Cassava in Asia, its Potential and Research Development Needs

Proceedings of a Regional Workshop held in Bangkok, Thailand, 5-8 June, 1984

Centro Internacional de Agricultura Tropical (CIAT)
ESCAP - CGPRT Centre

ISBN-84-89206-48-1

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Organized by:
Centro Internacional de Agricultura Tropical (CIAT)
and ESCAP Regional Co-ordination Centre for Research and Development of Coarse Grains, Pulses, Roots and Tuber Crops in the Humid Tropics of Asia and the Pacific (ESCAP CGPRT CENTRE)

With financial support from the Ford Foundation for some of the participants and printing of proceedings, and the cooperation of the Government of Thailand

Cover photo, Kazuo Kawano: Rayong 1 at Mahasarakan Station, Thailand.

Centro Internacional de Agricultura Tropical (CIAT)
Apartado 6713
Cali, Colombia

ISBN 84-89206-48-1
March 1986
Print order: 800 copies

Centro Internacional de Agricultura Tropical; ESCAP CGPRT Centre. 1986. Cassava in Asia, its potential and research development needs: proceedings of a regional workshop held in Bangkok, Thailand, 4-8 June, 1984. Cali, Colombia. 442 p.

1. Cassava — Asia — Congresses. 2. Cassava — Production — Congresses. 3. Cassava — Economic aspects — Congresses. I. Centro Internacional de Agricultura Tropical. II. ESCAP Regional Co-ordination Centre for Research and Development of Coarse Grains, Pulses, Roots and Tuber Crops in the Humid Tropics of Asia and the Pacific. III. Workshop on Cassava in Asia, its Potential and Research Development Needs (1984 : Bangkok, Thailand).

Contents

I. Introduction

Objectives of the Workshop*

Douglas R. Laing

This workshop, planned and organized jointly by CIAT and the ESCAP/CGPRT Centre, will study cassava's recent development and its potential for future expansion in tropical Asian countries. Many of the professional collaborators have been able to attend the workshop through financial assistance provided from their own national resources. This indicates a new and awakening interest in this crop and in developing a research network, the members of which can work together to increase national productivity and utilization of this critical food and feed crop.

The objectives of the workshop are to describe and estimate (1) cassava's market potential in tropical Asia, (2) new technology as the basis for increased cassava production, and (3) cassava research and development needs. Individual country reports to be presented discuss cassava's role in the country's agricultural economy and/or improving the country's cassava productivity. In these countries cassava is viewed as a crop with significant development potential since it is adapted to poor soils and low and fluctuating rainfall patterns. This is particularly important because most land available for development in Asia is characterized by poor soil and climatic conditions.

The IARC's (International Agriculture Research Centers) have played a useful role in strong collaboration with national institutions in the tremendous progress that has been achieved in the major world cereal crops. This progress has allowed many developing countries, particularly in southeast Asia, to become self-sufficient in these crops. This development has been generally dependent upon higher use of purchased inputs, has taken place in a generally more favorable economic climate, and has taken place in the best lands available in the tropics, usually under irrigated conditions.

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* Excerpts from the Opening Statement by Dr. Douglas R. Laing, Director for Crops Research, CIAT.

When one cosiders cassava, it is clear that these same conditions cannot be repeated. The world economic situation is now more difficult and the land available for future expansion is not as fertile. What remains to be done is another green revolution, but this time in the non-cereal crops and in the less favored non-irrigated production areas. This revolution must be one which does not require a high level of purchased inputs such as fertilizers and pesticides, and must be based on dependable technology for less favored conditions of both soil and climate. It is here that cassava can play a critical role as an energy crop for both food and feed. Such a green revolution in cassava must obviously take place in an integrated way to ensure that the technology and economics of utilization keep pace with production in order that the crop maintain its comparative market advantage.

To achieve such a revolution in each country, regional cooperation in research can achieve much more than if each country continues to work in isolation from its neighbors. A regional network of collaborators can be more effective in surmounting the constraints to increased productivity and utilization of cassava.

It is for this important reason that this workshop was organized. The time is ripe for increased regional cooperation in cassava research in the Asian region. The workshop can be useful in defining the role that can be played by international, regional, and national agencies in a truly cooperative network.

Agricultural research, in many economic studies, has been shown to have very high benefit:cost implications. Collaborative international research can be particularly effective in reducing research costs and in speeding up the production of the outputs of research, namely new technology adapted to farmers conditions.

Opening Statement

Mr. S.A.M.S. Kibria
Executive Secretary of ESCAP

"Distinguished participants, ladies and gentlemen:

It is a pleasure to welcome all of you to this workshop on Cassava in Asia, its Potential and Research Development Needs.

Your task to assess the scope for increasing Asia's production and utilization of cassava certainly has significant implications, both nutritionally and economically. In the tropics, as you know, cassava is surpassed in importance only by rice, sugarcane, and maize as a source of calories. Indeed, some 200 million people worldwide, especially the poor, depend on this starchy root crop as a dietary staple, including many in Indonesia, the Philippines, and parts of the Pacific. Cassava is also important because of its close association with Asia's rural poverty. Even in those countries producing it as livestock feed, cassava is usually cultivated on the kinds of marginal lands tilled by the poorest farmers. For example, Thailand, now the world's largest exporter of cassava, grows much of it in its semiarid northeastern region.

From a variety of viewpoints, cassava appears to be an attractive crop. Grown in poor soils under harsh weather conditions, cassava needs little tending and is also resistant to diseases and insects. In addition, for relatively low production costs, it yields two-thirds more calories per unit of land than the major foodgrains, though the protein content is lower. Even so, as an inexpensive source of human energy, cassava can and does make a notable contribution. Yet, despite these favorable factors and the precarious subsistence of the poor, cassava has received less scientific attention than other crops. One wonders at cassava's virtual exclusion from development when this region already has many hungry millions, a mounting population, and dwindling scope for expanding the present farmland. Obviously, good gains in rice and wheat do not satisfy the needs of those with no access to these costlier cereals.

No one disputes that cassava is both a viable food staple and source of income for our impoverished farmers. But allow me to go a bit further into why there seem to be compelling reasons for developing high-yielding varieties of cassava or employing intensive methods in its cultivation. For one, Asia's land scarcity will worsen substantially by the turn of the century because of population growth, with 30 to 33% reductions in per capita land supply projected for most of the low- and middle-income countries. Meanwhile, current trends indicate that the ranks of the hungry in the Asia-Pacific region will increase in absolute terms over the next two decades, although the proportion of malnourished people in our populations may somewhat decline. Thailand and the Philippines dramatically increased cassava production during the 1970s, much of it by enlarging the cultivated areas, but their expansion rates are expected to slow down because of environmental consequences in Thailand and difficult geography and costs in the Philippines.

Clearly, land expansion is not the answer it once was for boosting production of cassava or other crops, and that applies to most other Asian countries as well. Yet the need for more food and low-input crops for the region's poor has never been greater and may well grow even more critical in the years ahead. One means of meeting this challenge is to find ways to make cassava more widely available as both a calorie source and income generator for Asia's poor farmers. We in the secretariat will be keenly interested in the outcome of your deliberations. For example, what cost-effective technologies could overcome these problems and what are their relationships to production, processing, and marketing? If cassava has not reached the limits of its potential, what are the research needs that must be met to enable the continued increase in productivity of this crop?

ESCAP's CGPRT Centre has been established at Bogor to stimulate cooperative regional research so that answers to these and other questions may be found. The Centro Internacional de Agricultura Tropical, or CIAT as it is widely known, has already achieved a well-deserved reputation for its innovative work in developing cassava. Here in Thailand, for instance, CIAT is assisting in the development of germplasm specifically suited to local conditions. I am indeed pleased that CIAT and our CGPRT Centre are already cooperating closely, and hope that our combined know-how will yield ever-increasing dividends in this field. I should also like to express our thanks to the Royal Thai Government for joining us in organizing this workshop and for its continuing generosity in sharing its expertise with other developing countries. I feel confident that this workshop will inject new vigor into the search for ways to develop cassava in Asia, and I wish you every success in your deliberations. Thank you very much."

Welcoming Address

His Excellency Mr. Borom Tanthien
Deputy Minister of Agriculture and Cooperatives of Thailand

"Your Excellency, distinguished participants, ladies and gentlemen:

It is a great honor to give my address to the inauguration of the Workshop on Cassava in Asia, its Potential and Research Development Needs here in Bangkok. First of all, let me, on behalf of the Royal Thai Government and Ministry of Agriculture and Cooperatives, welcome you to Thailand. I hope you will find your stay here pleasant and comfortable, and please enjoy our Thai hospitality.

Thailand, like most developing countries in this region, relies heavily on agriculture. The agricultural sector contributes more than 20% of the National Gross Domestic Product (GDP). This sector is a major source of food supply to feed our population and also the most important foreign exchange earner.

Cassava is one of the most important crops of Thailand both in terms of national economy and social aspects. Firstly, the major cassava production areas are located in the northeastern and eastern regions of the Kingdom. The northeastern region in particular, is classified as the most depressed area of the country. The per capita income in 1982 was the lowest, only US$123 (2831 Baht), whereas the national average was US$233.

Secondly, Thailand is the second largest cassava producing country in the world next to Brazil. In 1982 Brazil's annual production was 25.1 million tons and Thailand was 16.7 million tons; 13.6 and 13.3 million tons for Indonesia and Zaire respectively. Over 90% of Thailand's production was for export and the balance for domestic use, unlike the other cassava producing countries where production was solely for domestic consumption.

Therefore, the cassava produced in Thailand depends heavily on foreign markets and any market change will directly affect the national economy. I wish to emphasize that over 80% of our cassava exports went to the EEC market alone in the form of cassava pellets, and the balance went to Japan and U.S.A. The reliance on a single market has created serious marketing problems, especially when the EEC imposed a quota system to reduce the quantity of imports from Thailand in 1982.

Owing to this special feature, the government of Thailand has launched a massive rural development scheme to uplift the socioeconomic conditions of the rural poor. The major strategies are to improve production efficiency, to promote rotation cropping or crop replacement, and finally, to investigate an alternative use of cassava.

To improve production efficiency, the government has recently introduced a new variety called Rayong 3 to replace the previous Rayong 1. This new variety has proved to give a better yield and better agronomic characteristics.

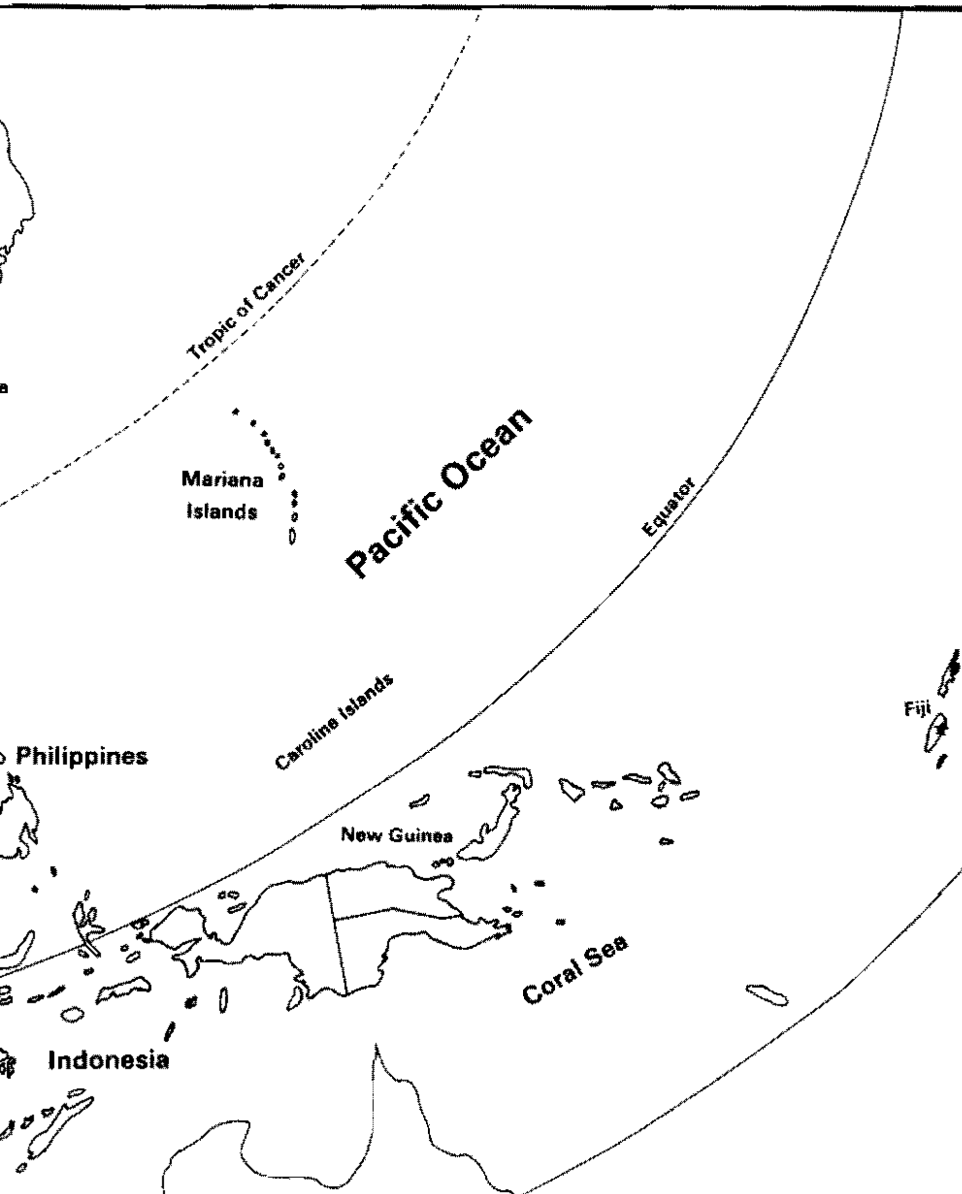
To resolve the marketing problem, the investigation of alternative uses is being carried out by the Thailand Institute of Scientific and Technological Research. The effort is gearing the way for the ultimate development of gasohol industry and high protein yeast extraction.

One of the major objectives of this workshop, I understand, is to exchange views and information among the world's major cassava producing countries, to find ways and means to increase production efficiency, as well as to reduce production cost. To improve productivity per unit area is also a successful way to boost production. These are in line with the government policy in the improvement of the socioeconomic conditions of the rural poor.

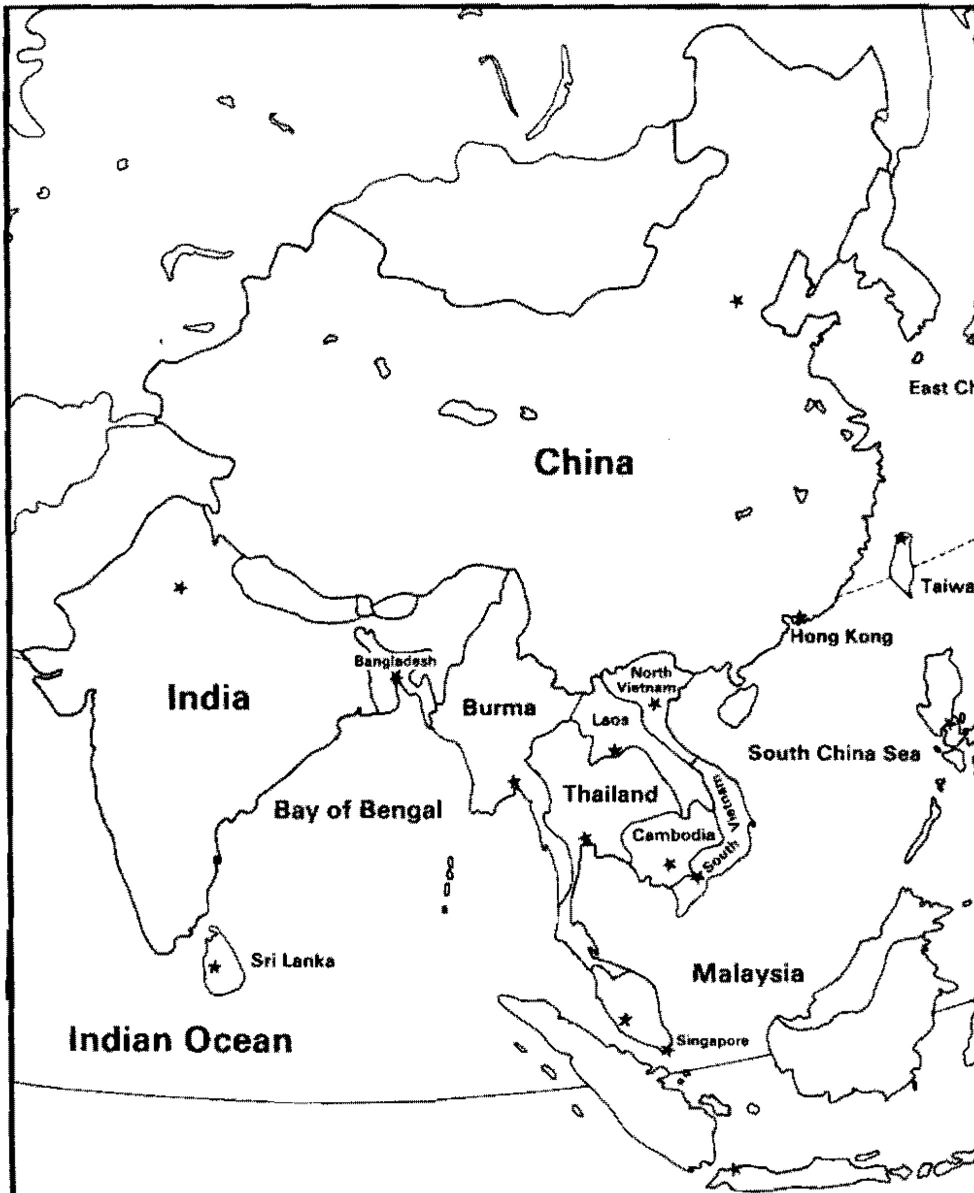
The development needs in farm diversification, improvement of production efficiency, and alternative uses of cassava require close collaboration and exchanges of know-how and experiences among countries concerned. This initiative is very important and essential for the well-being of farmers in the region. The collective effort will help to remove the trade protectionism which is usually created by the strong economic countries for their own benefit. This cooperation will be a good starting point for us in the region to form this collective effort. I hope in the future such regional cooperation will also extend to other crops.

May I wish you all a successful meeting. Thank you."

II. Cassava's Market Potential in Tropical Asia



ndicate the capital city of each country.



Map of tropical Asian countries. Sta

Trends in the Production and Use of Cassava and Other Selected Food Crops in Tropical Asia

J.S. Sarma
L.A. Paulino

Introduction

This paper examines the trends in the production and use of root and tuber crops and food grains in tropical Asia. For purposes of this workshop, it would have been desirable to limit the paper to upland crops; however, the available statistics on production and area are aggregates from both upland and lowland areas, and so the trends presented in this paper are not separated by climate.

The root and tuber crops discussed here include potatoes, sweet potatoes, cassava, yams, and other root crops. Production data are in terms of fresh roots. Food grains include rice (unmilled, or paddy rice), wheat, maize, sorghum, millets, other cereals, and pulses.

By definition, tropical Asia covers all Asian countries between the Tropic of Cancer and the Tropic of Capricorn. Several countries lie partly within this band and thus are partly temperate and partly tropical. Production and area trends presented here relate to entire countries, including their temperate zones. The analysis covers Bangladesh, Burma, China, Hong Kong and Singapore, India, Indochina (comprising Laos, and Vietnam), Indonesia, Malaysia, the Pacific Islands (comprising Fiji and Papua New Guinea),* the Philippines, Sri Lanka, and Thailand. The data for China are presented separately (unless otherwise indicated) because information on this country's agricultural economy is still relatively sparse, and the reconstructed and revised estimates available probably do not give a complete picture.

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* Fiji and Papua New Guinea have been included in the study although they belong geographically to Oceania.

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The source of data on harvested area, production, domestic utilization, and trade of the crops used in this paper is the Food and Agriculture Organization (FAO) data base comprising the supply utilization accounts and the production yearbooks. In several cases FAO data differ from those based on national sources, and the differences in some cases are quite large. Since this analysis is a comparative study at the regional level, the consistent set of FAO time series is used. It should be noted that the reliability of data on roots and tubers, including cassava, is less than that of food grains in some countries. It is also possible that improvements in the methodology effected in some countries might have introduced non-comparability over time.

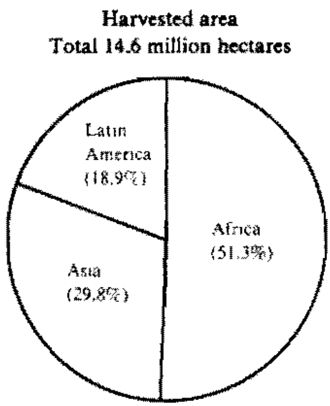
Global Perspective, 1982

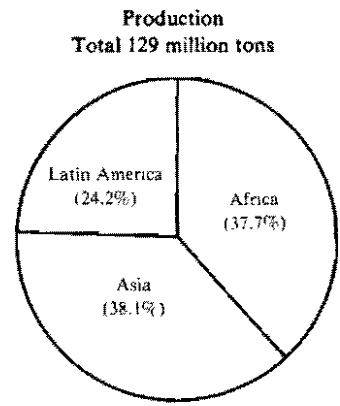
Cassava

In 1982 the world's cassava production, all of which came from developing countries, was estimated at 129 million tons, or a caloric equivalent of 39 million tons of wheat. About three-fourths of this production was shared almost equally between Asia and Africa; Latin America contributed the remaining one-fourth. More than half of the total cassava area of 14.6 million hectares was in sub-Saharan Africa, but the average yield in this region was much lower than in Asia and Latin America. Productivity in both Asia and Latin America was about 11 tons/ha compared to only 6.5 tons/ha in sub-Saharan Africa. Tropical Asia (including China) represented about 38% of the total production and 30% of the total area of world cassava (Figure 1). The region accounts for practically all of the cassava production of Asia.

Roots and tubers

Table 1 shows that the world production of fresh roots and tubers as a group in 1982 totaled 550 million tons, about 63% of which came from developing countries. Nearly all of the production from developed countries was potatoes, but that from developing countries consisted of about 37% cassava, 33% sweet potatoes, 20% potatoes, and 10% other roots and tubers. The developing countries accounted for more than 70% of the 47 million hectares of world harvest of these crops, but their average yield (10 tons/ha) was low compared to about 16 tons/ha in the developed countries. Among the developing regions, root and tuber yields were highest in Asia (12.6 tons/ha) and lowest in sub-Saharan Africa (6.6 tons/ha). Tropical Asia (including China) accounted for about 37% of the production and slightly over a thirdof the world's area in roots and tubers in 1982; these are 1% less than the shares of world production and area in all of Asia.





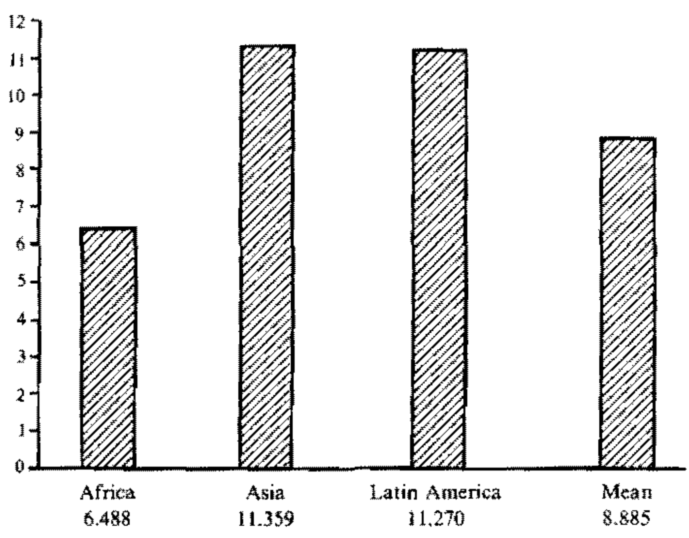


Figure 1. *World cassava area, production, and yield, 1982.*
Source: FAO *Production yearbook, 1982.*

Table 1. **World production and area of root and tuber crops and food grains by region, 1982.**

Country group*	Roots and tubers				Food grains			
	Production		Area		Production		Area	
	(million tons)	(%)	(million ha)	(%)	(million tons)	(%)	(million ha)	(%)
Developed countries	206.8	37.4	13.3	28.0	885.0	50.7	324.1	40.6
Developing countries	345.6	62.6	34.2	72.0	859.4	49.3	474.5	59.4
Asia	208.5	37.7	16.6	34.9	632.9	36.3	300.2	37.6
North Africa/ Middle East	8.0	1.5	0.7	1.4	66.2	3.8	49.2	6.2
Sub-Saharan Africa	82.8	15.0	12.6	26.5	47.1	2.7	61.0	7.6
Latin America	46.3	8.4	4.3	9.2	113.2	6.5	64.1	8.0
World	552.4	100.0	47.5	100.0	1,744.4	100.0	798.6	100.0

* Following the FAO economic classification of world countries and the IFPRI regional grouping of developing countries.

