay loam.

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