Sources: Basic data are from the FAO *Production yearbook, 1982*. The estimates for China are from the data set assembled by Bruce Stone of IFPRI.

Food grains

World food grain production in 1982 was 97% cereals and 3% pulses. Total food grain output in that year, amounting to 1744 million tons, was about equally shared between the developed countries, 51%, and developing countries, 49%. (The relative share of developing countries may be a little overstated because rice, which is mostly grown in these countries, is expressed in paddy terms.) This output came from 800 million hectares, 60% of which was in the developing countries. Average yields calculated from these figures are 1.8 tons/ha for developing countries compared to 2.7 tons/ha for developed economies. Food grain production in the developed countries was almost wholly (99%) cereals, while about 4% of production in the developing countries was pulses. Asia, which accounted for about 36-37% of both production and area of the world's food grains, recorded a yield of 2.1 tons/ha. Tropical Asia (including China) contributed a third of the world's food grain production in 1982, or about 94% of the food grain output of Asia as a whole.

The Regional View, 1982

Cassava

Cassava production in tropical Asia was nearly 46 million tons in 1982, a little less than half of which was produced in Thailand. Indonesia (12.8 million tons) and India (5.6 million tons) were the other two major producers of cassava in tropical Asia (Table 2). Average yield of cassava was high in India at 18 tons/ha, followed by Thailand's 14 tons/ha; in Indonesia it was less than 10 tons/ha.

Roots and tubers

The harvested area under root and tuber crops as a group was about 6.4 million hectares, of which cassava accounted for a little more than 60%. A total of 67 million tons of roots and tubers was produced in tropical Asia during 1982. Thailand, India, and Indonesia were the major root and tuber crop producers, and shared 80% of the total output.

Food grains

Based on 1982 data, tropical Asia produced nearly 275 million tons of food grains, a little over half of which came from India. Paddy rice was the most important grain, constituting two-thirds of the output. Coarse grains comprising maize, sorghum, and millets contributed 38 million tons or 14% to the total. About 46% of the 185 million hectares of food grains was devoted to rice, with an average yield of a little more than 2 tons/ha. The

Table 2. **Area and production of cassava, roots and tubers, and food grains in tropical Asia, 1982.**

Country	Area (000 ha)			Production (000 t)		
	Cassava	Roots & tubers	Food grains	Cassava	Roots & tubers	Food grains
Bangladesh	0	172	11382	0	1775	22233
Burma	5	24	5996	50	186	14871
Hong Kong & Singapore	0	1	0	0	5	0
India	310	1235	126590	5567	16767	145252
Indochina	512	1013	8809	2887	5311	17301
Indonesia	1300	1655	12353	12800	15375	38219
Malaysia	35	58	730	375	553	2072
Pacific Islands	17	182	20	193	1282	30
Philippines	200	483	6872	2300	3576	11878
Sri Lanka	51	70	907	500	679	2214
Thailand	1500	1540	11596	21000	21363	21077
Tropical Asia (excluding China)	3930	6433	185255	45672	66872	275147
China	380	9743	95618	3300	136700	317715
Tropical Asia (including China)	4310	16176	280873	48972	203572	592862

Note: Parts may not add to totals due to rounding.

Source: FAO *Production yearbook, 1982.*

area under coarse grains was 29 million hectares yielding an average of about 1.3 tons/ha. Wheat was the other important cereal but was grown exclusively in the temperate regions (mostly India) with a total output of 39 million tons.

Production Trends*

Cassava

Between the period 1961-65 and the period 1976-80, the production of cassava in tropical Asia more than doubled, reaching an annual average of 38 million tons during the later period (Table 3). Two countries contributed three-fourths to the increase in production: Thailand (56%) and India (20%). Indonesia's share in the production of the region declined sharply from two-thirds in 1961-65, to about one-third in 1976-80. This was due to a meager .5% annual growth in cassava production over this period. By contrast, Thailand's rapid growth in output improved its share from one-tenth to one-third. India and Indochina together accounted for a quarter of the region's cassava production in the late 1970s.

Assessing the growth rate trends from 1961-1980 (Table 4), cassava production expanded at an annual rate slightly less than 5% — a little more than half due to area expansion. Cassava yields increased at 2.2% per annum.

Looking at the data from 1961-1980 by decade, Table 5 shows that growth in area and production in tropical Asia was much higher in the 1970s than in the 1960s. Growth in area went from .69% per annum in the first decade to 5.64% in the second decade. Production growth went from 2.3% per annum in the 1960s to 8.2% in the 1970s.

Growth rates showed considerable variation among the countries in the region. The most rapid production increase was in Thailand, which nearly tripled its production growth rate from the 1960s to the 1970s, largely due to corresponding area increases. This production expansion was in response to the export demand from the EEC, and resulted in cassava cultivation being extended into areas with poorer soils. Consequently, average yields in Thailand essentially remained stagnant. The lack of increased yields may also be partly due to a need for technological improvements.

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* The analysis of trends is generally based on the quinquennial averages for 1961-65 and 1976-80, the average growth rate being calculated as a compound growth rate between the mid-years of the two periods. However, as indicated in some cases, especially for cassava, growth rates from semi-logarithmic equations for the periods 1961-80, 1961-70, and 1971-80 are used.

Table 3. **Average annual area, production, and yield of cassava in tropical Asia, 1961-65 and 1976-80.**

Country	1961-65 Area (000 ha)	1961-65 Production (000 t)	1961-65 Yield (t/ha)	1976-80 Area (000 ha)	1976-80 Production (000 t)	1976-80 Yield (t/ha)
Burma	1	5	10.675	2	22	9.117
Hong Kong & Singapore	0	0	0	neg.	1	n.a.
India	254	2295	9.036	374	6412	17.167
Indochina	155	1147	7.400	409	3332	8.147
Indonesia	1572	11833	7.529	1386	12662	9.138
Malaysia	23	218	9.478	38	387	10.214
Pacific Islands	13	137	10.538	16	182	11.375
Philippines	90	562	6.246	176	1759	9.975
Sri Lanka	44	328	7.465	86	591	6.873
Thailand	113	1789	15.808	971	13102	13.491
Tropical Asia	2264	18316	8.090	3459	38452	11.118

Note: Parts may not add to totals due to rounding.

n.a. = not available.

Source: FAO *Production yearbook tapes, 1975, 1979, and 1980.*

Table 4. **Annual growth rates (%) in area, production, and yield of cassava in tropical Asia, 1961-80.**

Country	Area	Production	Yield
Burma	11.36	10.24	-1.00
India	2.51	7.22	4.59
Indochina	6.06	6.85	0.74
Indonesia	-0.71	0.61	1.33
Malaysia	2.87	4.06	1.16
Pacific Islands	1.55	1.94	0.39
Philippines	4.27	7.21	2.82
Sri Lanka	4.71	4.43	-0.27
Thailand	15.34	13.94	-1.22
Tropical Asia	2.66	4.94	2.22

Source: FAO *Production yearbook tapes, 1975, 1979, and 1980.*

Table 5. **Annual growth rates (%) in area, production, and yield of cassava in tropical Asia, 1961-70 and 1971-80.**

	Area		Production		Yield	
Country	1961-70	1971-80	1961-70	1971-80	1961-70	1971-80
Burma	15.77	7.44	15.74	6.00	-0.003	-1.36
India	4.17	0.52	13.53	1.39	8.99	0.87
Indochina	-1.42	18.89	-1.90	20.82	-0.49	1.62
Indonesia	-0.59	-0.42	-0.93	2.23	-0.34	2.66
Malaysia	4.93	6.66	4.44	4.94	-0.47	-1.61
Pacific Islands	1.67	1.62	1.88	1.62	0.21	0
Philippines	-1.05	11.70	-2.16	23.41	-1.12	10.48
Sri Lanka	7.58	-4.03	2.93	3.59	-4.32	7.94
Thailand	7.87	18.76	6.95	18.89	-0.85	0.11
Tropical Asia	0.69	5.64	2.32	8.16	1.62	2.39

Source: FAO *Production yearbook tapes, 1975, 1979, and 1980.*

Both India and the Philippines recorded impressive production increases. In India the rapid increases occurred in the 1960s rather than the 1970s and were due more to increased yields, which contributed two-thirds to the production, than to increased area. In the Philippines, the rapid production growth occurred in the 1970s, when the growth rates for area and yield both exceeded 10%.

The yields in Indonesia during 1971-80 rose at an average rate of 2.7% per annum, compared to a slight decline in1961-70. This growth in yield more than compensated for the decline in cassava area in the 1970s, as evidenced by the annual 2.2% growth in production.

Both area and production of cassava declined in Indochina in the first decade, and then underwent very rapid growth between 19-21% in the second decade. It is probable that data problems contributed to these exceedingly high figures.

Roots and tubers

The production of roots and tubers (which include cassava, potatoes, sweet potatoes, yams, and other roots) totaled 58 million tons annually during 1976-80 (Table 6), with cassava accounting for nearly two-thirds of this amount. The average output of potatoes and sweet potatoes was 10 and 8.5 million tons, respectively; together, they shared 32% of the root and tuber crop output. The major root and tuber producers during 1976-80 were India (16.2 million tons), Indonesia (15.4 million tons), and Thailand (13.4 million tons). These three countries accounted for 78% of the region's output. Nearly half of India's root and tuber crop production was potatoes, followed by cassava, which accounted for a little less than 40% of production. Cassava made up about 97% of the roots and tubers in Thailand. It is the major root crop in Indonesia (82%); sweet potatoes account for almost all the rest of root and tuber production there.

Table 6. **Average annual area and production of roots and tubers in tropical Asia, 1961-65 and 1976-80.**

Country	1961-65 Area (000 ha)	1961-65 Production (000 t)	1976-80 Area (000 ha)	1976-80 Production (000 t)
Bangladesh	100	786	164	1656
Burma	20	65	18	92
Hong Kong & Singapore	9	56	1	6
India	797	6225	1286	16241
Indochina	397	2388	827	5864
Indonesia	2227	23061	1776	15380
Malaysia	50	379	60	528
Pacific Islands	132	927	173	1217
Philippines	271	1469	456	2946
Sri Lanka	58	389	115	772
Thailand	140	1980	1007	13445
Tropical Asia	4201	37724	5881	58146

Source: FAO *Production yearbook tapes, 1975, 1979, and 1980.*

The production of these commodities as a group increased at an annual rate exceeding 2.9% between the early 1960s and late 1970s. Thailand experienced the highest growth in production, reaching a phenomenal 13.6% increase due mainly to the growth of cassava. India and Indochina recorded production growth rates exceeding 6% per annum. Potato production in India increased at 7% per annum.

The average annual harvested area under roots and tubers in tropical Asia was 5.9 million hectares during 1976-80, yielding a per hectare output of less than 10 tons. Nearly 70% of this area is shared by Indonesia, India, and Thailand. Average output per hectare in both Thailand and India was around 13 tons/ha, while that in Indonesia was less than 9 tons. The Philippines and Indochina also have significant areas under roots and tubers.

Growth of area under roots and tubers in the region between 1961-65 and 1976-80 was only 2.2% a year as compared to a 2.9% production growth. This suggests an improvement in yield of approximately 0.7% per annum, or less than a ton per hectare in absolute terms. Apart from Thailand, rapid growth in the area under roots and tubers was experienced by Indochina (5.0%) and Sri Lanka (4.7%). The Philippines, India, and Bangladesh exhibited growth rates ranging between 3.0% and 3.5% per annum.

Thailand and Indonesia recorded a decline in the overall yield of root and tuber crops between 1961-1980. On the other hand, India showed a remarkable improvement of about 60% (from 7.8 to 12.6 tons/ha), largely due to an increase in potato yields. Crop yields were stagnant in the Pacific Islands and Sri Lanka, but Bangladesh, Burma, Indochina, Malaysia, and the Philippines recorded yield improvements varying between 1 and 2 tons/ha.

Food grains

Total food grain production in tropical Asia, which averaged nearly 254 million tons a year during 1976-80 (Table 7), was composed of about 66% paddy rice, 13% wheat, 16% other cereals, and 5% pulses. As may be expected, India accounts for the largest portion (58%) of total production; Indonesia, Bangladesh, and Thailand have relatively lower production but are nevertheless significant producers. Paddy is widely grown, principally under irrigated conditions, and represents 80% or more of the national production in six countries of the region. Maize, like rice, is also widely grown, but here again India produces 40% of the output. Minor cereals including sorghum and millets, which together form 9% of food grain

Table 7. **Average annual production of food grains (000 t) in tropical Asia, 1961-65 and 1976-80.**

	1961-65			1976-80		
	Paddy	Wheat	Total food grains	Paddy	Wheat	Total food grains
Bangladesh	15,048	37	15,348	19,211	504	20,009
Burma	7,786	38	8,168	10,609	68	11,125
Hong Kong and Singapore	19		19			
India	52,733	11,191	99,382	73,866	31,335	146,433
Indochina	12,699		13,301	12,961		13,703
Indonesia	12,396		15,387	25,478		29,183
Malaysia	1,154		1,163	1,924		1,943
Pacific Islands	21		38	26		59
Philippines	3,957		5,264	7,043		10,045
Sri Lanka	967		1,002	1,824		1,886
Thailand	11,267		12,430	16,055		19,270
Tropical Asia	118,047	11,266	171,502	168,998	31,907	253,654

Source: FAO *Production yearbook tapes, 1975, 1979, and 1980.*

production in tropical Asia, are relatively important only in India. Most of the region's pulses are produced in India where the crop provides a major source of protein in the diet.

Wheat exhibited the fastest production growth, exceeding 7% annually during the 20 years ending in 1980 (Table 8). Very rapid increases in wheat production were achieved in Bangladesh and northern India. Maize production in the region expanded at a fairly rapid rate of nearly 3%. Rice, the major crop of tropical Asia, showed a slower yearly growth in total production of 2.5%, although individual production growth rates of 3.8% or more were recorded in Indonesia, Sri Lanka, the Philippines, and Malaysia.

The average annual production growth of food grains as a group in tropical Asia was 2.7%. Average annual production growth rates of 4% or more during 1961-80 were achieved in Indonesia, the Philippines, and Sri Lanka, while rates of 3-4% were recorded in Malaysia and Thailand. Yearly increases in food grain production between 2-3% occurred in Burma, India, and the Pacific Islands.

Of the 82 million ton increase in tropical Asia's food grain production between 1961-65 and 1976-80, paddy accounted for over 60%. Wheat

Table 8. **Annual growth rates (%) in area and production of food grains in tropical Asia, 1961-80.**

	Area			Production		
	Paddy	Wheat	Food grains	Paddy	Wheat	Food grains
Bangladesh	0.81	9.39	0.91	1.66	*	1.79
Burma	0.27	2.14	0.41	2.20	3.99	2.19
Hong Kong and Singapore	**		**	**		**
India	0.70	3.34	0.50	2.32	7.27	2.63
Indochina	-0.57		-0.42	0.14		0.20
Indonesia	1.40		0.99	4.98		4.41
Malaysia	1.96		1.96	3.80		3.80
Pacific Islands	0.90		2.53	1.24		2.97
Philippines	0.68		1.83	3.81		4.31
Sri Lanka	2.95		3.10	3.99		4.00
Thailand	1.43		2.36	2.34		3.08
Tropical Asia	0.72	3.38	0.71	2.45	7.32	2.66

* More than 10 percent.

** Less than -10 percent.

Source: FAO *Production yearbook tapes, 1975, 1979, and 1980.*

represented almost 25% of the total increase, although its relative share of production in the late 1970s was only 13%. In the case of the other food grain items, the relative contributions to the increase in total production during the period were around 7% for maize, and about 6% for other cereals and pulses combined.

About three-fourths of the growth of food grain production in the region during 1961-80 could be attributed to increases in crop yields, and one-fourth to area expansion. The major contribution of crop yields to production growth was especially evident in paddy and wheat. Area expansion contributed more than the growth of crop yield in maize. Crop yield was the major source of growth of total food grain production in Burma, India, Indonesia, and the Philippines. Growth of food grain production in Thailand, Sri Lanka, and the Pacific Islands was due more to area expansion than to improvements in yield. In Bangladesh and Malaysia, the contributions of crop yield and area to increased production were nearly equal.

Maize, sorghum, and millets. These upland crops with potential use in animal feed are of special interest in relation to cassava. The average production of maize, which is widely grown in tropical Asia, increased from 10.1 million tons in the early 1960s to 15.9 million tons in the late 1970s (Table 9). India accounted for roughly 40% of the output during the later period, followed by Indonesia with 20%. The Philippines and Thailand were the other two major maize-growing countries with a share of 17-18% each. The rapid expansion of maize production in Thailand, at an average rate exceeding 8.5% (Table 10), was entirely due to area expansion. Like cassava, the yield of maize in Thailand declined as cultivation was extended to marginal lands. Similarly, the major contribution to production growth in India came from increases in area (79%), as maize yields rose by less than .5% per year over the 1961-80 period. The overall 3% average growth rate in maize production in tropical Asia (to which area expansion contributed about 60%) was generated by increased demand for animal feed in the region, except in India and Indonesia, and, in the particular case of Thailand, by the fast growth of maize exports.

Of the 12 million tons of sorghum produced annually in tropical Asia during 1976-80, 98% was produced in India (Table 9). Although small quantities of the crop also are grown in Sri Lanka, the Pacific Islands, Indochina, and Thailand, it was only in Thailand that average yearly output exceeded 220,000 tons during 1976-80. Sorghum production in tropical Asia increased at a slow 1.5% annual rate (Table 10). This was the

Table 9. **Average annual production of maize, sorghum, and millets (000 t) in tropical Asia, 1961-65 and 1976-80.**

	1961-65			1976-80		
	Maize	Sorghum	Millets	Maize	Sorghum	Millets
Bangladesh	4			2		
Burma	58		53	82		53
Hong Kong and Singapore						
India	4,593	8,848	7,728	6,102	11,629	9,539
Indochina	492			577	24	
Indonesia	2,804			3,390		
Malaysia	9			17		
Pacific Islands	1	1		5	5	
Philippines	1,273			2,950		
Sri Lanka	10	1	19	22	2	20
Thailand	816	47[a]		2,718	221	
Tropical Asia	10,060	8,897	7,800	15,865	11,881	9,612

a) Average of 1964 and 1965.

Source: FAO *Production yearbook tapes, 1975, 1979, and 1980.*

Table 10. **Annual growth rates (%) in area and production of maize, sorghum, and millets in tropical Asia, 1961-80.**

	Area			Production		
	Maize	Sorghum	Millets	Maize	Sorghum	Millets
Bangladesh	-5.68	0.02	-5.57	-5.46	-1.52	-4.63
Burma	-1.01	-	1.38	2.60		0.56
Hong Kong and Singapore						
India	1.45	-0.81	-0.28	1.85	1.53	1.33
Indochina	1.35	6.93[a]		0.78	7.07[a]	
Indonesia	-0.61			1.30		
Malaysia	2.10			3.95		
Pacific Islands	11.26	10.11		14.97	12.38	
Philippines	3.37			5.70		
Sri Lanka	5.31	3.02	2.37	5.90	8.28	0.72
Thailand	8.66	18.76[b]		8.57	12.30[b]	
Tropical Asia	1.82	-0.81	-0.26	3.12	1.53	1.32

a) Relates to 1971-80.
b) Relates to 1964-80.

Source: FAO *Production yearbook tapes, 1975, 1979, and 1980.*

same growth rate for India, which was the major producer. Although sorghum yield improved at 2.4% in India, the area under the crop declined over the period, particularly in the early 1960s.

In the case of millets, tropical Asia produced an annual average of 9.6 million tons in 1976-80, most of which was again produced in India (Table 9). Burma and Sri Lanka also grew small quantities of millets. As in the case of sorghum, the area under millets declined over the 1961-80 period, although at a slower rate (Table 10). The crop's production growth of 1.3% per annum was a little less than the growth of sorghum (1.5%).

China

Cassava. In China, cassava is grown primarily on the dryland slopes of Guangdong province and the Guangxi Zhuang autonomous region. Data collected by Bruce Stone of the International Food Policy Research Institute (IFPRI) indicate that in 1964 the cassava production did not exceed 1 million tons cultivated over an area of about 100,000 ha. The corresponding figure in 1980 is estimated at 3 million tons from an area of about 350,000 ha, which would imply an average yield of 8.6 tons/ha. (Stone feels that the FAO's estimate of 226,000 ha in 1980 is too low.)

Roots and tubers. Available data on roots and tubers in the People's Republic of China indicate an average annual production of 148 million tons during 1976-80, from a harvest area of 11.2 million hectares. This would suggest a yield per hectare of 13 tons, or about the average level mentioned earlier for tropical Asia. The annual production growth in 1961-80 averaged 3.1%, which could be attributed wholly to increases in yield, since the area under tuber crops in the country showed an average decline of about 0.4 % per annum.

Food grains. During 1976-80, Chinese food grain production averaged almost 270 million tons. About half of the total production was paddy and a fifth was maize. Millet and sorghum together represented only 5%; other grains, mostly wheat, made up the rest of the country's grain production. Assembled time-series data suggest that food grain production in China expanded at an average rate of over 4% per annum during the 1961-80 period, resulting in a near doubling of the production between 1961-65 and 1976-80. (The early 1960s were years of exceedingly low output levels in China; consequently, production growth measured from this initial period would tend to be somewhat exaggerated.) Increases in the production of paddy, the principal food grain in China, determined the rate of production growth. Between the early 1960s and the late 1970s, the production of maize doubled but growth of sorghum production was very slow and that of millet stagnant.

Trends in Utilization

Cassava

About a third of the annual production of 38 million tons of cassava in tropical Asia during 1976-80 was exported. Of the balance, nearly four-fifths was consumed as food, directly or in processed form. Feed use represented nearly 3%, with the remaining balance being equally divided into other uses and allowance for waste. Among the individual countries, about 96% of the average production of 13.1 million tons of cassava in Thailand during 1976-80 was exported (Table 11). This left only half a million tons for domestic use, which was utilized wholly for food. The FAO data do not show any domestic feed use of cassava in Thailand, Burma, Sri Lanka, or India (Table 12). Nearly 20% of the domestic supply is used as feed in Malaysia, but less than 10% is used in the other countries. Utilization data for Sri Lanka show a large 30% allowance for wastage.

Of the total food use of 20 million tons of cassava in the region, 40% was consumed in Indonesia, followed by 30% in India. Indochina countries and the Philippines consumed 22% of the total. Hong Kong and Singapore imported about 100,000 tons of cassava in the form of starch and tapioca pearl, of which a little less than 60% was reported to be locally consumed.

Table 11. **Average annual production, net trade, and domestic use of cassava (000 t) in tropical Asia, 1966-70 and 1976-80.**

Country	1966-70 Production	1966-70 Net trade[a]	1966-70 Domestic use	1976-80 Production	1976-80 Net trade[a]	1976-80 Domestic Use
Burma	11	-2	13	22	0	22
Hong Kong & Singapore	3	-44	47	1	-82	75
India	4356	0	4355	6412	0	6412
Indochina	1012	0	1012	3332	0	3332
Indonesia	10946	621	10323	12662	1042	11619
Malaysia	260	64	195	387	64	324
Pacific Islands	151	0	151	182	0	182
Philippines	473	-2	475	1759	-3	1762
Sri Lanka	371	-5	376	591	0	591
Thailand	2615	2370	284	13102	12553	542
Tropical Asia	20198	3002	17233	38451	13574	24863

a) Net trade = exports - imports.

Source: FAO *Supply utilization accounts tape, 1981.*

Table 12. **Distribution of total domestic use (%) of cassava in tropical Asia, 1966-70 and 1976-80.**

Country	1966-70				1976-80			
	Food	Feed	Waste	Other[a]	Food	Feed	Waste	Other[a]
Burma	92	0	8	0	90	0	10	0
Hong Kong & Singapore	25	6	2	67	68	5	2	25
India	93	0	7	0	93	0	7	0
Indochina	80	10	10	0	81	10	10	0
Indonesia	68	2	10	21	69	2	11	18
Malaysia	75	21	3	1	78	18	3	1
Pacific Islands	77	8	15	0	77	8	15	0
Philippines	81	6	0	12	90	6	0	4
Sri Lanka	70	0	30	0	70	0	30	0
Thailand	99	0	0	1	100	0	0	0
Tropical Asia	76	2	9	13	79	3	9	9

a) Includes planting materials and non-food uses.

Source: FAO *Supply utilization accounts tape, 1981.*

Domestic use of cassava in tropical Asia increased from 17 million tons in the early 1960s to 25 million tons in the late 1970s (Table 11), indicating an average growth rate of 3.7% a year. Relative to total production, the use of cassava directly as food declined from 65% during 1966-70 to 50% in 1976-80, as cassava exports increased from 15% to 35% over the same period. The domestic use of cassava for feed exhibited the most rapid growth of over 7%, nearly double that of the overall growth of total domestic utilization. Nearly half of the food use was in the form of roots, and the other half in the form of starch or tapioca pearl.

Most of cassava exports were in the form of dried cassava or pellets from Thailand and Indonesia. The average yearly exports of cassava flour, starch, and tapioca during 1976-80 totaled 630,000 tons of fresh root equivalent, mainly from Thailand and Malaysia; this represented a decline from the late 1960s, when the level of exports of these commodities was nearly 900,000 tons. During 1966-70 Indonesia exported 74,000 tons of cassava starch, but this dropped to 20,000 tons in the late 1970s.

Cassava imports by countries in tropical Asia increased about 100,000 tons over the referenced period (Table 13). Hong Kong and Singapore imported about 99,000 tons in the late 1970s, part of which was re-exported. Cassava imports by Hong Kong were in the form of tapioca while those by Singapore were starch. Indonesia also imported 62,000 tons of cassava, mainly in the form of starch.

Table 11 shows that the ratio of the total domestic utilization of cassava to its production in tropical Asia decreased from 85% in the early 1960s to 65% in the 1970s. This decline indicates that the ratio of net exports to total production rose from 15% to 35% during the period. Net exports as a percentage of total production in Indonesia increased marginally from 5.7% to 8.2%; in Malaysia, this proportion declines from 25% to 16%, indicating expanded domestic use of cassava in that country.

Roots and tubers

Of the average production of 58 million tons of roots and tubers in tropical Asia during 1976-80, 44 million tons, nearly three-fourths, was utilized domestically (Table 14). The balance of 14 million tons (largely cassava) represented net exports and changes in stocks. As indicated earlier, more than half of the region's consumption of roots and tubers was cassava, followed by potatoes with 24% and sweet potatoes with 18%. Other roots and tubers accounted for less than 3%.

The distribution of the domestic use of roots and tubers was 78% for food and 9% for seed and other uses (Table 15). Feed use of these commodities as a group was only 2%; about 10% was reported as waste.

Table 13. **Average annual exports and imports of cassava (000 t) in tropical Asia, 1966-70 and 1976-80.**

Country	1966-70		1976-80	
	Exports	Imports	Exports	Imports
Burma	-	2	-	-
Hong Kong & Singapore	3	47	17	99
India	neg.	-	neg.	-
Indochina	-	neg.	-	-
Indonesia	621	-	1104	62
Malaysia	69	5	66	2
Pacific Islands	-	-	-	-
Philippines	4	6	neg.	3
Sri Lanka	-	5	-	neg.
Thailand	2370	-	12553	neg.
Tropical Asia	3067	65	13740	166

Note: Figures of exports and imports refer to cassava flour, tapioca, starch, and dried cassava converted into fresh roots.

Source: FAO *Supply utilization accounts tape, 1981.*

Table 14. **Average annual domestic use of roots and tubers and food grains (000 t) in tropical Asia, 1966-70 and 1976-80.**

	1966-70		1976-80	
	Roots & tubers	Food grains	Roots & tubers	Food grains
Bangladesh	1,459	18,117	980	21,896
Burma	59	7,379	93	10,191
Hong Kong and Singapore	159	1,281	228	1,770
India	10,108	112,207	16,665	146,422
Indochina	2,239	14,451	5,862	15,241
Indonesia	13,813	20,258	14,308	31,510
Malaysia	273	2,364	408	3,490
Pacific Islands	1,009	145	1,236	237
Philippines	1,334	6,879	2,953	10,658
Sri Lanka	482	2,193	774	2,741
Thailand	548	11,520	886	14,747
Tropical Asia	31,483	196,854	44,393	258,903

Source: FAO *Supply utilization accounts tape, 1981.*

Table 15. **Distribution of total domestic use (%) of roots and tubers in tropical Asia, 1966-70 and 1976-80.**

Country	1966-70				1976-80			
	Food	Feed	Waste	Other	Food	Feed	Waste	Other
Bangladesh	80	0	10	10	78	0	15	6
Burma	81	0	10	10	82	0	10	8
Hong Kong and Singapore	47	21	4	27	60	20	4	16
India	83	0	11	7	81	0	11	8
Indochina	74	9	10	7	76	9	9	6
Indonesia	74	1	9	16	73	2	10	15
Malaysia	71	22	5	2	75	20	4	1
Pacific Islands	81	2	17	0	81	2	17	0
Philippines	85	5	3	6	89	5	2	3
Sri Lanka	71	0	28	1	70	0	29	1
Thailand	95	0	5	1	96	0	4	0
Tropical Asia	78	2	10	10	78	2	10	9

Note: Parts may not add to totals due to rounding.

Source: FAO *Supply utilization accounts tape, 1981.*

As Table 14 shows, the two single largest consumers of root and tuber crops in tropical Asia are India (38%) and Indonesia (32%). Data for the 1976-80 period indicate that 81% of the total consumption of these commodities in India was for food, while in Indonesia this percentage was 73% (Table 15). In the Philippines 89% of the total domestic consumption of roots and tubers was for food. Potatoes composed half of the root and tuber consumption in India, and in Indonesia cassava was the main root and tuber crop consumed. Cassava accounted for 60% of the domestic use of roots and tubers in the Phillipines.

Between 1966-70 and 1976-80, domestic use of roots and tubers in tropical Asia increased at 3.5% per annum, a slightly lower rate than that for cassava. Potato consumption showed the most rapid growth at an average rate of 7.2%, while sweet potatoes exhibited a very slow growth rate of less than 1% per annum. The growth rate of feed use at 6.2% per annum was much higher than that of food use, which expanded at a rate of 3.6% per annum.

The annual increase in the consumption of roots and tubers was about 5% for India, roughly half of the rapid increase of 10% found in Indochina. Consistent with the slow growth in the production of roots and tubers in Indonesia, consumption growth was also stagnant in this country between the late 1960s and 1970s. Domestic consumption of potatoes doubled in India over this period. In the Philippines, the rapid growth in the consumption of total roots and tubers, more than 8% per annum between 1966-70 and 1976-80, was largely due to cassava. The only decrease in consumption during this period was in Bangladesh, where the domestic use dropped from 15 million tons to 10 million tons, an average annual decline of about 4%.

Food grains

Paddy, wheat, and maize are the principal components of food grain consumption in tropical Asia. Paddy, the main staple food of the region, represents the bulk of consumption in most of these countries, especially in Bangladesh, Burma, and Thailand. A significant portion of wheat consumption in tropical Asia is imported and supplements the amount produced in Bangladesh, Burma, and India, which are partly in the temperate zone . Maize, which is consumed in the region both directly for food and as animal feed, represents a significant portion of the domestic utilization of food grains in Hong Kong, the Philippines, Singapore, and Taiwan.

The average annual consumption of food grains in tropical Asia rose from 197 million tons in the late 1960s to 259 million tons during the late 1970s, representing a growth rate of 2.8% a year between these periods. Growth of food grain consumption was particularly rapid in Indonesia, Malaysia, the Pacific Islands, and the Philippines, where average annual increases of 4% or more occurred from 1966-70 to 1976-80. Fairly rapid increases in domestic utilization exceeding 3% annually were achieved in Burma, Hong Kong, and Singapore. The slowest growth rate in food grain consumption was registered by the Indochina countries at only .5% per year. India, where total domestic use rose at 2.7% per year during this period, accounted for about 57% of the total food grain consumption in tropical Asia during the late 1970s (Table 14).

About 65% of the food grains in tropical Asia during 1976-80 was consumed directly as food, 9% was used for animal feed, and the remaining 26% went to other uses such as seed and waste allowance (Table 16). Feed use of grains was highest in Hong Kong and Singapore at 45%; it was also high at 27% in Malaysia, 16% in Thailand, and 15% in the Philippines. The proportion of grain used as feed was higher for maize and other non-rice cereals in all countries except India. In fact, the feed use of these grains was even higher than their food use in Hong Kong, Singapore, and Malaysia. The percentages of food and feed uses of maize and other non-rice cereals were almost equal in Thailand and the Pacific Islands. In all other non-rice countries, major utilization of these grains was as a food source.

Table 16. **Distribution of total domestic use (%) of food grains in tropical Asia, 1966-70 and 1976-80.**

	1966-70			1976-80		
	Food	Feed	Other[a]	Food	Feed	Other[a]
Bangladesh	60	7	33	62	7	31
Burma	62	7	31	62	8	30
Hong Kong and Singapore	58	32	10	49	45	6
India	68	8	24	68	8	24
Indochina	58	8	34	59	8	33
Indonesia	71	6	23	71	7	22
Malaysia	57	22	21	54	27	19
Pacific Islands	84	5	11	80	11	9
Philippines	64	13	23	63	15	22
Sri Lanka	76	4	20	74	5	21
Thailand	49	15	36	48	16	36
Tropical Asia	66	8	26	65	9	26

a) Includes seed, non-food use, and waste allowance.

Source. FAO *Supply utilization accounts tape, 1981.*

Between 1966-70 and 1976-80, feed use of all food grains taken collectively in tropical Asia increased at a rate half a percent higher than their direct use as food. Utilization of food grains for animal feed exceeded 5% per annum in Hong Kong, Singapore, Malaysia, the Philippines, and Indonesia. However, with respect to maize and other non-rice cereals, feed use rose twice as rapidly as food use. Their use for feed increased at a very rapid annual rate of 9% in Malaysia and 10% in Thailand; the Philippines also recorded a rapid increase of 6.5%.

China

The primary use of cassava in China appears to be for animal feed, especially in hog production. In some poor communes where cassava is grown, it is consumed by the population as a staple food. In addition, China also exports cassava to the EEC and there is evidence that these exports alone formed about a third of production in 1980.

Available consumption data for China suggest that of the average 230 million tons of food grains consumed each year during the 1977-80 period, 43% was paddy, nearly one-fourth was wheat, and about a third was accounted for by other food grains. Direct food use represented the bulk of the total domestic use of food grains in the country; about 10% went to feed and other uses including seed, waste, and non-food purposes.

Conclusions and Implications

Cassava production in tropical Asia increased rapidly during the last two decades, largely due to the rapid growth rate in Thailand in response to the import demand by the EEC for cassava as animal feed. More than half of this growth output was achieved through increases in area.

Prospects for cassava production in the immediate future are not encouraging; import demands for cassava by the EEC are expected to decline considerably as a result of the quota agreement between the Community and Thailand. The other major market for cassava is in direct human consumption, essentially in tropical developing countries. But the growth in direct food demand also appears to be slowing down; the income elasticity of demand for cassava in many developing countries is low, declining, and, in several of these countries, already negative. Furthermore, expansion of cassava starch utilization faces problems of competition from substitutes.

However, there is reason to believe that the long-run future of cassava can improve. With increases in per capita incomes, the demand for livestock products is growing at a rapid rate in Asia and other developing countries. Evidence suggests that the derived demand for livestock feed is expanding at an even faster rate, principally due to growth in poultry and hog production, where modern techniques have become more feed-intensive. Consequently, maize and sorghum imports into Asia for animal feed have increased rapidly in recent years. Provided prices are competitive, there may be a considerable potential for cassava (with supplements of soymeal or groundnut cake) as a substitute for maize and sorghum in the domestic manufacture of livestock feed in East and Southeast Asia. If this can be accomplished, the demand for cassava will expand significantly.

Since the crop is cultivated in poor soils where few other crops can be grown, stimulating cassava production will help to improve the socio-economic conditions of the population in these areas, as has been experienced in the northeastern parts of Thailand. However, urgent steps are necessary to find alternative demands for this crop in order to mitigate the hardship that will result from the expected decline in import demands by the EEC for Thai cassava products.

The cassava yields in several countries of tropical Asia are presently low. There is also a large untapped genetic potential which can be exploited to make cheaper calories available per hectare through the adoption of improved technology. Improvement in yields and a decline in unit costs and prices will have large nutritional and income implications for the vulnerable sections of the population for whom cassava is a major staple food.

Increases in the future demand for cassava as feed will, apart from relative prices, depend on the supply of maize and sorghum, which are the major food grains used for animal feed. As shown in this paper, the production of food grains as a group in tropical Asia has expanded at a fairly rapid average rate of 2.7% per annum during the past two decades; maize production in particular increased at an even faster rate of more than 3%, in response to rising feed demand. The production of sorghum increased at a relatively slower annual rate of 1.5%. Preliminary findings of an IFPRI study of the future food grain supply/demand situation in Asian countries (excluding China) suggest a deficit of food grains as a whole in the year 2000.

In light of these implications, there appears to be an urgent need for more in-depth studies leading to a research and development program aimed at improved yields and increased use of cassava in tropical Asia.

Acknowledgement

The authors would like to thank Darunee Kunchai for her assistance in the study.

Prospects for Cassava in the World Economy in the Year 2000

Delane E. Welsch

Introduction

The analysis of world cassava prospects presented here includes developing countries, as producers and consumers of cassava products, and developed countries, as consumers of raw materials derivable from cassava products. Prospects for cassava trade and suggested policy directions for producing countries are also included.

The style of the analysis is speculative. Papers in this workshop by Sarma and Paulino, Nelson, Lynam, and others present solid analyses of the past and present situations of cassava regionally and worldwide. Based upon an understanding gained from that work, some basic assumptions about the state of the world between now and the year 2000 are presented, followed by speculations on how economic forces will shape the cassava industry by that time.

Assumptions

Political

A basic assumption is that there will not be a world war nor a nuclear conflagration between now and 2000. There may be regional conflicts and civil wars, but these will not significantly affect world trade or energy supplies. Only a very small increase in real prices of energy is expected.

Of more direct relevance to cassava, it is assumed that the domestic and international political significance of the European Economic Community (EEC) is too great to come apart because of the Common Agricultural Policy (CAP). Therefore, the CAP will be modified in an evolutionary and consensual manner, until it reaches fiscal viability. The modified CAP will

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have essentially the same structure as now, but the levels of protection will be somewhat less, bringing internal grain prices down relative to, but still above, world grain prices. Cassava imports will be permitted at the 7-10 million ton level, or 15-20% of non-feed grain ingredients, which in turn will remain at about one-third of compound feed ingredients.

Trade barriers in general, both tariff and non-tariff, will remain at about the same levels and affect the same commodities in 2000 as they do now.

Scientific

Another assumption is that there will not be any major biotechnological or genetic engineering breakthroughs that radically alter the species and cultivars which the world's farmers now use. (This is probably the least realistic assumption of the lot.) Nor will there be any major scientific breakthroughs from conventional agricultural research systems. In other words, it is assumed that there will not be another green revolution in the next 16 years. This does not rule out a steady output of new technology in agriculture enabling a steady increase in agricultural productivity, if prices are conducive to adoption.

Demand

Income elasticities of demand for cassava in developing countries are, on the whole, low, declining, and in some cases, becoming negative. But within the specific subgroup of low-income people in cassava-producing countries, the income elasticity of demand for cassava is quite high. It is assumed that these elasticities will remain about the same to the year 2000.

The demand for livestock products is growing steadily worldwide. It is growing more rapidy in tropical developing countries, especially those without the potential for major increases in domestic maize production. The derived demand for livestock feed is growing more rapidly than the growth in demand for livestock products, because the growth in livestock production has triggered the generation and adoption of new technology, which is based on modern feeding practices that rely heavily on compound feeds. This is more prevalent in swine and poultry production, with beef production tending to remain mostly the culling of draft animals and grass-fed, slaughter animals. Dairy production, while expanding in the tropical developing countries, has a very low base from which to expand. It is assumed that these situations and trends will continue to 2000.

Resources

The final assumption is that no major new cassava areas will come into production during the next 16 years. This means no new major production expansions, such as occurred in Thailand in the 1970s.

Cassava in 2000

Africa

Sub-Saharan Africa currently plants more than one-half of the world's cassava area, but because of low yields it produces less than 40% of world output. Nigeria and Zaire are two of the largest cassava-producing countries in the world (the others are Thailand, Brazil, and Indonesia). There are conflicting views about the nature of production in Africa. Some call it mainly subsistence, with plantings in backyard gardens and consumption in the fresh form. But Lynam (1984) points out the extensive trade in processed cassava in Nigeria and Ghana, where it is an emerging staple food for low-income groups in urban areas.

The cassava industry in Africa will probably operate in 2000 pretty much as it operates today, namely, producing cheap food for low-income people. Production will expand substantially to meet demand from low-income rural and urban groups, both of which will grow rapidly during the next 16 years. Given the projected gap between food supplies and needs in Africa by 2000 (Paulino, 1984), cassava consumption is likely to expand to groups not now eating cassava but whose incomes are declining due to armed conflict, drought, and economic dislocation. There may be small amounts of starch production in those countries whose industrial sectors develop sufficiently to generate a demand for industrial starch. Production will be forthcoming by bringing more marginal lands under cultivation, by shortening the rotation in bush-fallow systems, and by substituting cassava for low-yielding cereal crops. There will be little or no increase in yield per hectare. There is little outlook other than a pessimistic one for the population, food, and political situations in Africa for the next 16 years.

Latin America

The Americas produce about one-quarter of the world's cassava output, with Brazil accounting for about 80% of that amount. Consumption is primarily by low-income groups, with moderate amounts going to livestock feed, starch, and alcohol production.

Alcohol production from cassava will probably not be important by the year 2000; in fact it will be surprising if any cassava-based alcohol plants are still in operation then. Sizable numbers of low-income people will continue to consume cassava as a staple. It is possible that production and consumption may spread to low-income groups in countries not now major cassava producers. The growth in use of cassava for livestock feed in Latin America is uncertain. If low-cost and effective drying technology can be developed, and if root prices can decline sufficiently to make cassava noticeably cheaper than imported feed grains, yet high enough to generate a production response, then it is conceivable that the livestock compound feed industry may be a strong growth factor in the Latin American cassava industry in the year 2000.

Asia and the Pacific

Thailand, Indonesia, and India dominate the cassava picture in Asia and the Pacific. The cassava industry is quite different in each of the three.

Thailand may be the world's largest cassava producer, accounting for one-half of the cassava produced in Asia, yet practically none is consumed directly as human food. It is by far the largest exporter in the world of cassava products for livestock feeds, yet practically none is fed to Thai domestic animals. Thailand exports about one-half of the world trade in cassava starch, and also uses a considerable amount of starch domestically.

Cassava is a staple food in Indonesia and has considerable potential in government food security strategies. Indonesia also exports some cassava for animal feed and produces considerable starch.

Cassava is mainly produced in two states in India. In Kerala, cassava is a staple food for large numbers of low-income people, whereas starch and tapioca pearl are the major end uses for cassava produced in the western part of Tamil Nadu.

China has entered the world cassava picture only recently. After small export volumes to the EEC in 1979, exports jumped to 300,000 tons each year from 1980-1982. The Philippines, with minor production for livestock feed, and Papua New Guinea are the other major participants in the Asian cassava industry.

What happens in Asia between now and 2000 depends a great deal on what happens in the EEC. The EEC appears to be attempting to steadily reduce the amount of cassava imports from Thailand, while encouraging cassava imports from other countries in the region. Examples of this are the encouragement to the Chinese to boost their exports from 300,000 tons to 1 million tons, and the lack of any specific attempt to reduce imports of other non-grain feed ingredients, such as corn gluten feed and citrus pulp from the U.S.A.

Further destabilizing the Thai cassava industry have been Thai government policies and procedures designed to ration the reduced EEC quotas among Thai exporters. Instead of collecting the economic rent resulting from the EEC quota and using it to benefit farmers or promote the industry, the Thai government has instead followed procedures which have pushed costs up without gain to anyone.

Possible scenarios

The prospects for cassava are considered under four alternative scenarios: (1) a complete halt to EEC cassava imports; (2) the requirement for cassava to pay the same import duty as maize on an equivalent energy basis; (3) the lifting of current restrictions on imports from Thailand; and (4) something in between (akin to the current situation).

In scenario (1), the price of fresh roots, chips, and pellets in Thailand would drop until production ceased or alternative uses cleared the market. If current prices (0.70 to 0.80 baht/kg for fresh roots)* bring forth about 6 million tons of pellet production per year, then as prices declined so would output until at about 0.35 baht/kg nearly all farmers would stop production. The price at which production ceases could be as low as 0.25 baht/kg; at a price of 0.40-0.50 baht/kg probably as much as 4 to 5 million tons of pellets would be forthcoming.

The implications of the supply curve just described are startling. First, it would make cassava fully competitive with maize as a livestock feed over the long run, and much cheaper than maize at current prices. Second, it would make cassava starch (unmodified) fully competitive with (and currently cheaper than) maize starch. Jones (1983) concludes that price competitiveness is the key to re-penetrating old markets that have shifted from cassava to maize (U.S.A.) and keeping new markets (the newly industrializing countries) from building their own maize starch plants. In summary, scenario (1) brings us to 2000 with an active cassava industry in Thailand: cassava in Thai livestock rations up to the nutritional limit, greatly expanded Thai cassava starch exports, and Thai compound livestock feed exports. The Philippines and Malaysia will have gone out of cassava production and will import their animal feed and starch needs from Thailand.

Scenario (2) will result in much the same end result as scenario (1), except at slightly higher prices, as the price of cassava relative to maize and protein supplements finds its equilibrium. D.J. Leuck (personal communication) estimates that the cassava pellet price in Europe, if brought under the variable levy system, would have to drop 52%, 43%, and 40% from 1980 averages to remain in dairy, broiler, and hog compound feed rations, respectively, at 1980 average levels. He calculates that a 40% decline in cassava pellet price would translate to fresh root prices in Thailand of 400

*US $1.00 = 23 baht.

baht/ton in nominal terms or 279 baht/ton in real (1980) prices, and doubts whether Thai production would be forthcoming at such low prices. My view is that substantial production would still be forthcoming at those prices. At the low prices implied by scenarios (1) and (2), Thailand would be either the only supplier or the major supplier, with Brazil perhaps contributing to exports to Europe.

Scenario (3) is as speculative as the first two. In it, EEC cassava use jumps quickly to the 8-10 million ton level and thereafter grows at the average rate of growth of compound feed use. Thailand would remain the major supplier, with China, Indonesia, and Brazil being substantial suppliers.

Scenario (4), the current situation, is actually more speculative than the first three. The actions of the EEC and the Thai government's response are very destabilizing for the Thai cassava industry. EEC actions of restricting Thai exports, while encouraging cassava exports from other countries, plus the 1985 expiration of current restrictions and no hint of policy in 1986 and beyond have added great uncertainty to the Thai industry. A further EEC-caused frustration has been the periodic EEC complaint about dust, and insistence on a Thai shift to hard pellets. However, with 8 million tons of hard pellet processing capacity now installed in Thailand, Europe is now willing to pay for only about 40% of Thai exports in hard pellet form and wants soft pellets for the remainder.

Thai policy is destabilizing because the effect of basing export quotas on stocks on hand on a certain date, and then issuing quotas for only about 20% of these stocks, is to push exporting costs sharply upward. Since Thai cassava export prices are a function of EEC internal prices of cassava substitutes (feed grains and other feed ingredients) and protein supplements (chiefly oilseed cakes), Thai exporters cannot pass these higher costs on to European consumers. Instead, the effect is to lower fresh root prices at the farm level. Thus, the potential economic rent resulting from imposition of quotas, which could have been captured by the Thai government, has instead been dissipated into higher cost. The effect on the system of a huge (80%) carryover of stocks from one exporting period to the next is as of yet unknown, but it is not likely to be beneficial.

The Thai-EEC relationship so clearly dominates the world trade in cassava for livestock feed and cassava starch that any prediction of the state and level of the world cassava industry is clearly dependent upon which of the alternative scenarios discussed (or other possible scenarios) prevails. It is difficult to predict, however, it is doubtful that scenario (1) will prevail. In the short run, Thai farmers would be better off with scenario (3). In the long run, the Thai economy would probably be better off with scenario (2), as a technically and economically efficient cassava industry would likely result (assuming the Thai government would not interfere in the industry in a detrimental way). This scenario would, however, probably eliminate cassava export possibilities in most other cassava-producing countries in the region. Scenario (4), the present situation, is undoubtedly the worst scenario that could prevail over the next 16 years.

Looking briefly at the other countries in the region, the cassava industry in the Kerala state of India is not likely to be affected much by whatever happens in the Thai-EEC situation. Cassava will continue to be an important part of the diet of poor people, and so the Indian government, through policies and programs affecting poor people, will have the greatest effect on the Kerala cassava industry. The Tamil Nadu cassava industry in India, on the other hand, is much more commercially oriented, and its form in 2000 will depend partially on the level of world cassava prices and partially on the Indian government's cassava import and export policy.

Malaysia has recently announced a policy of de-emphasis of cassava production and has started forcibly halting cassava production by squatters, which is a major source of production. If world cassava prices decline as in scenarios (1) and (2), then I would expect cassava production in Malaysia to practically disappear, and starch and animal feed needs to be imported from Thailand. If higher prices prevail, then some cassava production will ensue, but Malaysia will still be a net importer of cassava products in 2000.

I see much the same picture for the Philippines, except that the Philippines may have more land with very low opportunity costs and much less restrictions on land use than Malaysia. The Philippine government is also promoting the cassava industry, and more is being spent on research. If scenarios (1) or (2) prevail, then the resulting low world prices will pretty much drive cassava out. The Philippines, due to problems and costs of interland transport, will be able to import livestock feed from Thailand more cheaply than producing it domestically. This assertion ignores rural employment and foreign exchange considerations, which the Philippines may find important.

Speculation on cassava in China in 2000 is difficult, as there is not enough information. China clearly has the strength to do much in cassava production. Whether it does or not depends on many factors, including relative costs and how cassava export prices will be set.

Conclusions

The research policy implications of the foregoing speculations seem clear. Costs of production in any country in which the cassava industry is linked directly to the world economy will have to come down. In the Thai case, this means an approximately 30% (perhaps as high as 50%) reduction in production costs. Such a reduction will probably come about through a substantial increase in yields. Maintaining a low-input system is not necessarily a requirement of the industry. There is no doubt that the EEC currently drives the Thai cassava engine, but it is doubtful that this situation will continue to the year 2000.

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Cassava in the Agricultural Economy of Bangladesh

Kamal Uddin Ahmad

Introduction

In Bangladesh, cassava has historically been considered a vegetable under the name *shimul alu* (kapok potato). Cassava's nutritional, commercial, and other values, however, are either unknown or underestimated. Its total production is so low that it has yet to find a place in the annual official production figures of crops. Unofficial estimates put the production at about 5,000 tons/yr.

Cassava is grown in upland areas mainly by Garo tribal people and their nontribal neighbors, in the former districts of Mymensingh, Tangail, and Sylhet. It is used as a vegetable, often to go with *daal* (a pulse), but it is never used as a replacement for rice. Some voluntary organizations, including the Swedish Free Mission in Rajshahi and Kushtia, World Vision at Demra, Dhaka, RDRS in Rangpur, and NCCB in Barisal are said to have had some cassava projects (Fuller, 1980). In Rajanahi and Kushtia, cassava is used to a large extent in sericulture. It is also used as a fence around gardens where the roots are harvested once a year and young leaves are consumed as a protein-rich vegetable. Cassava is sometimes considered to be a type of 'hunger bank' for poor people as it is a source of carbohydrates during periods of food shortages.

History

After years of neglect by both researchers and extensionists, reports of cassava's successful development in other countries encouraged the Division of Horticulture of the Bangladesh Agricultural Research Institute (BARI) to review cassava's prospects. Cassava's advantages of being a backyard plant producing starchy roots that can be picked as needed

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during its 2-3 year (or more) life span (Ahmad, 1970), prompted an evaluation of cassava cultivars from Indonesia. The results of this evaluation showed that annual average yields of 22.5 tons/ha could be attained (Ahmad, 1974). Its use in home consumption as a vegetable served with fish curry and its potential for starch extraction also created some awareness of cassava's potential as a 'second-line' alternative food policy (Ahmad, 1973).

As the population continued to grow and chronic food shortages persisted, wheat, an imported food grain, was introduced to supplement rice, the locally produced food grain. With the rapid incorporation of wheat into the local diet, domestic wheat production was considered. Wheat was already being grown as a minor crop in the northwest region during the winter season with low-yielding varieties. The introduction of high-yielding varieties and the joint efforts of research and extension programs brought about a phenomenal increase in wheat production. The level rose from a mere 100,000 tons to more than 1 million tons from 1975 to 1983. Similarly, Irish potato production, which was only 200,000 tons in 1955, was boosted by the establishment of a Potato Research Centre, a seed importation and multiplication program, and various promotional activities, including cold storage facilities with a capacity of 250,000 tons by 1984. These activities raised potato production to nearly 1.2 million tons in 1984.

With the emergence of wheat and potatoes as the second and third most important staple food crops, cassava was nearly forgotten. Only a few efforts were continued by one or two private individuals and the Bangladesh Council of Scientific and Industrial Research.

Research and Development

Recent experiments by the Division of Horticulture, BARI, involving varietal trials with local and exotic material (Rashid, 1982 and 1983), were undertaken at BARI headquarters in Joydebpur and at the Bangladesh Agricultural University in Mymensingh. Cassava yields ranged between 22 and 25 tons/ha in 1982 and more than 30 tons in 1983. Some leading varieties/lines were local C012, C011, C004, and exotic Genjapati and Bogor. Postharvest analysis showed a range of hydrogen cyanide (HCN) content between 47 ana 291 mg/kg, with the local C004 having the lowest HCN content and Genjapati having the highest. Local varieties grown under local conditions appeared to have very low HCN contents (Fuller, 1980). Various characteristics among the different varieties had the following ranges:

Dry matter	36.7-41.7%
Ash	0.8-1.2%
Crude protein	0.5-1.4%
Starch	29.9-35.5%
Carotene	9-183 mg/100 g
Vitamin C	36-55 mg/100 g

Although some agronomical and propagational studies are being conducted, research of the kind and dimension that is usually needed for the development of a crop has not been carried out.

Prospects and Problems

In Bangladesh, root crops are treated more as vegetables than as staples. Cassava's main appeal then, lies in its use as a vegetable. Its richness in certain nutrients such as vitamin C and minerals, and its dry matter, calories, and fiber make it a good addition to fish curries and vegetable mixtures. A farmer who grows cassava on his homestead can feel secure about his vegetable supply during the leanest vegetable season of September-December (Table 1).

Among roots and tubers of the tropics (namely cassava, yam, sweet potato, white potato, and aroids), cassava has the highest caloric value (153 cal/100 g of edible portion) and the highest caloric yield (11.6 million cal/ha), although it ranks fourth in terms of million cal/ha/month (Booth, 1974). Although cassava has a high proportion of carbohydrates, calcium, and vitamin C per unit quantity, it is deficient in other vitamins and in protein. It is also highly perishable after harvest; the inability to store cassava presents serious problems in the marketing and utilization of the crop, resulting in extremely heavy but unrecorded losses (Booth, 1974).

Cassava historically has had limited importance in the Bangladesh diet, and it would probably be difficult to gain acceptance of it as a major staple food. It currently ranks sixth among carbohydrate staples, while maize is

Table 1. **Estimated availability of vegetables (000 t) in Bangladesh at different times of an average year.**

January	90	May	106	September	42
February	114	June	98	October	26
March	136	July	66	November	26
April	114	August	58	December	44
Total	454	Total	328	Total	138

Source: Ahmad, 1982.

gradually emerging as a food crop of major importance next to rice, wheat, white potatoes, and sweet potatoes.

The use of cassava as a major staple is not without precedent. It is mainly a backyard subsistence crop in Africa, consumed both in fresh and processed forms by low-income people. In Brazil, cassava is also a staple food, mainly among the poor, and it serves a similar purpose in Indonesia and in Kerala, India. India's attempt to produce cassava as food for the poor, by using relatively high-yielding varieties which depend upon intensive cultural practices, fertilizer use, and partial irrigation, may be worth emulating by Bangladesh, but not at the cost of other crops that would produce better yields in terms of cal/unit area/time.

The cattle and poultry situation in Bangladesh is one of the worst in the world, largely because of the dearth of animal feed; both the homestead/household and commercial animal production enterprises are in dire need of feed. Dried cassava could alleviate this scarcity, although it competes with maize in this respect. In Thailand and Indonesia, dried cassava is considered to be quite competitive with maize. Cassava wholesale prices are about US $90/ton and maize prices are between US $120 and $150/ton.

It is worth investigating the possibility of producing dry cassava for about US $0.10/kg, which would make it competitive. In Bangladesh, this is a feasible proposition because of cheap labor, relatively low production costs, and processing with solar drying.

Cassava can additionally be used in starch manufacturing. Bangladesh annually imports about 20,000 tons of starch for use in its textile and jute mills. One or two small starch manufacturing units are presently based on root crops such as potatoes. Cassava could serve as a filler, enabling the plant to run for longer periods of time than it could by depending on potatoes alone. Since cassava has an indeterminate harvest period, it has the advantage of being available at any time of the year. It would not have to be stored, so it would not incur the cost of cold storage, as is the case with potatoes.

In Bangladesh, cassava starch also has potential use in the manufacturing of paper, textiles, and monosodium glutamate, in various food industries, and even in plywood making. Thailand's monosodium glutamate production and food and paper industries, which together consume more than 150,000 tons of its own starch, can serve as an example to Bangladesh. Instead of importing starch, it can produce its own from crops like maize and cassava.

Production Costs

Because production costs of cassava are relatively low compared to many other crops which require higher investments, inputs, and management, it can be considered a source of low-cost calorie production. Moreover, for a country like Bangladesh where the size of the farm is very small, a crop must give maximum yields in a minimum period of time. Table 2 shows approximate production costs and returns for some commonly grown crops. Cassava may be cheaper to grow per calorie, but money made from potato production is invested and earned in only one-third of the time taken by cassava. Nevertheless, cassava is usually grown under more marginal, upland conditions which makes the time dimension somewhat spurious.

Conclusions

Although cassava is an important food staple in many parts of the world because of its nutritive values and uses in other areas such as animal feed production and starch manufacturing, it may take some time before it becomes a major food staple in Bangladesh.

Upland areas suitable for cassava production must remain above flood level during the year. There are two such areas in Bangladesh. One is located in the low rainfall areas of the west where fruit tree growing is important. The other region is to the east and is characterized by hilly terrain and high precipitation from June through October. This region is subject to extensive erosion. In the west cassava is likely to find a place as

Table 2. **Comparative production costs and returns per acre (approximate $US).**

Items	Paddy	Wheat	Potato	S. Potato	Cassava[a]
Total cost	140.48	101.32	246.44	114.92	140.00
Gross return	240.00	156.00	387.00	160.00	200.00
Net return	99.52	54.68	140.56	45.08	60.00
B/C ratio	1.70	1.54	1.57	1.39	1.43
Crop duration (days)	145	115	90	150	330
Net return/day	.68	.48	1.56	0.30	0.18
Yield (t)	1.48	.96	7.96	7.41	9.26
Gross return/t	162.16	162.50	48.61	21.60	21.60

a) Estimated by the author.

Source: Ahmad, 1984.

an intercrop in the fruit orchards, and in the east, cassava production can be accomplished only with effective soil conservation techniques.

It is important to note that Bangladesh is in great need of animal feed, that it imports all of its starch needs, and that it experiences vegetable shortages. Therefore, cassava's potential cannot be summarily overlooked. With higher-yielding varieties and the use of inputs like fertilizer and irrigation systems, the yield might be raised to the levels of Tamil Nadu in India. Such a high production level per unit area could benefit a country like Bangladesh, which has an extremely small per capita land area.

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Cassava in the Agricultural Economy of China

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Introduction

Cassava was introduced into China from Southeast Asia in 1820 and thus has a cultivation history of more than 160 years. The book, *Agronomy Series,* published in 1900 in China, gives detailed descriptions of cassava morphology, characteristics, soil management, planting methods, conservation of stem cuttings, flour-making, and economic benefits. Presently, cassava is an important starch and feed crop known as an 'underground barn'.

Agro-climatic Zones

Cassava-growing regions in China can be classified into three types according to their ecological characteristics:

1. Major growing region. This includes the tropical and subtropical areas south of the Tropic of Cancer, mainly the southern part of Guangdong, Guangxi, and Yunnan. The growing area in this region is about 300,000 ha, or about 85-90% of China's total cassava area.

2. Region for expansion. This includes the area north of the Tropic of Cancer and south of 30°N. Although it is the region with the highest potential for cassava development, the present cultivated area is limited to 10-15% of the total area.

3. Region for test planting. This includes the area between 30° and 40°N, where early varieties can be tested, but commercial cultivation has not yet been attempted.

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Production

In general, cassava production in China does not compete with other major crops for good land. It is grown on barren hillsides and marginal lands where cultivation is usually done sporadically by local people. Under these conditions, yields are low due in part to inadequate management. In 1983, the total area under cassava was about 400,000 ha and the average fresh root yield was about 8.2 tons/ha. Presently, China harvests over 3 million tons of fresh roots annually, or the equivalent of about 1.2 million tons of dry chips. The produce is mostly used as animal feed. Recently, China has been exporting 500,000 tons of dry cassava chips and about 20,000 tons of cassava starch annually.

According to the current selling price of cassava in China, the gross return on a hectare averages about 750-900 yuan,* providing a net return to the farmer of 150-300 yuan per hectare annually. When processed into starch, fructose sweetener, or monosodium glutamate, the value of cassava increases to 1650-6870 yuan/ha with the net return increasing to 750-3000 yuan/ha.

Nevertheless, few additional uses have been developed for cassava. Its uses in other processing industries such as processed food, sugar, pharmaceuticals, papermaking, and textiles have been limited. Attention currently is focused on finding more diverse uses for cassava. For example, research on the use of cassava starch for glucose and fructose production and on the use of fermented cassava for high-protein preparations has begun. Some progress has been made in these fields.

Cropping Systems

Research to expand cassava production and increase productivity has to date focused on improved crop management practices. Areas that show promise are briefly described below.

Intercropping

Rural people usually intercrop groundnuts, beans, or green manure crops between the rows of cassava plants, or interplant cassava between the rows of young forest trees and fruit trees so as to make full use of sunlight, water, and soil resources. When intercropped with cassava,

* US $1.00 = 2 yuan.

groundnuts and beans normally yield 750-900 kg/ha and 450-750 kg/ha per annum, respectively. Groundnuts are usually used as an intercrop under better soil conditions the first half of the year and jute or other crops in the second. In this case, three crops can be reaped annually, not only raising economic benefits, but also conserving water and maintaining soil fertility. Investigations showed that intercropping cassava with forest trees could improve soil aeration and promote tree growth so that their survival rate is over 90% and the immature period is curtailed by 2 to 3 years. When the trees are felled in 15 years, cassava can be interplanted again to give economic returns while the young trees are growing. Thus, the goal of promoting forestry with food production can be obtained.

Close planting and proper thinning

On arid and infertile soils cassava can be planted at a density of 18,000-24,000 plants/hectare. In better soil, spacing of 10,500-12,000 plants/hectare has been tested. Experiments on the Xijiang state farm showed that if seedlings are thinned to two per planting hole, the root yield increases between 28.6%-31% compared to the single seedling practice.

Plowing and ridging

Some experiments show that the best tilling depth for cassava is about 20-30 cm. Production will decrease by 15-20% if the depth is less than 20 cm. Plowing the soil into ridges for planting helps increase tilling depth, particularly in infertile and shallow soil areas. A large-scale experiment on 200 ha of the Xijiang state farm showed that the average yield of plots with 15 cm high ridges was only 12 tons/ha, while that of plots with 25-30 cm high ridges could average 15 tons/ha, 25% over the former. In addition, contour ridging on hilly slopes helps prevent soil erosion.

Biennial cultivation

In China's subtropical area, cassava is usually harvested 8-10 months after planting. The cold weather during the winter in this area reduces the growing season and thus limits increased yields. The yield, however, can be increased significantly if biennial cultivation is practiced with the stem cut off 8-9 months after planting. An experiment showed that cassava harvested the same year it was planted produced 20.2 tons/ha of fresh roots, while cassava cultivated biennially produced 33.2 tons/ha. It is believed that the starch content of biennial cassava harvested in September is about 2% higher than that of the annually harvested plants. Such a system increases the efficiency of processing and rate of equipment use. Biennial cultivation, which needs cultivating and manuring only once during its growing period, can also save labor and hence reduce production costs. It is therefore considered a low-input but high-profit approach for cassava production in subtropical China.

Development Prospects

Land appropriate for cassava cultivation totals about 1,200,000 km^2, occupying 12% of China's total area. These areas constitute a major production base for development of rainfed crops in the tropical and subtropical regions. Cassava is a high-yielding, drought-resistant crop that has played a remarkable role in rainfed agriculture. With the development of transportation and more diverse uses of cassava products, the cassava industry will surely expand in China. The first objective of cassava development in China is to serve domestic markets. Once this is realized, then the need to expand exports will be considered.

Scientific research on cassava production is currently being undertaken in China. The Chinese government has appropriated special funds for research on the multipurpose uses of cassava. A number of complex factories of considerable size will be established in Guangdong and Guangxi to pave the way for the modernization of processing and diversification of cassava utilization. This will give great impetus to the development of the cassava industry. However, there are still several constraints to future cassava development in China:

1. Lack of improved varieties. Improved cassava varieties are scarce and cultivars are few. It is therefore highly important to devote resources to the selection and breeding of planting materials so as to produce superior lines suitable for different ecosystems.

2. Soil erosion. Local farmers tend to grow cassava on hilly land, but due to poor management there is severe soil erosion. Effective measures should be adopted to conserve water and check soil erosion in order to conserve soil fertility. The main steps presently being taken are planting cassava on terraced strips and intercropping cassava with other crops using proper spacing.

3. Inadequate processing and use of cassava. Since products are not widely marketed, growers lose their enthusiasm for growing cassava. Thus, processing and transportation should be improved to create better conditions for the marketing and utilization of cassava products, thereby increasing its production.

4. Lack of systematic planning and technical assistance. Cassava production, processing, and marketing in most cassava-growing areas is done

with little, if any, planning or technical assistance. Cassava roots or products often become overstocked with large postharvest losses due to delayed transportation and marketing.

5. Poor storage of stem cuttings. Cassava-growing areas in China mostly lie within the subtropical zone where cassava is usually harvested before December. In this case, stem cuttings have to be stored over the winter season. If poorly kept, they will suffer freeze injury. Moreover, cuttings of the upper stems dry up readily due to their immaturity. This creates a shortage of planting material the following year.

Cassava development in China will continue to make use of marginal lands. It will be incorporated in an integrated development program of agriculture, forestry, animal husbandry, and rural industry. The size and rate of development will depend on specific demands at home and abroad. Promoting cassava development will initially focus on the improvement and popularization of better varieties, and the introduction and use of advanced cultural techniques to increase yields and prevent extensive, unplanned expansion of cultivated area. It is planned that by the year 2000, the total area under cassava in China will have increased to 500,000-600,000 ha, the average yield will have increased to 10.5-12 tons/ha, and total production to 4-6 million tons/year. Gradually, the direction of cassava development will be shifted from use as a subsistance crop to a commodity crop. This will require standardizing its product quality, optimizing the management of production, and diversifying crop utilization.

Besides developing improved varieties, the main task is to introduce crop rotation and intercropping so as to give rise to a multiple cropping system. With multiple cropping, maturity and harvesting times can be planned to provide a continuous source of roots, thus promoting cassava commodity production. Larger scale production will in turn facilitate the development of better processing, transportation, and storage facilities.

Cassava in the Agricultural Economy of India

S.R. Subramanian

Introduction

Cassava has acquired worldwide recognition for its domestic and industrial uses. In India it is consumed as a staple as well as a food supplement, either directly or as dry chips. Dry chips are powdered and used for a traditional steam-cooked breakfast dish called *puttu*. Industrial uses of cassava in India are mainly for sago (tapioca pearl), starch, and cattle feed. Other industrial possibilities are for the production of alcohol and glucose. Cassava is not only flexible in terms of uses, but it also grows under a wide range of agro-climatic conditions. These attributes, along with its efficiency in producing carbohydrates, have contributed to the important role cassava plays in the economy of tropical countries.

Area, Production, and Yield

With the advent of World War II and the cessation of imports to India, cassava became indispensable in overcoming serious food shortages and in the textile industries as a starch source.

The area planted to cassava in India makes up 2.3% of the world's cassava area and 0.2% of India's total cropped area. In 1967-68, the cassava area in India was 347,000 ha. It steadily increased to 392,000 ha in 1975-76 and then slowly decreased to 310,000 ha in 1981-82 (Table 1). Cassava production followed a similar pattern: 4.6 million tons in 1967-68, increasing to 6.6 million tons in 1975-76, and then decreasing to 5.6 million tons in 1981-82. Cassava yields have slowly risen from 13.4 tons/ha in 1967-68 to 17.9 tons/ha in 1981-82. This yield is very low compared to the

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Table 1. **Cassava area, production, and yield in India.**

Year	Area (000 ha)	Production (000 t)	Yield (t/ha)
1967-68	347	4643	13.37
1968-69	358	4636	12.91
1969-70	352	5214	14.78
1970-71	353	5215	14.77
1971-72	354	5938	16.73
1972-73	363	6371	17.54
1973-74	367	6358	17.31
1974-75	387	6325	16.32
1975-76	392	6638	16.73
1976-77	385	6375	16.52
1977-78	358	5688	15.87
1978-79	361	6052	16.74
1979-80	365	5952	16.30
1980-81	320	5868	18.29
1981-82	310	5567	17.94

Source: Agricultural situation in India. Vols. 23 to 38. Government of India, New Dehli.

yield of 78 tons/ha obtained under experimental conditions in South America. It shows a vast potential for improvement through genetic upgrading of Indian varieties.

Estimated compound growth rates for the period 1967-1983 revealed that the area under cassava decreased at a rate of 0.5% per year, while annual production increased at a rate of 0.9%. This increase in production was accomplished by an increase in yield, registering a compound growth rate of 4.3%.

Cassava is grown mainly in two southern states, Kerala and Tamil Nadu. During 1981-82, these two states accounted for 91.6% of the area under cassava in the country. Of the two states, Kerala alone contributed 77.9% of the area under cassava in India, while the area in Tamil Nadu was 17.2%. Both these states also witnessed an increase and then a decrease in cassava area.

The productivity of the crop in Kerala increased from 14.1 tons/ha during 1967-68 to 16.8 tons/ha in 1981-82. The increase was from 9.7 tons/ha to 31.3 tons/ha during the above period in Tamil Nadu (Table 2).

The compound growth rates worked out for the period 1967-1982 showed that the cassava area decreased at the rate of 0.8% per year in Kerala while production decreased by 0.5%. The slower decrease in production was due to a marginal increase in productivity (growth rate of

Table 2. **Cassava area, production, and yield in Kerala and Tamil Nadu.**

Year	Kerala Area (000 ha)	Kerala Production (000 t)	Kerala Yield (t/ha)	Tamil Nadu Area (000 ha)	Tamil Nadu Production (000 t)	Tamil Nadu Yield (t/ha)
1967-68	297	4198	14.10	43	419	9.66
1968-69	296	4081	13.75	42	400	9.51
1969-70	295	4665	15.78	43	513	11.79
1970-71	293	4671	15.91	47	566	12.05
1971-72	299	5351	17.30	42	545	12.82
1972-73	304	5692	18.67	50	629	12.59
1973-74	306	5630	18.37	51	644	12.58
1974-75	317	5625	17.69	52	564	10.72
1975-76	326	5390	16.48	50	1115	22.27
1976-77	323	5125	15.85	48	1128	23.50
1977-78	322	5114	15.84	52	1310	24.86
1978-79	289	4226	14.57	54	1682	31.15
1979-80	290	4223	14.54	58	1591	27.43
1980-81	243	4097	16.84	53	1539	28.87
1981-82	241	4073	16.84	42	1324	31.32

Source: Agricultural situation in India, Vols 23 to 38. Government of India, New Dehli.

0.4%). In Tamil Nadu, compound growth rates for area, production, and yield during the above period were 1.4%, 11.5%, and 10.0%, respectively.

In Tamil Nadu, cassava is mainly grown in two districts: Salem and Kanyakumari. The area under cassava in Salem increased from 8,000 ha in 1960-61 to 25,000 ha in 1980-81. In Kanyakumari, the area decreased from 16,000 to 12,000 ha during the above period (Table 3). These two districts together had about 70% of the area under cassava in Tamil Nadu and about 12% of the area in India. An interesting feature is the spectacular increase in the productivity of cassava in Salem. The compound growth rates were 20.3% for area, 13.3% for production, and 11.5% for yield. The corresponding figures for Kanyakumari were -12.39%, 1.40%, and 4.24%, respectively.

The area under cassava declined marginally in the country over the last 15 years. In Kerala the crop has been under cultivation for more than 150 years, but the productivity has remained rather low. Having long been a major staple food in the state, it is slowly being replaced by rice, at least in the diets of the upper-middle class people.

The use pattern in Tamil Nadu, particulary in the Salem district, has been quite different. Here cassava was used principally in the processing factories, and the demand for direct consumption was negligible. The

Table 3. **Cassava area, production, and yield in Salem and Kanyakumari.**

	Salem			Kanyakumari		
Year	Area (000 ha)	Production (000 t)	Yield (t/ha)	Area (000 ha)	Production (000 t)	Yield (t/ha)
1966-67	19	193	9.89	14	139	9.69
1967-68	23	229	9.88	14	142	9.59
1968-69	29	287	9.78	14	142	9.59
1969-70	21	237	10.88	14	211	14.28
1970-71	16	182	10.99	14	210	14.28
1971-72	21	354	16.61	15	149	9.68
1972-73	24	409	16.43	17	164	9.58
1973-74	30	503	16.43	11	112	9.58
1974-75	28	388	13.83	10	95	8.89
1975-76	25	647	25.00	11	182	16.08
1976-77	21	642	29.85	13	169	13.00
1977-78	24	732	29.38	13	236	18.16
1978-79	27	83	38.87	12	218	17.87
1979-80	28	883	31.54	12	182	14.93
1980-81	25	906	36.27	12	213	17.80

Source. Season and crop reports of Tamil Nadu, 1960-61 to 1980-81

existence of about 230 sago factories and 270 starch factories in this district was mainly responsible for the increase in the production of cassava. The area under cassava steadily decreased in the Kanyakumari district of Tamil Nadu during the last two decades. In this district a steady shift from annual crops to perennial crops like coconut was observed.

Production and Marketing Analysis

A study was conducted in the Salem district of Tamil Nadu on the production and marketing of cassava (Uthamalingam, 1979). Cassava is mostly grown under irrigated conditions in this district. In the study area, the average percentage of net sown area of the farm under cassava was 33.8%. The cost of production per hectare was Rs 5274.70 and Rs 2848.62,* respectively, for irrigated and rainfed production (Table 4).

The cost of production per ton of cassava was Rs 214.30 and Rs 240.70 under irrigated and rainfed conditions, respectively, and the productivity was estimated to be 23.0 and 10.7 tons/ha. The low yields were the reason for the high cost of production. Nearly 97% of the farmers sold their

*US $1.00 = Rs 8.00.

Table 4. **Cost and returns of cassava production (Rs/ha), Salem, 1979.**

	Irrigated	Rainfed
Variable costs		
Preparatory cultivation	272.98	180.43
Seeds and sowing	220.47	221.95
Manures and manuring	1101.62	529.17
Irrigation	300.13	-
Cultivation	477.63	228.18
Harvest	237.74	177.52
Interest on working capital	274.11	140.41
Total variable costs	2884.68	1477.66
Fixed costs		
Land rental	1776.43	989.74
Interest on fixed capital	387.52	228.35
Depreciation	210.71	147.76
Land revenue and taxes	15.36	5.11
Total fixed costs	2390.02	1370.96
Total costs	5274.70	2848.62
Yields (t/ha)	22.96	10.74
Production costs t	214.30	240.70
Returns		
Value of roots	6701.68	3179.31
Value of by-products	355.11	263.13
Gross returns	7056.79	3442.44
Marketing costs	404.11	189.02
Net return	1377.98	404.80
Net return/t	60.00	37.00

US $1.00 = Rs 8.00

produce directly to starch factories. About 30% of the processors were vertically integrated, in the sense that they were also cultivators of cassava. The marketing cost per ton of roots worked out to Rs 17.60. The major component of this was transportation cost. For every ton of cassava purchased by the factories, 40 kg were deducted for soil and moisture. This was the second largest cost in marketing. Farmers received a price varying from Rs 280 to 310/ton.

In Kerala cassava made up 13% of the total cropped area, compared to 4.2% in Tamil Nadu. Moreover, cassava accounted for 25.4% of the area sown by the lower stratum of farmers owning up to half a hectare of land, as against 4.6% in the case of farmers with more than 4 hectares of land. Therefore, fluctuations in cassava prices affect small farmers disproportionately. Another disquieting feature was that the cassava price was declining in relationship to other competing crops (Rajeswari Amma, 1980).

Processing

The two main products made out of cassava are sago (tapioca pearl) and starch. The sago and starch factories are concentrated in the Salem district of Tamil Nadu. However, less than 10% of the production of cassava products is consumed in Tamil Nadu; the rest is exported to other parts of the country. Against the annual requirement of the sago factories for 1 million tons of cassava roots, the local supply is only 0.6 million tons. The balance comes from neighboring areas.

The sago factories work an average of 180 days a year, whereas the starch factories work for 140 days. Together they require an average investment of Rs 200,000. The output is 3.5 tons of sago and 4.5 tons of starch per day. The starch recovery from roots is 25% by weight in both sago and starch factories. The cost of production per ton of sago works out to Rs 1450 and that of starch to Rs 1250. The percentage net return over total cost is about 4.5% and 6.5%, respectively, in sago and starch factories.

Thippi, the wastes from sago and starch factories, is used in the manufacture of cattle feed. A plant with an investment of Rs 1 million could work for about 200 days with an average input of 8 tons/day. Thippi could constitute 25-40% of the raw material for the cattle feed. The cost of production per ton of feed is about Rs 710, and the return is about 4% over total cost.

Employment Requirements

The labor required per hectare of cassava production is 104 man-days for an irrigated crop and 54 man-days for a rainfed crop. The most labor-intensive operation is harvesting. The women-days of labor required per hectare are 160 and 85, respectively, for irrigated and rainfed crops. The sago factories producing 3 tons/day use 11 man-days, 49 woman-days, and 5 juvenile-days of labor per day. Similarly, the starch factories with an average output of 3.8 tons/day require 8 man-days, 35 woman-days, and 6 juvenile-days of labor per day. The cattle feed industry, with an average capacity of 8 tons/day, uses 6 man-days and 3 woman-days per day.

Integrating Production and Processing

Production and processing of cassava are done by distinctly separate entities. Profits would be higher if different stages of production and processing were integrated, but without affecting the level of employment. An estimate of costs and returns was made when cassava production was integrated with sago production and cattle feed production. For an integrated unit with a capacity of 10 tons of sago and 10 tons of cattle feed per day working over an operating period of 200 days annually, an investment of Rs 2.290 million would be required. For a 9% return on initial investment, a processor could pay Rs 325/ton of cassava at current market prices for sago and animal feed. The existing coefficient of variation of cassava price was around 14%, and this could be reduced markedly through integrated operation. To keep an integrated unit of the above size working requires 150 ha of land under cassava at the average level of productivity per hectare now observed in the study area.

Projections and Problems

The demand for cassava has increased due to its multifaceted industrial uses, not due to direct consumption. In spite of the increased demand, the area under cassava has decreased marginally. This was particularly marked in the traditional cassava-growing state of Kerala, while there was a marginal area increase in Tamil Nadu. The food habits of even the low-income strata were found to be shifting from root crops to cereals. This might militate against increasing the area under cassava. However, there is an increasing demand for cassava for industrial uses, such as in the production of sago, starch, and cattle feed. The potential for production of alcohol and protein also might be explored. The possible alcohol production from cassava with a yield of 20 tons/ha is 3600 liters. This renewable resource could be used in motors as fuel and could help alleviate the mounting energy problem (Leihner, 1981). An increased demand for cassava could easily be met by increasing yields, which are very low at present compared to the potential shown by experimental yields.

For the farmer to cultivate a crop, the important incentive is price. The price for cassava is unfavorable compared to alternative crops, and price fluctuations are also high in cassava. To overcome these problems, the cultivators and processors need to be linked. This might be done by integrating the two functions. Since most cassava producers are small farmers, there is a need for institutional intervention. Some kind of producers' organization could be established with the objective of getting a higher price for the roots and ensuring a continuous supply to the processing units.

In Tamil Nadu, the surface water flow has been harnessed almost fully and the ground water potential is dwindling. Because cassava uses water efficiently, it is coming up in nontraditional areas replacing sugarcane. In the traditional growing areas where the water table is going down, it might be necessary to recycle the effluents of the starch processing units for irrigation in order to maintain the present acreage.

Although many products like cassava chips and pellets, flour, starch, sago, and flakes could be produced, emphasis should be placed on lowering the cost of such products and popularizing them in the diets of the people. In conclusion, the high adaptability of this crop could be used best by strengthening research and development in cassava.

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Cassava in the Agricultural Economy of Indonesia

Bambang Guritno
S.M. Sitompul

Production

Cassava is the second most important upland crop (after maize) in Indonesia. Out of a total of 4 million hectares of cassava cultivated in Asia, 1.4 million hectares are located in Indonesia. The greatest share of Indonesia's cassava is grown on Java, which has around 1 million hectares (Figure 1). Cassava area on Java increased steadily between 1950 and 1965, to a maximum of 1.4 million hectares, but dropped in 1966 and declined slightly thereafter to the present level of about 1 million hectares. From 1950 to 1972 cassava yield on Java was relatively constant at an average of 7.4 tons/ha. Since 1972, yields on both Java and the outer islands have increased, and in 1981 the national average was just over 9.7 tons/ha, a 29% increase in just 9 years (Figure 2). This increase has been achieved without any direct government program for cassava.

The outer islands differ from Java in the pattern of change in both cassava area and total production. The cultivated area on the outer islands has continually increased since 1950, but reported yields decreased from 1950 to 1966, increased in 1974, and thereafter have remained relatively constant at 9.7 tons/ha. The apparent decline in yields was due primarily to changes in data collection procedures rather than to significant changes in cassava cultivation practices. The increase in cultivated area on the outer islands has been due to considerable clearing of new areas from alang-alang (*Imperata cylindrica*) for cassava. The clearing of this land has been carried out largely by migrants from Java to produce cassava for tapioca and dried cassava export. In Lampung province on Sumatera, the area planted to cassava has expanded rapidly.

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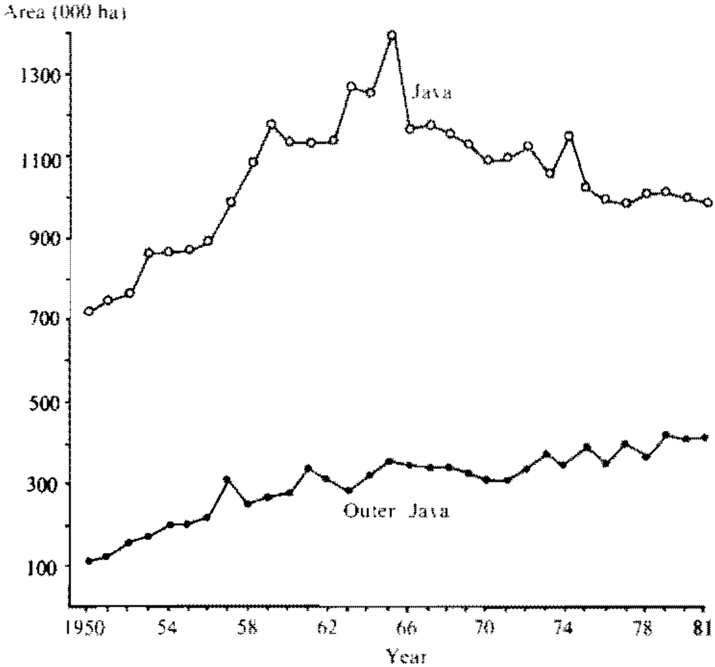

Figure 1. *Cassava area in Java and outer Java, 1950-1981.*

In contrast to Lampung province, a number of factors have tended to reduce the areas used for cassava production on Java (Roche, 1983). Major construction and rehabilitation of irrigation systems underway throughout Indonesia during the 1970s permitted rainfed crops such as cassava to be replaced by irrigated rice, and late season upland crops to be replaced by a second irrigated rice crop. The government's afforestation efforts in steep upland areas and extensive plantings of perennial cash crops have also tended to reduce land areas available for cassava on Java. Cassava prices declined relative to prices of competing food crops during the 1970s, which reduced the incentives for cassava production. Finally, it is also likely that cassava intercropping has become more extensive and, in general, the planting density of intercropped cassava is lower than when it is planted in pure stands.

Cassava production is concentrated in marginal agricultural areas of generally low soil fertility which are often characterized by a pronounced dry season. There appear to be few serious problems with cassava pests and diseases in Indonesia (Roche, 1983). The red spider mite (*Tetranychus urticae*) and cassava ash disease (*Oidium manihotis*) are common dry season problems, but cause only minor economic losses. Cassava bacterial

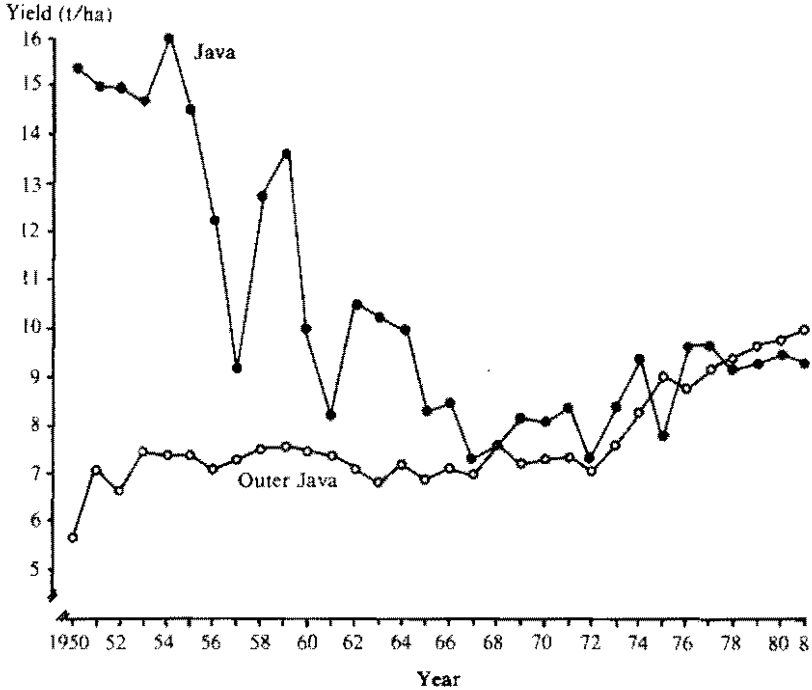

Figure 2. *Cassava yield in Java and outer Java, 1950-1981.*

blight (*Xanthomonas manihotis*) is a serious concern in a few areas, but is of minor importance where cassava cultivation is most extensive. Various root rot problems arise frequently on poorly drained soils, but again cause overall minor losses.

Cassava production systems on Java differ from those of the outer islands and most of the rest of Asia in the predominance of intercropping and the application of at least some fertilizer. Around 54% of Java's farmers intercrop cassava in a variety of systems involving upland rice, maize, and legumes. These labor-intensive systems are particularly appropriate on land-scarce Java, where 53% of the farmers operate less than 0.5 ha and only 4.7% have more than 2 ha (Roche, 1983).

Although cassava intercropping is usually more profitable per unit of land, a substantial share of the crop is planted in pure stands, depending upon rainfall, land type, and market. Monoculture plantings are most common near urban markets, occasionally even on irrigated land. Intercropping predominates in more remote locations where farming systems tend to be more subsistence-oriented. As levels of soil fertility and rainfall decline, first upland rice, then legumes, and finally maize are eliminated from these systems (Roche, 1983). Most cassava is planted in pure stands in the outer islands where farm holdings are larger and less intensively cultivated, and where soils are generally less fertile and more acid than those of Java.

Fertilizer use in Indonesia is limited largely to nitrogen (principally urea) and phosphorus (concentrated superphosphate), the prices of which are subsidized substantially. Average rates of fertilizer use are low for cassava as compared to crops such as rice and maize, particularly when cassava is planted in monoculture. Current farm practices stand in contrast to agronomic trials, which consistently show the high profitability from fertilizer use on cassava. This situation indicates the need for a cassava extension program in Indonesia.

An estimate of the returns possible from improved agronomic practices is given in Table 1, which compares costs and returns of cassava production in two areas of Indonesia. The agronomic practices (fertilizer, plant spacing, and weeding) recommended on the basis of farm trials can lead to a substantial increase in yields and profitability on both the East Java and Lampung sites. Cassava production costs could be reduced by almost 50%, indicating the large increase in cassava supply likely to occur with new cultivation practices.

Table 1. **Cost analysis of cassava production (per hectare) at two Indonesian locations, 1983-1984.**

	Farmers' pattern		Recommended pattern	
	East Java	Lampung, Sumatera	East Java	Lampung, Sumatera
Yield (t/ha)	10.2	9.4	28.3	22.4
Cost (% of total)				
Labor	45.4	73.5	42.8	69.4
Land rent	35.8	7.8	25.1	6.6
Fertilizer and manure	11.7	13.0	26.7	18.8
Interest, depreciation, taxes	7.1	5.7	5.4	5.2
Total	100.0	100.0	100.0	100.0
Total value (000 Rp)	204.0	188.0	566.0	448.0
Total cost (000 Rp)	142.2	140.9	207.3	184.6
Net income (000 Rp)	61.8	47.1	358.7	263.4
Production (cost/kg)	13.9	15.0	7.3	8.2

Approximate rate of exchange: US $1.00 = Rp 960.00.
Source: Achmad Suryana, 1980.

Even though cassava is one of Indonesia's major food crops, the total value of domestically-produced cassava is only a small fraction of the total value of rice, the preeminent national staple. In contrast to rice, cassava has received little attention from the government despite its important contribution to upland farm incomes. Typically between one-sixth and one-third of upland farm incomes come from cassava on Java (Roche, 1983). End uses of cassava vary considerably, however. The marketed shares of cassava are high near cities and starch factories, but in more remote locations most of the cassava is consumed directly by farm families.

Trade and Use

Before World War II, Indonesia was the world's major exporter of cassava starch. Recently, however, domestic demand has accounted for the great bulk of utilization. During the late 1970s, about 48% of Java's cassava output was consumed as food in fresh and dry forms, 27% was processed into domestically-consumed starch, and the remainder was exported as *gaplek* (peeled root which has been cut into pieces and dried) and starch (Table 2).

Because of competing domestic demands, Indonesia has not been able to fully exploit the export market provided by government policies in the European Economic Community (EEC). Indonesia's reduced importance in world cassava trade was due to the disruption caused by the Japanese occupation in World War II, the subsequent war of independence, and, finally, to population pressure which led to replacement of cassava by more preferred staple crops.

Table 2. **Cassava use (000 t fresh root equivalent) by form and by market on Java, 1976.**

	Marketed	Home consumption	Total
Domestic			
Fresh roots	710	1190	1900
Urban	100	10	110
Rural	610	1180	1790
Gaplek	900	860	1760
Gaplek flour	80		80
Starch	2020		2020
Export			
Gaplek	1776		1776

Source: Unnevehr, 1983.

Thailand presently dominates world export of cassava both in the forms of gaplek (Table 3) and starch (Table 4). Cassava is a minor Indonesian export, contributing only about 2% of the total value of non-oil exports during the 1977-83 period (Indonesia, 1983b). These exports, although small, have an important impact on the incomes of relatively poor farmers. Demand for cassava exports provides a floor price for farmers in years of high domestic production.

As a foodstuff, cassava plays an important role in the Indonesian diet, and ranks second after rice, contributing about 10% of the total calorie consumption. A number of distinct patterns of cassava consumption can be identified. Firstly, consumption levels vary considerably among and within regions. As Table 5 shows, consumption is greatest in rural areas; in towns and cities it is limited largely to small per capita quantities of fresh roots and starch products. The form in which cassava is consumed also varies regionally. For example, the inhabitants of Yogyakarta and East Java consume mostly gaplek, while in Central and West Java much more is consumed in fresh forms.

Secondly, cassava consumption varies considerably by season, depending upon the availability and price of other staples, especially rice. Cassava consumption is greatest in seasons when rice is most expensive. Consumption of fresh cassava increases during the third quarter (July-September) when rice prices increase. Gaplek consumption increases during the fourth quarter, coinciding with low availability of rice and maize.

Table 3. **International gaplek trade (000 t).**

Year	Exporter					Importer
	Thailand	Indonesia			China	EEC
		Total	Lampung	Java		
1970	1097	332	74	261	n.a.	n.a.
1971	970	458	86	365	n.a.	1348
1972	1111	342	100	240	16	1545
1973	1530	75	36	42	11	1482
1974	2030	393	199	187	4	2121
1975	2104	303	203	87	114	2447
1976	3316	149	150	10	58	3243
1977	3669	183	149	38	3	4031
1978	6041	308	194	98	2	6461
1979	3880	710	170	495	128	5877

n.a. = not available.

Source: Nelson, 1982.

Table 4. **Cassava starch imports and sources (t).**

Country	1971	1972	1973	1974	1975	1976	1977	1978	1979
Importer									
United States	82,564	49,134	64,341	74,421	38,422	40,347	37,641	35,057	32,886
Source									
Brazil	10,303	5,331	5,170	15,492	7,011	992	506	847	6,849
Thailand	67,471	42,778	57,120	57,501	30,314	35,495	36,175	32,163	22,596
Others	4,790	1,025	2,051	1,428	1,097	3,860	960	2,047	3,441
Importer									
Japan	46,952	50,560	71,799	139,749	71,105	82,093	94,206	90,622	69,355
Source									
Thailand	n.a.	n.a.	n.a.	130,854	68,178	79,606	94,206	90,622	52,852
Others	n.a.	n.a.	n.a.	8,895	2,927	2,487	0	0	16,503
Importer									
Taiwan	n.a.	n.a.	n.a.	n.a.	5,624	4,964	11,601	n.a.	n.a.
Hong Kong	5,700	7,125	8,929	12,326	13,840	14,434	10,322	14,454	11,162

n.a. = not available.
Source: Nelson, 1982.

Table 5. **Regional per capita consumption (kg/yr) of major staples in Java, 1976 and 1978.**

1976	Jakarta	West Java	Central Java	Yogyakarta	East Java[a]
Urban areas					
Rice	112.3	120.0	101.7	96.5	98.8
Maize	0.4	0.3	1.0	0.1	2.1
Cassava (fresh root equivalent)	4.4	5.3	12.0	10.4	10.9
Roots	3.7	5.1	11.4	7.0	0
Gaplek	0.1	0.2	0.2	2.9	0.2
Starch	0.6	0.2	0.4	0.5	1.7
Rural areas					
Rice		149.1	93.0	77.2	78.8
Maize		0.4	16.0	3.8	31.8
Cassava (fresh root equivalent)		28.5	50.1	108.2	81.9
Roots		26.8	22.3	18.9	26.3
Gaplek		0.8	21.1	80.2	43.5
Starch		0.9	6.7	9.1	12.1
1978					
Urban areas					
Rice	104.8	120.5	90.8	89.4	93.9
Maize	0.1	0.2	0.6	-	3.8
Cassava (fresh root equivalent)	5.7	8.1	9.9	7.9	12.4
Roots	4.7	8.1	9.5	6.4	10.6
Gaplek	0	0	0.1	0.7	1.3
Starch	1.0	0	0.3	0.8	0.5
Rural areas					
Rice		141.1	82.3	67.4	74.7
Maize		0.6	24.5	11.3	32.9
Cassava (fresh root equivalent)		25.3	64.2	96.3	79.3
Roots		23.3	25.0	23.5	20.8
Gaplek		1.2	21.3	68.6	57.2
Starch		0.8	17.9	4.2	1.3

a) Includes the island of Madura.

Source: The data are from special tabulations done on Susenas V and VI survey data by the Central Bureau of Statistics in Indonesia. Calories per day were converted to kilograms per year on the basis of the following ratios: rice - 3,600 cal/kg; maize - 3,200 cal/kg; cassava (fresh) - 1,095 cal/kg.

Thirdly, the consumption of cassava varies by product form and income status. Figure 3 shows that gaplek consumption declines rapidly with income in rural areas. Fresh root consumption increases with income at the lower rural income levels, but declines at higher income levels.

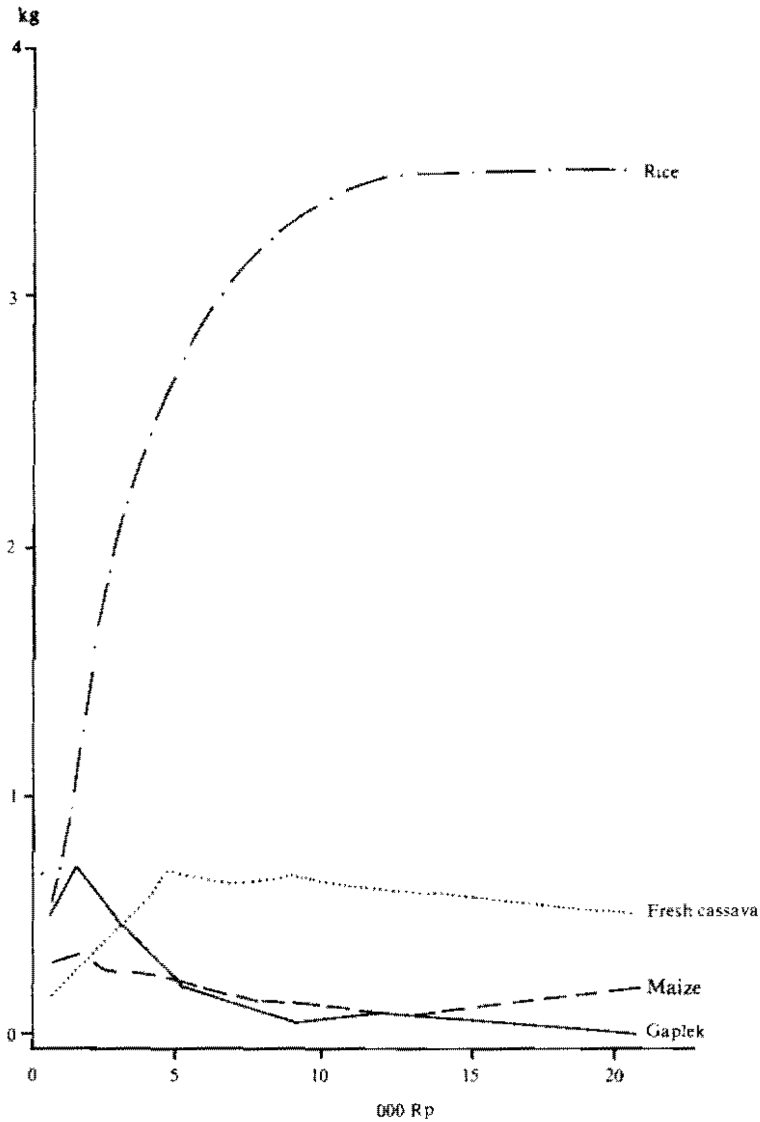

Figure 3. *Weekly per capita consumption of rice, maize, and cassava by income group in rural areas, 1976.*

Source: Falcon et al., 1984.

There has been an apparent increase in recent years in the percentage of Indonesia's cassava that is processed into starch. About 17% of the crop was used for starch in 1974, but this share grew to 24% in 1979. The bulk of starch processing occurs in West and Central Java, and in Sumatera's Lampung province (Table 6). Starch production increased very rapidly in Lampung during these years because of a doubling of local fresh root output and an expansion of starch processing facilities.

Most of Indonesia's starch is used for domestic consumption in processed foods, particularly the crisp wafer called *krupuk*. It has been estimated that about 65% of the starch was used in krupuk production and about 15% was used for other snack foods (Nelson, 1982). Textile manufacturers used about 10%, glucose production probably accounted for 3%, and the remaining 7% was used for direct household consumption.

Indonesia's cassava exports have been a small and variable portion of the domestic production in recent years. During 1979, the peak export year, cassava shipments amounted to only 15% of the total output. Indonesian gaplek exports have never even approached the export quotas imposed by the EEC in late 1981: 500,000 tons in 1982 and 750,000 tons in 1983. Incentives to expand exports have been limited principally by infrastructure problems. Inland roads are poor and marketing costs are high. Most of Indonesia's ports are capable of handling only relatively small ocean vessels. As a result, the Indonesian farmer tends to receive lower prices for cassava than his Thai counterpart in the years when Indonesian prices are at the f.o.b. export floor.

Table 6. **Indonesia starch production by province, 1974 and 1979.**

	Starch (t)		Fresh root equivalent (t)	
	1974	1979	1974	1979
West Java	188,220	239,220	941,100	1,196,100
Central Java	126,020	149,180	630,100	745,900
East Java	33,300	57,780	166,500	288,900
Java total	347,540	446,180	1,737,700	2,230,900
Lampung	27,750	150,750	138,750	753,750
North Sumatera	15,900	24,100	379,500	120,500
Riau	30,900	30,900	154,500	154,500
Other provinces	9,600	9,600	48,000	48,000
Total	431,690	661,530	2,158,450	3,307,650

Source: Nelson, 1982.

Production Trends

If recent trends continue in area and yields of cassava, total production of cassava on Java can be expected to increase slowly in the coming years as rising yields will slightly outweigh declining area. Past production trends show that the harvested area will decrease by 0.4%, or about 4,000 ha/yr, to a total of 976,000 ha in 1988. Cassava yields on Java have been growing 3.6% annually since the late 1960s and will, at this rate, reach 11.6 tons/ha in 1988. Based on these trends, it is estimated that total production on Java will reach 11.3 million tons in 1988, about 14% higher than the 1981 level. Figures 4 and 5 show the projected trends in cassava area and yield for Java and the outer islands of Indonesia.

Cassava production in the outer islands is expected to increase not only in harvested area, but in yield as well. The area harvested has increased 2.5%/yr, about 7,600 ha/yr since 1968. If this continues, by 1988 the area will reach 461,000 ha. If the increase in yield continues at 1.8%/yr, it should reach 10.7 tons/ha in 1988. Given the above trends, cassava production in the outer islands should total 4.4 million tons in 1988.

The estimated production for all of Indonesia should reach 16.3 million tons by 1988, 19% higher than that for 1982. The projected increases in cassava yields are based on the assumption that, as in the past, no serious attention will be given by the government to developing cassava's potential. In this case, yields will increase largely as a function of crop intensification under current technology due to population growth.

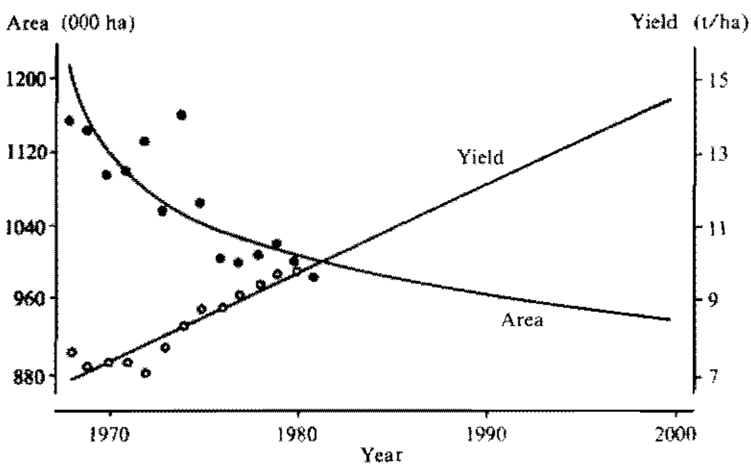

Figure 4. *Trend in area and yield of cassava, Java and Madura.*
Source: Sitompul and Guritno, 1983.

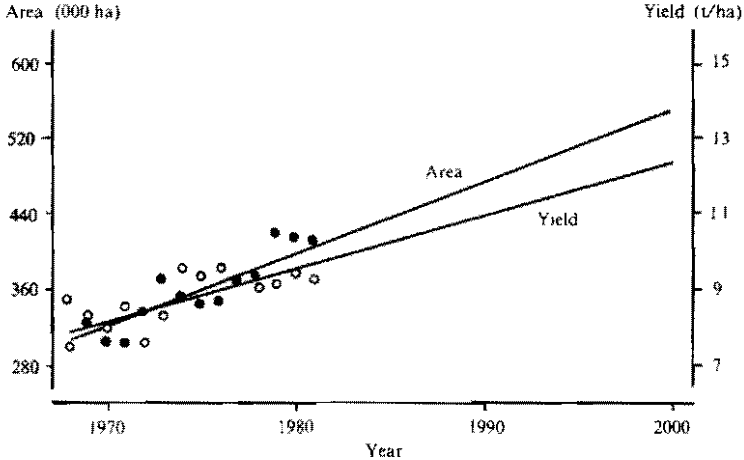

Figure 5. *Trend in area and yield of cassava, outer islands.*
Source: Sitompul and Guritno, 1983.

Research Needs

Research needs for increasing cassava production on Java differ from those on the outer islands. Research on Java is focusing on efforts to increase yields in cassava-based intercropping systems on the limited land available. On the outer islands, where cassava is generally planted in areas of low fertility reclaimed from alang-alang, research efforts concentrate on increasing production on both small farms and cassava estates.

The outer islands can be divided into areas with a wet climate (only 2 dry months per year) or a dry climate (fewer than 6 wet months per year). Here 'dry' does not necessarily mean low annual rainfall, but rather a serious water availability problem for both plant growth and human needs during some period of the year. In general, rain only falls in such areas for 3-4 months, the rest of the year being dry. It is during this time that water shortage becomes a problem. One reason for the Lampung area's success in increasing both harvested area and production is Lampung's wet climate. Since cassava can be planted almost any month of the year, the demands for raw materials for processing can be supplied practically throughout the year.

Variety trials

Programs presently underway to obtain high-yielding varieties include breeding (although this requires a long period) and testing the yielding ability of local and introduced cassava varieties. In considering the objectives of this program, the following factors must be taken into account: Java needs high-yielding varieties with little branching and narrow leaves for intercropping, along with good taste (i.e., low levels of hydrocyanic acid). Outside Java, there is a need for high-yielding varieties with a high starch content and, particularly for dry areas, a variety that has a high drought tolerance.

Cropping systems

Improving soil fertility by better soil management for stable, long-term production is a major goal. Aspects of this objective include tillage practices, mulching, fertilizer use, and maintenance of soil status with a suitable cropping system. With the use of a suitable cassava variety, compatible intercrops, and a suitable cropping sequence, the frequency of intercropping might be increased so as to improve land productivity.

Extension services

Extension services for farmers are very much needed in order to transfer new agricultural technology. Improved coordination is needed between the Department of Agriculture, research institutes, and universities to speed up technology transfer. In the past, coordination between these organizations has been poor. The effective formation of a National Root Crops Working Group with members from different institutions working together on root crops would be one step in improving coordination and organization of research programs.

Potential Use and Demand

Domestic demand must play a major role in the marketing of Indonesian cassava in the future. The present situation reveals limited prospects for cassava exports. The main handicaps in exporting emerge from the relatively low production of cassava, the restriction of the EEC export quota, and high domestic marketing and transportation costs. However, the Indonesian government will give added attention to cassava exports as part of a policy to reduce dependence upon oil exports.

Although the export potential is problematic, the total domestic demand for cassava should continue to grow in the future. Despite the overall negative relationship between consumer income and direct consumption of cassava, fresh and dried cassava will be important staple foods for Indonesia's low income groups for many years to come. Processed products made from cassava starch tend to be income elastic and their demand is expected to increase with income and population growth. There is also considerable potential for cassava in the livestock feed industry, although this form of utilization has not yet been exploited; it will depend upon the availability and prices of protein supplements such as soybean and leaf meals.

New industrial uses of cassava may also be important sources of demand in the future. With the objective of reducing sugar imports, the Indonesian government is developing the production of cassava-based sweeteners (high-fructose syrup and maltose). At the end of 1981, a factory for cassava sweetener production was built in East Java with a daily capacity of 25 tons of fructose syrup (5.5 kg of fresh cassava yield 1 kg of syrup). Similar factories are planned for other cassava production centers over the next few years.

Cassava will also be used to produce ethanol in areas outside of Java. The ethanol industry is still in an initial stage; a pilot plant with an annual capacity of 5 million liters was constructed in Lampung, Sumatera, in 1982. The government has long-term plans to produce 20 billion liters of ethanol annually from cassava and other root crops. The principal objectives of the alcohol fuel program are to provide a renewable substitute for petroleum, to increase farmer incomes, and to develop employment and technical capacity in Indonesia's industrial sector.

While these new industrial sources of demand could absorb much of the increased cassava production possible with new farm technology, the economics of cassava fructose syrup and ethanol are not yet clear. Given present world prices for sugar and petroleum, it is likely that large subsidies will be needed to assure the profitability of fructose syrup and ethanol plants.

Impact of Cassava Research

Rice is the preeminent food in Indonesia and other food crops have received relatively little attention in past agricultural development efforts. Several groups, however, have carried out projects with the aim of increasing cassava production. The Faculty of Agriculture of the University of Brawijaya obtained research grants from the International Development Research Centre to carry out experiments on Mukibat cassava from 1974-1980.* A cassava breeding program has also been undertaken by the Food Crops Research Institute, and two high-yielding varieties, Adira I

* The Mukibat system consists of grafting a stock of ordinary cassava (*Manihot esculenta*) with a scion of *Manihot glaziovii* (Guritno *et al.*, 1984).

and II, have been released. The agricultural research stations have also organized trial plots for tests of varieties and fertilizer use.

The results obtained by these institutions generally have not yet been adopted by farmers. The primary constraint in transferring technology has been the lack of coordination between cassava researchers and the government extension services. Within the research community, only limited technical skills have been devoted to cassava. Research projects are generally short-term in nature and the lack of guaranteed continuity inhibits researchers from developing long-term interests in cassava. Various government agencies are engaged in cassava research, but a lack of supervision and coordination has probably led to unnecessary overlap and inefficient duplication of research efforts.

To help solve these problems, several root crop researchers conducted a meeting in 1980 at the National Biological Institute, at which a National Working Group on Root Crops was established. During this meeting they agreed to allocate research and development activities in cassava in accordance with the specializations, interests, and facilities available at the various institutions. Valuable information has been collected from the participants concerning past and on-going research efforts. Periodic meetings at 6-month intervals were established to follow the development of cassava. It was anticipated that scientific papers would be produced, from which guide books and brochures could be developed for extension purposes.

Unfortunately, the Working Group has not been able to carry out these planned activities on a consistent basis. Leadership has been irregular and available funds for attending meetings have been very limited. Perhaps the impetus for an effective national working group could be provided by the initiation and support of an Asian regional network on cassava coordinated by an international organization. Coordination of research and technology transfer are particularly important for rainfed crops such as cassava because they are grown in much more varied environments than crops such as irrigated wheat and rice, which responded so dramatically to past development efforts in Asia.

Acknowledgements

This paper is based primarily on Falcon et al., 1984, and results of the Cassava Research Project, Faculty of Agriculture, Brawijaya University, Malang, Indonesia.

The authors wish to thank Don Aspinal of AUIDP and Fred Roche of A/D/C for editorial assistance, but with the standard caveat that they are not responsible for any errors or omissions in the final result.

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Cassava in the Agricultural Economy of Malaysia

Tan Swee Lian
Delane E. Welsch

Production

Cassava, the major root crop cultivated in Peninsular Malaysia, ranks seventh in crop area, following rubber, oil palm, rice, coconut, cocoa, and sugarcane. The area under cassava is small and has fluctuated a great deal over the past two decades (Table 1), rising from 12,235 ha in 1960 to 22,231 ha in 1963, dropping to 11,553 ha in 1974, and rising again to 20,908 ha in 1976, which was essentially the level it was at in 1963. The area has dropped steadily since 1976, with 9,599 ha in 1981 being the lowest on record.

These fluctuations in area illustrate two basic features of the cassava industry in Malaysia: one, cassava is a very minor crop and two, the cassava industry is very sensitive to world prices. All field crops are minor in Malaysia in the sense that the country's agriculture is dominated by plantation crops. For example, in Peninsular Malaysia, there were 1,717,000 ha under rubber, 879,900 ha under oil palm , and 246,000 ha under coconut, in contrast to the 12,097 ha under cassava in 1980 (Mohd. Tamin et al., 1982).

Cassava is a minor crop for several reasons. First, land ownership and land use is carefully controlled by the government, which allocates little land to minor crops. Cassava is often grown on mining reserves (land allocated to tin mining, but where actual mining has not yet started), or on disturbed land after mining has been completed. Cassava is also often grown illegally by squatters. Illegal holdings refer to land that is neither owned by nor leased to the farmer and they usually comprise clearings in the midst of government land reserves, forest and mining reserves, and even plantings along grass verges of rural roads. In 1973, 72% of the cassava in Perak state was estimated to be planted on such holdings

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Table 1. **Area and production of cassava, Peninsular Malaysia, 1960-1981.**

Year	Area (ha)	Production (t)
1960	12,235	n.a.
1961	12,728	n.a.
1962	18,873	n.a.
1963	22,231	n.a.
1964	18,438	n.a.
1965	16,344	n.a.
1966	14,669	n.a.
1967	18,138	n.a.
1968	17,036	n.a.
1969	17,532	n.a.
1970	17,667	207,200
1971	14,857	161,768
1972	13,151	279,400
1973	11,820	238,720
1974	11,553	254,326
1975	15,112	281,710
1976	20,908	241,840
1977	20,502	357,345
1978	17,815	197,425
1979	16,635	225,057
1980	12,512	254,309
1981	9,599	211,178

n.a. = not available.

Source: Annual reports, Extension Branch, Ministry of Agriculture, Kuala Lumpur, Peninsular Malaysia.

(Aw-Yong & Mooi, 1973). With the rapid expansion of plantation crops, which have superior income-earning potential for the farmer and are important foreign exchange earners for the country, there is an increasing demand for the available arable land. Lately, enforcement authorities have reversed their earlier tolerance of illegal cultivators and are beginning to bear down on them. This appears to be one of the reasons for the decline in cassava area since 1976.

The second reason why cassava is a minor crop in Malaysia is its returns per hectare are relatively very low. Cassava has a low value per unit weight, and transportation costs are substantial. Although yields per hectare are respectable, in the range of 15 to 25 tons/ha (except on tin spoils where yields range as low as 8-10 tons/ha), cash costs of production are high. Costs are high because most labor used in Malaysian cassava production is hired, making returns above cash cost low. Plantation crops as well as intensive vegetable production may be as much as eight to ten times more profitable than cassava production on any land suitable for their production. For example, the net income/hectare/year for rubber is M$3651* at a rubber price of M$2.40/ kg, and M$5030 for oil palm at an oil price of M$1200/ton (Tunku Mansur & St. Clair-George, 1979). For cassava, it is M$480 at a root price of M$72/ton.

The mean national yield for cassava was estimated at 22 tons/ha in 1982. Yields of 45-60 tons/ha have been claimed in the first harvest season of cassava cultivation, but the usual yields ranging from 12-35 tons/ha are more realistic. The poorest yields range from 6-10 tons/ha.

Production costs vary widely depending on whether the land is rented, owned, or cultivated by squatters; whether planting materials are free or purchased; and whether fertilizer and pesticides are used, and if so, whether they are purchased, or obtained free as government subsidies. Costs for land preparation, planting, and harvesting are also highly variable (Table 2). On the average, however, costs of production on

Table 2. **Range in costs (M$/ha) of cassava production in Perak and Kedah, Peninsular Malaysia, 1983.**

Items	Perak		Kedah	
	Range	Mean[a]	Range	Mean[a]
Land rental	0-124	94	0-198	84
Land preparation	148-309	267	156-541	346
Planting materials	0- 59	27	0- 37	17
Planting	52-198	106	79-410	163
Fertilizers	0-335	140	0-410	292
Fertilizer application	10-124	47	25- 99	54
Weed control				
Manual weeding	74-198	146	111-180	153
Chemical spraying	56-222	148	49-148	111
Herbicides	n.e.	n.e.	n.e.	n.e.
Harvesting	79-791	267	124-860	455
Total		1242		1675

a) In the calculation of the mean, free inputs (e.g., in the form of subsidies) are excluded.
n.e. = not estimated.
Approximate rate of exchange: US $1.00 = M$2.35.
Source: Chan et al., 1983.

* M$ refers to the Malaysian ringgit. US $1 = M$2.29 at the rate of exchange on April 13, 1984 (Asiaweek, April 27, 1984).

mineral soils are estimated at M$1680/ha (Table 3). At a price of M$72.00/ton of fresh roots and an average yield of 30 tons/ha, the gross returns from 1 ha would be M$2160.

The sensitivity of the Malaysian cassava industry to world prices will be discussed in more detail later, but briefly, the relevant world prices are the

Table 3. **Estimated costs of cassava production on mineral soils, Peninsular Malaysia, 1983.**

Items	Labor (man-days)	Cost (M$/ha)	Cost (% total)
Land preparation			**17.9**
Plowing		100.00	
Harrowing		100.00	
Rototilling or ridging		100.00	
Planting			**9.2**
Planting materials		40.00	
Transport of planting materials		25.00	
Planting (including preparation of cuttings)	10	90.00[a]	
Weed control			**13.6**
1. Pre-emergence labor	1	13.00[b]	
1.0 kg fluometuron + 2.5 liters alachlor		76.00	
2. Manual (at 2 months)	10	90.00[a]	
3. Pre-harvest labor	2	26.00[b]	
27 liters paraquat		24.00	
Fertilizer application			**21.5**
Labor	5	45.00[a]	
500 kg compound fertilizer (12:6:22:3)		279.00	
80 kg muriate of potash		37.60	
Harvesting			**31.8**
Contract harvesting of estimated yield of 30 t/ha at M$17/t		510.00	
Removal of crop debris		25.00	
Land rental		100.00	**6.0**
Total cost		1680.60	**100.0**

a) Labor cost for planting, manual weeding, and fertilizer application is M$9.00 per man-day.
b) Labor cost for chemical spraying of herbicides is M$13.00 per man-day.
Approximate rate of exchange: US $1.00 = M$2.35.
Source: Chan et al., 1983.

c.i.f. (cost, insurance, and freight) prices of Thai tapioca starch, tapioca chips, and maize. All three sets of prices fluctuate considerably from year to year as well as seasonally, in response to world supply and demand conditions.

Cassava production in Peninsular Malaysia is concentrated in two states. In 1981, Perak accounted for 80% and Kedah for 6% of the area under cassava (Table 4). Each of the other nine states have at least a few hectares. Perak usually has had more than 50% of the area planted. Production statistics for Sabah and Sarawak are lacking.

Cassava, being a field crop of rather longer duration than groundnut or sweet potato, has less flexibility for fitting into annual cropping patterns. For this reason, monocropping of cassava is the most widespread cropping system in Perak and Kedah. For example, in 1981, 75.6% of the cassava in Peninsular Malaysia was monocropped (Malaysia, 1981a). Mixed cropping accounted for the rest of the cassava area, usually taking the form of an intercrop in young rubber, coconut, and fruit tree holdings. Less frequently, cassava is planted as the main crop with other short-term field crops (such as maize and groundnut) or with vegetables as intercrops. Rotational cropping of cassava with these short-term crops is also practiced to some extent.

Although cassava has traditionally been a crop of the small farmer, large-scale cassava plantations have been tried. One major plantation has been operating for about 11 years, but three other large plantations have ceased to operate due to managerial problems. This is another reason for the recent decline in cassava area.

Principal constraints on cassava yields may be traced to inadequate, or lack of, technological and managerial skills in its production, edaphic or climatological problems, and socioeconomic attitudes towards the crop. Cassava research strategies and objectives in MARDI (Malaysian Agricultural Research and Development Institute) are geared towards solving these problems as far as is feasible. Production technology to improve yields is generated through research in breeding, agronomy, and pathology. At the same time, attempts are made to reduce production costs by using more effective cultural, agronomic, and crop protection practices, as well as by using labor-saving technology such as the mechanization of labor in intensive field operations (e.g., planting and harvesting).

Uses, Markets, and Trade

In Malaysia, cassava is used in three ways: as fresh roots for direct human consumption, processed into starch of various forms for both

Table 4. **Area planted to cassava by state, Peninsular Malaysia, 1970-1981.**

State	Area (ha)											
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Johor	2,246	2,196	830	493	312	1,582	2,097	1,787	2,359	251	246	440
Kedah	478	673	417	2,588	1,943	4,510	4,103	2,803	1,260	869	660	614
Kelantan	522	602	394	406	464	503	458	513	308	209	214	243
Melaka	126	111	155	179	114	68	31	88	43	10	22	5
Negeri Sembilan	354	104	109	125	62	92	106	121	47	56	56	55
Pahang	2,415	1,763	1,497	242	301	305	155	143	1,000	124	76	101
P. Pinang & Seberang Perai	327	162	167	280	318	244	275	249	175	144	35	36
Perak	8,840	7,743	7,571	5,161	5,909	5,556	11,229	13,172	11,188	14,188	10,851	7,748
Perlis	38	62	30	24	14	50	81	87	9	3	9	9
Selangor	1,400	1,034	1,564	1,799	1,596	1,729	1,930	1,243	1,132	546	157	150
Terengganu	470	372	259	381	389	301	443	269	294	235	186	198
Total	17,456	14,822	12,993	11,678	11,422	14,940	20,908	20,502	17,815	16,635	12,512	9,599

Source: Malaysia, 1981a.

human consumption and industrial use, and chopped and dried as chips for livestock feed. The amount of fresh roots used in direct human consumption is very small; it is consumed not as a staple but as a snack. Roots for this use are grown almost entirely in backyard kitchen gardens for home consumption.

There does not appear to be an organized market for fresh roots used for food and, because they are grown in backyard gardens, data on these roots does not enter national or state production or consumption statistics. Sweet varieties, the most popular being Medan, are grown for this use. Bitter varieties, such as Black, Green, and Red Twigs, are grown for the starch and animal feed markets. While it appears that about 90% of fresh roots are processed into starch and about 10% into chips for animal feed, the allocation of roots between the markets depends on international and domestic prices.

Unnevehr (1982), in a study of cassava price behavior on Java, developed a conceptual model of cassava price determination that is useful in describing the determination of cassava prices in Malaysia. The model can be applied to countries that are such small traders in the world cassava market that they face "nearly perfectly elastic world demand and supply for these products. If all cassava prices are expressed in fresh root equivalents, [then] domestic prices are determined by the intersection of domestic supply with a kinked demand curve that is flat where export or import prices prevail. Between these two prices, domestic demand, [which is] a function of [cassava's] own price and the prices of other substitutes, prevails." (Unnevehr, 1982).

The sloping portion of the kinked demand curve thus represents a band within which domestic prices may move. The width of the band depends on: (1) the cost of transportation between importing and exporting countries; (2) trade policies, such as taxes, subsidies, and quotas; and (3) physical conversion rates from fresh roots to the particular processed product.

In the Malaysian case, the upper limit of the band can be represented by Thai f.o.b. (free on board) starch prices plus transport costs of starch from Thailand to Malaysia, plus Malaysian import tax on starch. (Import taxes and export subsidies widen the price band, while export taxes and import subsidies narrow it.) The upper limit is also represented by the c.i.f. price of Thai starch in import markets in which Malaysia could compete, minus transportation costs from Malaysia to those markets.

The lower limit of the Malaysian price band is slightly more complicated. At some price, of course, Malaysian farmers would simply stop producing cassava. Unnevehr describes the lower end of the Javanese price band as being the price of Thai tapioca pellets c.i.f. EEC (European Economic Community) ports, minus the cost of transporting Javanese pellets from Java to EEC ports. The same reasoning would hold for Malaysia, i.e., conceptually, the lower end of the Malaysian price band is the price of Thai tapioca chips c.i.f. EEC ports (actually, price afloat Hamburg or Rotterdam) minus the cost of transport from Malaysia to Hamburg or Rotterdam. However, a price such as this would only be hypothetical because Malaysia has not had the experience, nor does it have the infrastructure, to export chips to the EEC.

Small quantities of chips are exported to Singapore for use in livestock feed. In some years, small quantities of chips are also imported into Malaysia from Thailand for use in animal feed. While the c.i.f. price of maize (Malaysia imports all the maize used in animal feed) certainly provides an upper bound for Malaysian chips, it is not the effective upper bound for fresh roots because the upper bound for starch is higher. The c.i.f. maize and soybean meal prices to Singapore and Malaysia, however, determine how much the livestock feed compounders in either country are willing to pay for cassava chips. Thus, the price of Singapore chips effectively sets the lower bound on a fresh root equivalent basis for fresh roots produced in Malaysia.

Tunku Mahmud (1984) suggested various equations for the supply of cassava starch and the demand for chips. These were significant at the 5% level of probability. The Cobb-Douglas logarithmic equation was used to predict the supply of starch using the variables average annual starch price, average root price in the preceding year, and total annual rainfall in Perak. The supply curve was found to be inelastic, and both root price in the preceding year and rainfall were significant in determining starch supply.

A linear regression equation between annual chip price and the variables chip quantity used annually, average annual soybean and maize prices, and production volume of mixed poultry feed, revealed a very elastic demand for chips. Maize price was the strongest determinant of chip price, while soybean price had an important inverse relationship with chip price (since soybean provided the protein lacking in cassava).

Non-significant regression equations were obtained for cassava starch demand and chip supply. Tunku Mahmud used only the variables annual prices of cassava starch, corn flour, and monosodium glutamate to explain the annual demand for cassava starch. If the Thai cassava starch price had been included as a variable (as suggested by Unnevehr, 1982), a better relationship might have been obtained. For the supply of chips, only the variables chip price and root price in the preceding year were used for the regression. As chip production is usually determined by any excess over the demand of roots for starch production, the price of cassava starch, if included as a variable, might have produced a more significant regression.

Average annual ex-factory prices for the major processed cassava products and fresh roots at a major domestic market are given in Table 5. Factories are now required by law to report production and sales. Production data on various cassava products are shown in Table 6 for 1972-1980. The terms starch and flour are used interchangeably in Malaysia with respect to cassava, and refer to the same product which is cassava starch. Pearl and flakes are starch with further processing. Flake production was of minor importance in earlier years and has now almost disappeared. An estimated breakdown of domestic end uses of starch is shown in Table 7. While the relative amounts going into the various uses may be reasonable, the actual figures (as reported from factory production) may not be reliable. The import and export figures in Tables 8 and 9 are probably more accurate. Figure 1 compares imports, exports, and local consumption from 1975-1981.

The term refuse, as reported in Table 6, is the same as the term wet waste reported in Table 5, and refers to the remnants from starch factories after the starch has been extracted from the peeled and ground roots. It is used as pig feed and factories prefer to sell it (or feed it to their own pigs) in the wet form. Because refuse begins to sour about 24 hours after processing, any stocks left after 24 hours must be dried. Once dried, these stocks can be stored for up to 6 months.

Table 5. **Average annual ex-factory prices (M$/100 kg) of cassava products at Penang, Peninsular Malaysia, 1972-1981.**

Year	Starch	Flakes	Pearl	Waste (dry)	Waste (wet)	Chips	Roots
1972	21.17	30.25	22.34	9.44	2.76	14.27	3.53
1973	30.63	33.83	33.30	17.15	2.59	15.07	4.65
1974	40.17	59.55	43.45	21.29	3.40	26.17	6.37
1975	35.28	57.48	37.34	21.67	3.38	22.82	5.99
1976	40.02	36.72	42.29	22.28	3.35	21.45	6.35
1977	44.77	n.t.	47.74	20.10	3.60	n.t.	7.23
1978	40.73	n.a.	46.29	17.48	2.37	24.54	5.49
1979	50.87	n.a.	55.92	15.30	2.06	26.24	5.84
1980	70.10	n.a.	81.91	21.25	3.12	36.50	9.52
1981	67.88	n.a.	74.72	23.00	3.34	41.86	8.73

n.t. = no transaction.
n.a. = not available.
Approximate rate of exchange: US $1.00 = M$2.35.
Source: Federal Agricultural Marketing Authority (FAMA): 1972-77, quarterly commodity statistics; 1980, annual commodity statistics; 1978-79 and 1981, personal communication.

Table 6. **Production of cassava products (t), Peninsular Malaysia, 1972-1980.**

Year	Cassava starch	Pearl	Chips	Refuse
1972	35,646	11,226	7,145	96,512
1973	37,830	12,304	7,371	106,481
1974	39,240	10,851	5,765	109,328
1975	42,662	10,076	22,629	93,872
1976	57,541	10,544	16,842	122,015
1977	52,131	10,269	16,786	107,175
1978	44,782	12,806	17,050	100,929
1979	47,909	11,572	16,606	93,043
1980	39,930	9,898	8,972	68,591

Source: Monthly statistical bulletin, Department of Statistics, Kuala Lumpur, Peninsular Malaysia.

Table 7. **Estimated monthly cassava starch consumption by end use, Malaysia, 1982.**

End use	Quantity (t)
Monosodium glutamate	800
Glucose	500
Confectionery	300
Biscuit	400
Textile and others	3,000
Total	5,000 (60,000 yearly)

A brief description of the starch industry may be useful to the reader. Prices are quoted as ex-factory. Most factories employ a buyer who travels through the root-producing areas bidding on fresh roots delivered to the factory, with prices subject to adjustment for starch content. The buyer brings root samples to the factory for testing by a simple gravity method involving water displacement adapted from the Thai method. The base price is for roots having 26% starch. The price is reduced by M$0.20 per 1% decrease in starch content below 26%. The usual range in starch content is between 21% to 26%. (Ooi H.B., personal communication). Each factory derives its base price by considering starch prices at Ipon and Penang and internal processing cost. If the seller accepts the starch content discounted price then a delivery date is set and the farmer/producer is responsible for the cost of delivery, or delivery itself, of the roots to the factory.

Table 8. **Imports of cassava products (t) into Malaysia, 19709-1981 (all used for animal feeds).**

Year	Dried chips	Chips, other	Pellets	Other	Refuse	Total
1970	*	9			7,275	7,284
1971	19	6			7,030	7,055
1972	*	7			6,067	6,074
1973	227	5			3,582	3,814
1974	5,264	19			11,971	17,254
1975	2,117	22			4,970	7,109
1976	384	7			1,833	2,224
1977	10	*			3,689	3,699
1978	2,705		*	34	1,732	4,471
1979	52		-	8	805	865
1980	*		-	2	-	2
1981	2,051		*	8	624	2,683

* Less than 1 ton.

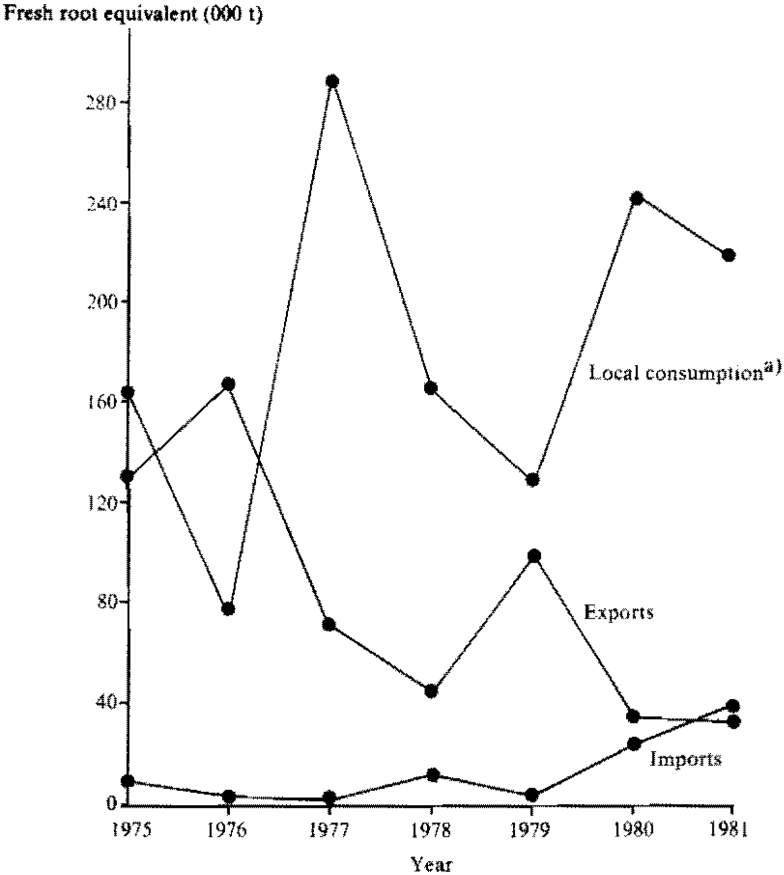
Source: Malaysia, 1981c.

Table 9. **Export of cassava products (t) from Malaysia, 1970-1981.**

Year	Starches & Flour	Flakes	Pearl	Other tapiocas	Total
1970	11,753	3,566	12,018	549	27,886
1971	6,831	517	9,947	55	17,350
1972	14,948	954	10,034	512	26,448
1973	15,555	1,477	10,561	645	28,238
1974	8,426	366	9,863	340	18,995
1975	12,949	701	8,030	393	22,073
1976	18,302	494	9,197	550	28,543
1977	7,595	295	3,236	1,018	12,144
1978	2,942	366	2,622	1,614	7,544
1979	10,248	788	4,850	1,026	16,912
1980	1,649	27	4,148	118	5,942
1981	1,305	83	3,841	434	5,663

Source: Malaysia, 1981c.

A survey conducted in mid-1982 found that none of the factory managers interviewed was purchasing standing crops to be harvested by the factory. Neither were any loans being extended to farmers prior to harvest, although they reported having done so in the past, and would do so again, if a regular supplier requested a loan and the factory was sufficiently solvent to make the loan. They also reported that they normally buy from regular suppliers year after year.



a) Local consumption was calculated from figures on fresh root production (Table 1), and imports and exports in fresh root equivalents (Tables 8 and 9), using the conversion rates of 17% for starches and 38% for chips.

Figure 1. *Imports, exports, and local consumption of cassava (fresh root equivalent), Malaysia, 1975-1981.*

Chye and Loh (1974) reported that in 1967 there were 46 cassava processing factories in Perak; 15 produced only starch, 27 produced only chips, and 4 produced both starch and chips. A 1982 study found only 11 factories operating in Perak (8 producing only starch and 3 producing only chips). The decline in numbers was accompanied by an increase in average size of the remaining plants, showing that total processing capacity had actually increased.

The technologies being used by Malaysian starch factories can be roughly subdivided into two broad categories: modern and traditional.

Modern plants use foreign manufactured equipment and are basically countinuous processing plants with centrifugal separation and flash drying of starch. Traditional plants use the sedimentation technique and batch processing. Traditional plants can be further subdivided into those which use only sedimentation and those which use a centrifuge to expel part of the water before placing the material into tanks for the sedimentation process. It appears that 2 of the 15 starch factories in Peninsular Malaysia use modern equipment and the remainder use only traditional methods. It should be pointed out that the two with modern equipment also use traditional methods for part of their production. A flow chart showing the steps involved in the traditional method for producing starch and pearls is shown in Figure 2.

The compound feed industry has been growing very rapidly during the past decade, as shown in Table 10. Part of the growth is due to an increase in livestock production brought about by growth in population and per capita incomes. Part is due to modernization of livestock production, with even small producers shifting from using table scraps and local refuse for feed to using purchased compound feeds. Livestock feed is discussed further in the next section.

Production and Use Potentials

Potential uses for cassava in Malaysia are varied and appear promising. Cassava has potential in the fresh food market, the starch market, the animal feed market, and the sweetener market. Its uses in the fresh food market are not considerable since cassava is used mainly as a snack food and not as a staple. The possibilities in the starch market are encouraging due to high demands for this product in manufacturing industries such as textile, paper, adhesives, and alcohol. Additional demands lie in the important area of the animal feed market. Annual importation of grain maize is high. Because the livestock industry is expected to grow at a fast rate, it would be advantageous to reduce maize imports by substituting more cassava into animal feed formulas. A reduction of sugar imports can also be accomplished if cassava produced in Malaysia is converted into high-fructose and glucose syrups. This is important because future expansion of sugarcane plantations is not probable. Other prospects lie in the production of gasohol fuel. The cost of oil and gas is expected to increase and cheaper energy sources should be investigated to reduce the existing over-dependence on petroleum fuels.

Fresh food market

Although no reliable figures are available on the volume of production of sweet cassava for human consumption, it can be safely presumed to be

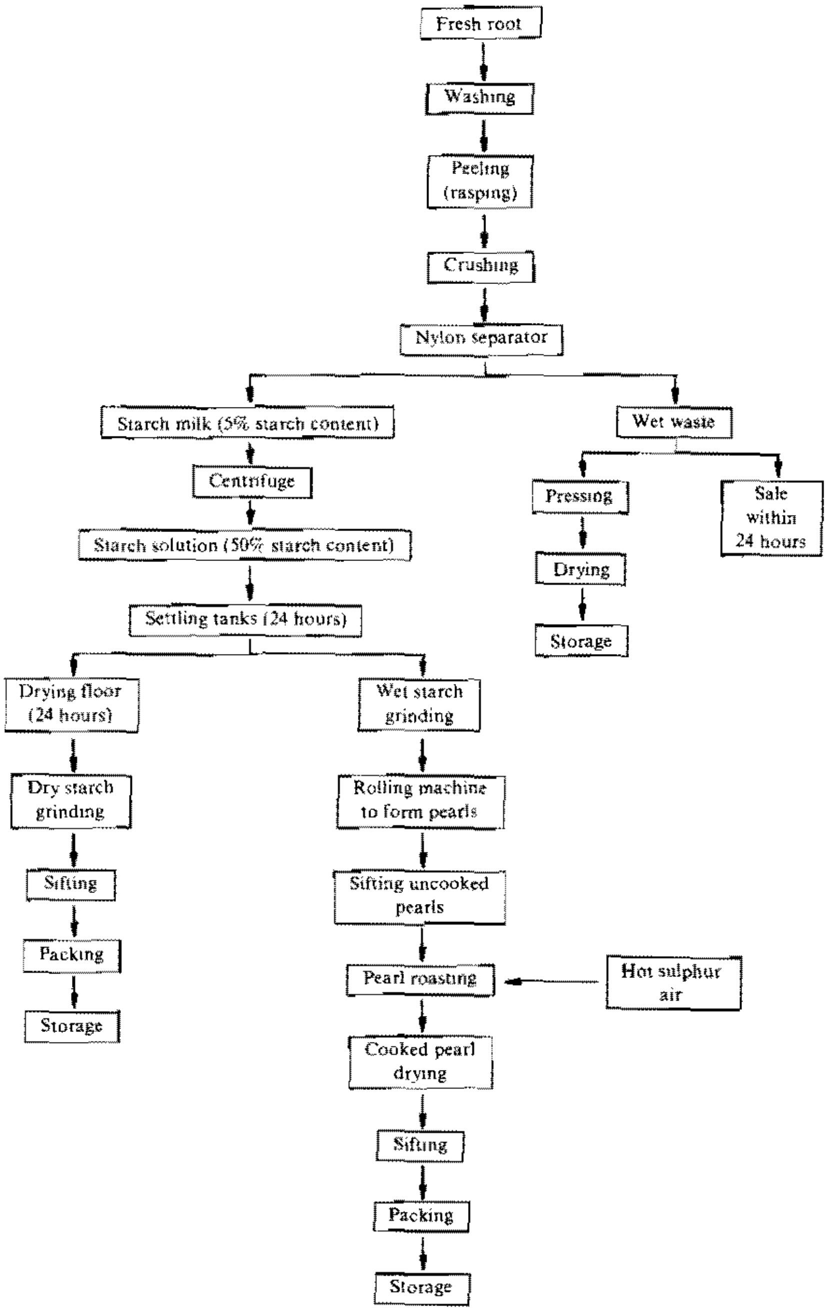


Figure 2. *Flow chart of traditional Malaysian cassava processing technology.*

Table 10. **Animal feed production (t), Peninsular Malaysia, 1972-1980.**

Year	Mixed poultry feeds	Pig feed	Milled wheat, bran, and pollards
1972	99,548	118,841	94,500
1973	117,148	103,056	94,012
1974	189,102	113,156	90,162
1975	191,900	123,740	88,974
1976	241,311	148,478	106,265
1977	272,311	113,851	115,789
1978	314,713	130,135	131,690
1979	334,588	122,731	116,313
1980	419,783	128,823	121,009

only a small fraction of the total cassava production figure. Because its principal use is as snack or dessert foods and not as a staple, any future significant growth in the demand for sweet cassava is unlikely.

Starch market

Cassava will remain an important source of industrial starch and high-quality starch (flour, flake, and pearl) destined for food industries in the future. It is probable that future expansion of cassava cultivation in the country will continue to find ready markets for its starch products in a local as well as international context.

Malaysia has long been exporting starch for industrial and food purposes to Singapore, Australia, Japan, the United Kingdom, some of the other countries in the EEC, Canada, and the United States. Declining trends in export figures for starches in the last few years (Table 9) are indicative either of reduced demand in these traditional overseas markets, or of increasing demand by domestic markets. Phillips (1978) suggested that the export market for cassava starch is not likely to grow in importance because of other competitors such as maize. He also suggested that domestic markets for cassava starch will become more important.

Local demand for starch should increase at a rapid rate equal to the demand for local food, textile, and other industries requiring starch as a raw material or as a necessary component. Important Malaysian industries that use starch include the manufacturers of monosodium glutamate and glucose (Chan et al., 1983). With the present government policy encouraging high technology industrialization, the growth rate of the manufacturing industries is projected to be 11% per annum over 1980-1985 (Malaysia, 1981b).

Animal feed market

A potential source of great demand for cassava lies in the animal feed industry. Presently, some 718,800 tons of grain maize worth M$290 million (1981 figures) are imported annually for the purpose of feed formulation. This demand for feed grains is expected to grow at a rate commensurate with the growth of the livestock industries. These are expected to expand faster than the population growth rate since there is a rising improvement in the standard of living. Research studies have already determined the feasibility of using cassava as a partial substitute in feed rations (particularly for pig and poultry). Levels up to 40% partial substitution have been found to be nutritionally sound. Currently, feed millers replace corn with cassava in feed formulations at levels of only 5% or so.

Although current use of cassava as an animal feed ingredient is minimal in comparison to the amount that enters the starch industry, its potential importance may be gauged by trends in the livestock sector. Cassava as an energy source has tremendous growth potential. It has the possibility of becoming not only a major feed ingredient for non-ruminant livestock species such as poultry and pigs, but also a concentrate component for feeding lactating ruminants. Presently, this energy-providing role in animal diets is largely constituted of grain maize, which is being imported in increasingly larger quantities. The livestock sector has been expanding at a rate of 2.2% per annum over the last decade (1970-1980). While the dairy and beef sub-sectors have not shown significant growth, the pig and poultry sub-sectors have been keeping pace with consumption. Over the 1980-1985 period, these non-ruminant categories are expected to grow at a rate of 5% per annum (Radin, 1983).

Although grain maize requirements of the livestock sector were projected to grow at 10% per annum (Devendra, 1977), actual maize imports rose at the rate of 39% per annum over the period 1975-1981, from 215,200 to 718,800 tons. If this trend holds, the amount of maize required in 1990 would be over 2.5 million tons. It is highly unlikely that this volume of grain could be grown locally, and efforts should be taken to minimize part of the imports by local energy substitutes. Currently, broken rice, sorghum, rice bran, wheat pollard, brewers' dried grains, and cassava are locally available and are being used to a small extent to partially replace maize in feed formulations. Which substitute is used and in what proportions, however, is largely dependent on relative prices and availability in the market.

Research on non-ruminant nutrition has shown that although up to 40% of a feed ration may be replaced by cassava, 30% is a safer and more practical level. Problems of diarrhea in chickens and splay legs in litters from sows fed with diets having more than 30% cassava are sometimes encountered (Hew, 1978).

To compare the competitiveness of cassava as a feed ingredient with corn and with broken rice (which is a more commonly used substitute), an example is given in Table 11 for a layers' diet. Cassava and broken rice were substituted at 30% in two separate formulations and compared with the basic maize diet. At current prices (April 1984), the cassava-maize diet is the most expensive, while the cheapest is the broken rice-maize diet. Furthermore, the cassava-maize diet has a much lower metabolizable energy (ME) content, but this level is still within acceptable limits (Yeong Shue Woh, personal communication).

Reasons for the higher price of the cassava-maize diet include the need for a higher soybean meal content and the inclusion of palm oil. This is because the ME of cassava is lower than that of maize or broken rice for poultry. Therefore, part of the energy requirements have to be satisfied by palm oil. The crude protein content of cassava is also low (Table 12) and has to be supplemented with more soybean meal.

However, when the price of cassava is M$0.29/kg (as it was in June 1983), instead of M$0.36, the cassava-maize diet is cheaper than the maize diet, although still more expensive than the broken rice-maize diet (Table 13). This is because relative prices of feedstuffs are closely related and tend to rise and fall together. Thus it is hardly surprising that feed millers are presently using only about 5% cassava in formulating their rations (Chan et al., 1983), and that broken rice is a more popular substitute for maize.

Another example is given in Table 14, where different levels of cassava were used in a diet for grower pigs. Only the diet with 10% cassava was cheaper than the basic maize diet at April 1984 prices. At the lower June 1983 prices, all the cassava-maize diets were competitive, with 40% being the cheapest. However, other substitutes may be even cheaper.

Three points can be made from the above examples:

1. Whether cassava or another locally available energy substitute is used to replace some of the maize in feed formulations depends on their relative prices.

2. The level of cassava used in a diet is again dependent on its price.

3. The reduction in cassava price necessary to bring cassava into the rations presented is on the order of 5% (1983 prices) to 15% (1984 prices), all other prices held constant.

Table 11. **Formulations of layers' diet based on maize, cassava, and broken rice at April 1984 prices for feedstuffs, Peninsular Malaysia.**

Ingredients	April 1984 price (M$/kg)	Maize diet formula 1 Ingredients (%)	Maize diet formula 1 Cost (M$)	Cassava-maize diet formula 2 Ingredients (%)	Cassava-maize diet formula 2 Cost (M$)	Broken rice-maize diet formula 3 Ingredients (%)	Broken rice-maize diet formula 3 Cost (M$)
Maize	0.44	63.6	27.98	27.0	11.88	32.5	14.30
Cassava chips	0.36	-	-	30.0	10.80	-	-
Broken rice	0.40	-	-	-	-	30.0	12.00
Soybean meal	0.75	21.0	15.75	26.6	19.95	22.1	16.58
Palm oil	1.55	-	-	1.0	1.55	-	-
Subtotal: Cost of variable ingredients			43.73		44.18		42.88
Fish meal	1.00	4.0	4.00	4.0	4.00	4.0	4.00
Grass meal	0.38	2.0	0.76	2.0	0.76	2.0	0.76
Limestone powder	0.06	8.0	0.48	8.0	0.48	8.0	0.48
Dicalcium phosphate	0.90	1.0	0.90	1.0	0.90	1.0	0.90
Vitamin & mineral premix	11.00	0.1	1.10	0.1	0.10	0.1	1.10
Salt	0.15	0.3	0.05	0.3	0.05	0.3	0.05
Total		100.0	51.02	100.0	51.47	100.0	50.17
Metabolizable energy (kcal/kg)		2790		2660		2720	
Crude protein (%)		17		17		17	

Approximate rate of exchange: US $1.00 = M$2.29.

Source: Yeong Shue Woh, personal communication.

Sweetener market

A more immediate possibility for further cassava exploitation is the reduction of sugar imports. In Malaysia, where only 15% of the sugar requirements are met by local production and no likelihood for future expansion in sugarcane cultivation exists, increasing amounts of sugar will have to be imported to satisfy the country's needs. In 1981, around 457,790 tons of sugar (raw, refined, and in various preparations) were imported at a value of M$510 million (Malaysia, 1981c).

The available technology for converting cassava into high-fructose and glucose syrups provides a means of substituting at least part of the demand for sugar. Presently, fructose and glucose syrups are particularly suited for canning as well as for the manufacture of jams, jellies, confectionery, and ice cream. High-fructose syrup (HFS) has a wide application in the soft drink industry because of its concentrated sweetening effect (Vuilleumier, 1982). Of all starch-derived sweeteners, HFS competes directly with sugar. Other uses of the syrup, such as in food processing, food preservation, and food manufacturing, remain to be explored.

Future Supply

The supply prospects are not nearly as promising as the use potentials. The basic economic fact is that, using current production technology, cassava is not as profitable as most production alternatives at prices which potential users are willing to pay. Given current profit levels and government policy, cassava is basically a scavenger for land. In Perak over 70% is grown illegally on land allocated for other purposes. If those producers had title or legal long-term lease rights to the land they now have in cassava, it is very likely that they would quickly shift to a lucrative plantation crop. Land on which it is legal to grow cassava mainly comprises:

- Short-term lease land prior to its further development into plantations or land schemes,
- Mining reserve land, waiting to be mined,
- Land disturbed by mining (mining spoils),
- Shallow peat soils,
- Inter-row areas during the initial establishment and juvenile years of rubber, coconut, or fruit plantations (small holdings only).

Table 12. **Energy and protein contents of various carbohydrate sources used in compound feeds for non-ruminants, Peninsular Malaysia.**

	Poultry Metabolizable energy (kcal/g)	Pig Digestible energy (megajoules/kg)	Crude protein (%)
Maize	3.430	15.8	8.8
Cassava	3.000	14.2	1.8
Broken rice	3.200	15.6	7.5
Rice bran	2.440	10.4	10.0
Wheat pollard	2.500	12.8	15.0

Source: Yeong Shue Woh, personal communication.

Because plantation crops are eight to ten times more profitable than cassava, they will be planted on all permissible Class 1 and 2 soils.* Intensive vegetable production is highly profitable and competes not only for mining spoils which are near population centers and hence active vegetable markets, but also for shallow peat soils, some of which are coming out of declining pineapple production. Oil palm also competes for shallow peat soils. Malaysia, therefore, has very little land available for low-profit crops (at present prices) such as cassava.

The magnitude of the technological change necessary to provide a viable cassava production sector is considerable. Cost of production per unit of output would have to be reduced by at least 25%, probably 50%, for cassava supply to meet potential demands at realistic relative prices. If mechanized production and harvesting technology could be developed at per unit costs 25-50% lower than present, then plantation production of cassava could probably be carried out on some of the large tracts of peat soils found in the country: 813,000 ha in Peninsular Malaysia (Coulter, 1957), 1,466,000 in Sarawak (Anderson, 1964), and 86,000 in Sabah (Thomas & Allen, 1965). Research to date has shown cassava to be adapted to the low pH conditions in peat, giving it an immediate advantage over many other crops. Nevertheless, other limiting factors in peat, such as nutrient deficiencies and high fluctuating water tables, have to be investigated closely before cassava cultivation on this soil is economically feasible.

Cassava cultivation on mineral soils will only be expanded if a technology is developed that substantially increases productivity and

* Class 1 and 2 soils refer to soils classified according to their suitability for cultivation. Class 1 soils have no or very minor limitations to crop growth, while class 2 soils have moderate limitations to crop growth (Wong, 1974).

Table 13. **Formulations of layers' diet based on maize, cassava, and broken rice at June 1983 prices for feedstuffs, Peninsular Malaysia.**

Ingredients	June 1983 price (M$/kg)	Maize diet formula 1		Cassava-maize diet formula 2		Broken rice-maize diet formula 3	
		Ingredients (%)	Cost (M$)	Ingredients (%)	Cost (M$)	Ingredients (%)	Cost (M$)
Maize	0.38	63.6	24.17	27.0	10.26	32.5	12.35
Cassava chips	0.29	-	-	30.0	8.70	-	-
Broken rice	0.33	-	-	-	-	30.0	9.90
Soybean meal	0.65	21.0	13.65	26.6	17.29	22.1	14.36
Palm oil	0.78	-	-	1.0	0.78	-	-
All other ingredients constant		15.4		15.4		15.4	
Cost of variable ingredients		100.0	37.82	100.0	37.03	100.0	36.61

Approximate rate of exchange: US $1.00 = M$2.35.

Source: Yeong Shue Woh, personal communication.

Table 14. **Formulations for grower pigs based on different levels of cassava, Peninsular Malaysia.**

Ingredients	April 1984 price (M$/kg)	Formula 1		Formula 2		Formula 3		Formula 4		Formula 5	
		%	Cost (M$)	%	Cost (M$)	%	Cost (M$)	%	Cost (M$)	%	Cost (M$)
Maize	0.44	63.3	27.85	51.3	22.57	38.3	16.85	26.4	11.62	13.8	6.07
Cassava	0.36	-	-	10.0	3.60	20.0	7.20	30.0	10.80	40.0	14.40
Soybean meal	0.75	14.5	10.88	16.5	12.38	18.5	13.88	20.0	15.00	21.0	15.75
Fish meal	1.00	5.0	5.00	5.0	5.00	6.0	6.00	7.0	7.00	8.0	8.00
Rice bran	0.38	15.0	5.70	15.0	5.70	15.0	5.70	15.0	5.70	15.0	5.70
Salt	0.15	0.5	0.08	0.5	0.08	0.5	0.08	0.5	0.08	0.5	0.08
Calcium phosphate	0.90	0.6	0.54	0.6	0.54	0.6	0.54	0.6	0.54	0.6	0.54
Vitamin-mineral premix	11.00	0.1	1.10	0.1	1.10	0.1	1.10	0.1	1.10	0.1	1.10
Limestone	0.06	1.0	0.06	1.0	0.06	1.0	0.06	1.0	0.06	1.0	0.06
Total		100.0	51.21	100.0	51.03	100.0	51.41	100.0	51.90	100.0	51.70
	June 1983 price										
Maize	0.38		24.05		19.49		14.55		10.03		5.24
Cassava	0.29	0.0	-	10.0	2.90	20.0	5.80	30.0	8.70	40.0	11.60
Soybean meal	0.65		9.42		10.72		12.02		13.00		13.65
Fish meal	0.81		4.05		4.05		4.86		5.67		6.48
Cost of variable ingredients			37.52		37.16		37.23		37.40		36.97
Digestible energy (kcal/kg)		3353		3341		3345		3359		3339	
Crude protein (%)		16.2		16.2		16.3		17.1		17.3	

Approximate rate of exchange: US $1.00 = 2.29 in April 1984; US $1.00 = M$ 2.35 in June 1983.

Source: Ong Hwee Keng, personal communication.

reduces costs and labor requirements. Since labor is becoming a scarce resource in the agricultural sector, mechanization possibilities must be fully explored.

The government is concerned with the high annual maize imports for livestock feed. In order to encourage greater utilization of local substitutes, such substitutes must be readily available to feed mills. Feed millers rely almost entirely on maize imports in formulating rations, not because of any particular prejudice against cassava, but because cassava is notoriously unreliable in supply. In an effort to rectify this situation, proposals have been made to promote cassava cultivation on peat.

If cassava were more steadily available and used in animal feed at a 20% level, it would represent a four-fold increase over the current 5% level of utilization. Maize in a basic diet is used at levels of about 65%. A 20% level of cassava would imply a 13% substitution of the maize component (20% of 65%). Using the 1983 figure of maize imports, i.e., 718,800 tons, this amounts to 93,444 tons of cassava chips (13% of 718,800 tons), and involves immediate savings of M$37.7 million in foreign exchange (13% of M$290 million). Using a 38% conversion rate of fresh roots to chips, the amount of fresh root production would be about 245,900 tons.

Assuming a mean yield of 25 tons/ha, about 10,000 ha of land would need to be planted with cassava. This scale of operation, to be worked by small farmers, has been proposed for the near future.

Similarly, significant savings in foreign exchange may be effected if the government were to give support to cassava production for the purpose of manufacturing high-fructose and glucose syrups, thus reducing Malaysia's high and expensive sugar imports.

Policy Implications

The view of cassava's future expressed in this paper can be summarized as optimistic in terms of potential sources of utilization but as pessimistic in terms of potential supply. Demand for starch and derived products can be expected to grow steadily as a result of increases in per capita income, population, and industrialization. This demand can be met by domestic production of cassava starch, imports, or a combination of both. If domestic production exceeds demand at world prices, there is limited scope for exports. Demand for livestock feed can be expected to grow rapidly due to increases in per capita incomes, population, and adoption of modern livestock production techniques, especially the use of compound feeds. Cassava is now of minor importance in compound feeds, but could become an important component (up to 30-40% of the total) if feed mills can be assured of a steady supply at prices competitive with imported maize and domestically produced rice bran and broken rice. It should also be pointed out that because rice bran and broken rice are by-products of rice production, which itself has limited scope for expansion, the supply of these two energy substitutes is inelastic. Thus, they eventually will be unable to keep pace with the growing demand for carbohydrate sources in compounded feed.

The future of cassava production appears rather dismal. Current hectarage is the lowest in 20 years, and appears to be headed even lower as authorities take action against illegal production. The consequences of such drastic reductions in cassava production are increased reliance on imported starch and imported maize.

The cassava industry in Malaysia illustrates the frequent conflict existing between the policy objectives of economic efficiency and food security. Given the Malaysian resource endowment and land use policies, as well as a large, low-cost cassava and maize producer nearby (Thailand), the economic efficiency criteria would probably lead to a policy which neglects the domestic cassava industry, imports maize for animal feed, imports starch as needed, and concentrates on highly profitable plantation crops. The government, however, places some weight on the policy objective of not being totally dependent upon imported ingredients for livestock feed. Since cassava is the logical source of energy for livestock rations, a government policy supporting the cassava industry would appear to contribute to achieving that policy objective.

Support could take several forms. The first would be a strong research drive on cost-reducing technology. The second would be a program encouraging feed compounders to include a sizable proportion (within safe levels) of cassava in livestock compound feeds. This might be achieved in several ways, such as promoting plantation cultivation of cassava reserved for feed mills, requiring feed compounders to purchase a fixed amount of cassava for every ton of maize imported, diversion of roots from starch factories to feed compounders, or allowing importation of Thai chips in years of short Malaysian root production. However, encouragement programs can only work if the development of appropriate cassava technology precedes them.

A third form of support would be to initiate policies promoting the production of cassava on peat soils with low opportunity cost. It was previously estimated that increased cassava use in compounded animal feeds, up to 20% of the total ingredients would absorb the production from about 10,000 ha of peat soils. There are more than 2 million hectares of peat soils in Malaysia, about 1 million of which may be shallow enough to be suitable for growing cassava. Not only is 10,000 ha only 1% of that amount, but 8,000 ha are already available on small holdings which have abandoned pineapple production. Thus the establishment of 10,000 ha of small holdings in cassava seems to be a reasonable and feasible target. As the demand for starch grows, expansion of cassava to an additional 10,000 ha, by either smallholders or by plantations, is probably also feasible. However, if an economically feasible expansion is to take place, it is necessary to have a government policy which supports this expansion and new technology.

Acknowledgements

We are indebted to Dr. Yeong Shue Woh and Mr. Ong Hwee Keng of the Livestock Research Division, MARDI, for their help in formulating the alternative diets for poultry and pigs, respectively. We also wish to record our appreciation of Mr. Chan Seak Khen, cassava agronomist at MARDI, for his constructive suggestions.

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Cassava in the Agricultural Economy of Sri Lanka

S.D.G. Jayawardena

Introduction

Cassava was introduced to Sri Lanka in the year 1786 from Mauritius by the Dutch governor Van der Graef. The only subsequent recorded importations were made in 1821 and 1917, and these too were from Mauritius. Since then cultivation of cassava has been mainly confined to peasant settlements or intercropped in young rubber and coconut plantations.

As in most other tropical countries, root and tuber crops in Sri Lanka have received very little attention either from scientists or in national production policies, especially when compared to cereals. This situation can mainly be attributed to the consumer preference for rice and wheat flour. Wheat flour is an important commodity due to the long established bread eating habits of a significant percentage of the population. Currently, annual wheat imports constitute a substantial drain on foreign exchange. In the context of providing food for the rapidly increasing population, which is estimated to grow to 21 million by the year 2000, root crops appear to have significant potential, especially at a time when rice production is becoming increasingly less profitable. Moreover, in Sri Lanka expansion of irrigated areas as a means of increasing rice production has reached a limit. On the other hand, the potential to produce food crops in upland areas remains unexploited.

Today in Sri Lanka cassava is consumed mainly by the poorest people, primarily because it is the cheapest source of food which can be consumed without additional inconvenience in preparation. Plantation workers and farmers constitute the major share of people who consume cassava. In this context, root crops in Sri Lanka stand out as one of the most important

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sources of energy for the working population who sustain the agricultural economy of the country.

Rice as the main food crop in Sri Lanka is becoming increasingly more costly due to its dependence on energy-based inputs for maximun production. Under such circumstances, cassava remains a potential food crop to be exploited during the next decade. The potential of cassava as a substitute for rice and wheat flour was amply demonstrated when cassava effectively bridged the food gap during the acute food shortages in the early 1970s. During that period the area under cassava increased significantly. However, with the increase in rice production and the assured supply of wheat flour imports during the late 1970s, the area planted to cassava has declined considerably (Table 1).

Production Areas

Cassava cultivation in Sri Lanka is primarily concentrated in the wet and intermediate zones, resulting in the formation of a very distinct production belt across these zones (Figure 1). Rainfall over the island follows a bimodal pattern under the influence of the northeast (October to February) and southwest (May to September) monsoons, forming two distinct seasons known as Maha and Yala, respectively. The wet zone receives rain from both monsoons, while 80% of the annual precipitation in the dry zone is from the northeast monsoon.

The distribution of rainfall in the dry zone coupled with soils which harden during dry periods makes it less favorable for successful cassava cultivation. However, on the southeastern coast where soils are light textured, 3,000-4,000 ha are cultivated to cassava during both seasons, mainly for direct consumption. In other areas of the dry zone cassava is cultivated mainly during the Maha season.

In the wet and intermediate zones cassava is cultivated during both seasons mainly as a backyard crop for direct consumption. However, in the districts of Gampaha and Kurunegala, cassava is intercropped with pineapple and coconut. The largest area of cassava in Sri Lanka is in the Kurunegala district in the intermediate zone, where the climate is ideal for the production of dried chips. It is in this area that cassava is processed for industrial use by producing dried chips. The area cultivated in cassava annually in this district is about 7,000 to 8,000 ha, which is mostly intercropped with coconut.

Table 1. **Area, production, and yield of cassava in Sri Lanka.**

Year	Maha season		Yala season		Total		Mean Yield (t/ha)
	Area (ha)	Production (000 t)	Area (ha)	Production (000 t)	Area (ha)	Production (000 t)	
1972	23,065.18	259.38	8,240.08	131.08	31,305.26	390.46	12.48
1973	21,046.55	349.27	30,425.91	261.74	51,472.46	611.01	11.87
1974	67,747.36	657.72	23,605.66	190.52	91,353.03	848.25	9.29
1975	46,018.21	436.76	33,210.93	330.22	79,229.14	766.96	9.68
1976	49,170.44	447.64	20,270.44	236.09	69,443.31	683.73	9.85
1977	39,345.74	413.48	15,230.76	131.29	54,576.05	544.78	9.98
1978	29,411.74	410.14	10,464.37	87.39	39,876.01	497.54	12.47
1979	16,043.03	160.40	17,504.85	203.75	33,548.17	364.16	10.85
1980	18,957.48	220.38	8,085.02	110.81	27,042.51	331.19	12.25

Source: Agricultural Statistics of Sri Lanka.

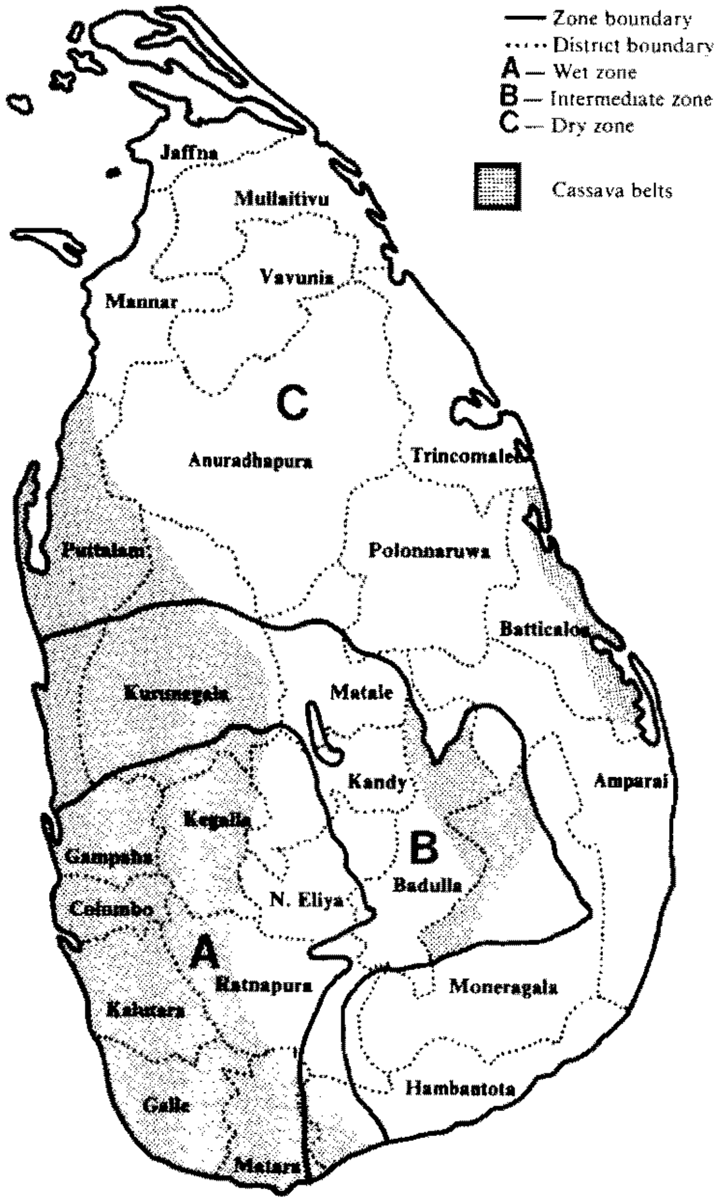

Figure 1. *Cassava production belts in Sri Lanka.*

Cropping Systems

Cassava grown as a backyard crop in the wet zone is brought to the market for sale either by the farmer himself or by a middleman. The area cultivated as a backyard crop varies from 100-1000 plants per farmer. Farmers generally harvest their crops when the rice prices in the market are relatively high, usually just before the harvest of the rice crop. Cassava produced as a backyard crop is rarely fertilized. Root yields in such systems vary from 8-12 tons/ha depending on the soil conditions. Under the backyard production systems the cost of production of cassava is negligible. If the farmer harvests the roots himself and transports them to the local market he can sell them for about 2000 to 3000 rupees (Rs) per ton (US $80-120). If the area in cassava is large, the farmer usually sells the produce to a middleman, who has to uproot and transport the cassava. He pays the farmer about Rs 1000-1500 (US $40-60) per ton. Generally, village farmers stagger their harvest and transport it by bullock carts to the village market for sale. Cassava cultivation as a backyard crop thus gives a considerable income to the farmer, and moreover, cassava is an assured supply of food.

When cassava is intercropped with pineapple or coconut the area can vary from 1-10 ha. In establishing new pineapple plantations, cultivators always plant a crop of cassava, mainly because the cost of establishing the cassava crop is very low. The land is plowed primarily to plant pineapple, but growing cassava helps to control weeds. Due to the application of coir dust as a mulch and fertilizer to pineapple, yields of cassava are high: around 15 to 20 tons/ha. Produce from such production systems is generally taken to the urban markets for sale, where the retail price of fresh cassava is about Rs 4.00/kg (US $0.16).

Production Costs

More than 75% of the total area in cassava falls under the above production systems, where planting material is not purchased, land is not prepared specially for cassava planting, and inorganic fertilizer is not applied. The other important feature of these production systems is that the farmers do not cultivate cassava season after season in the same land. Cassava is generally rotated with other crops. Under these production systems the profits are generally high, as the retail price of cassava in the village market is attractive. However, when cassava is cultivated on a commercial scale the cost of cultivation is estimated to be around Rs 5600 (US $225) per hectare. When cultivated on a commercial scale with recommended fertilizer applications, yields of about 20 tons/ha can be obtained.

At farm gate prices of about Rs 1500 (US $60) per ton, the profit per hectare is about Rs 24,375 (US $975). This level of profit in Sri Lanka is considered very attractive. However, due to difficulties in marketing large quantities of fresh cassava for direct consumption, cassava in Sri Lanka is rarely cultivated in extensive areas.

If the harvest is processed by chipping and drying, the selling price of a ton of dried cassava chips has to be more than Rs 3750 (US $150) to obtain the same profits as by selling fresh roots. The present market prices for dried chips are not sufficiently attractive to encourage large-scale cultivation of cassava for the dried chip industry in Sri Lanka.

Production Constraints

The principal cassava production areas are shown in Table 2. Cassava cultivation in Sri Lanka has traditionally been concentrated in the wet zone due mainly to climatic suitability. Moreover, the wet zone districts are the most densely populated. Government statistics indicate that most of the cassava production in Sri Lanka is consumed directly as fresh cassava. Since production of cassava mainly comes from home gardens, it is reasonable to assume that cassava produced in the wet zone is consumed there, because cassava is rarely transported by lorries to distant areas due to the high cost of transportation.

The main constraint in increasing the area under cassava in the wet zone is lack of unused agricultural land for large-scale cultivation. However, if intercropped with coconut, considerable areas of land could be found for cassava cultivation in the intermediate zone within the coconut triangle of the country. However, due to many technical reasons, farmers do not like to grow cassava in well-maintained coconut plantations as an intercrop. The present demand for cassava is in the form of roots for direct consumption, and as such it is not conducive to large production increases.

Research

In Sri Lanka 75 varieties of cassava have been identified and of these, 6 have been recommended for cultivation (Chandraratna and Nanayakkara, 1945). According to official records, no introductions have been made recently. Original attempts to improve yields and reduce hydrogen cyanide (HCN) content in cassava date back to 1943, when 21 hybrids were produced (Chandraratna and Nanayakkara, 1943). It is believed that what is cultivated today is the material multiplied over the years from these hybrids.

Table 2. **Cassava area (ha) by agro-climatic zones.**

	Season		Total
	Maha 80/81	Yala 81	
Wet & intermediate zones			
Colombo	815	764	1,579
Gampaha	2,187	2,000	4,187
Kalutara	1,215	977	2,192
Kandy	721	875	1,596
Matale	1,292	934	2,226
Nuwara Eliya	543	352	895
Galle	1,024	959	1,983
Matara	1,030	1,071	2,101
Ratnapura	2,668	2,369	5,037
Kegalle	1,895	1,927	3,822
Kurunegala	4,342	3,594	7,936
Badulla	1,775	647	2,422
Total	19,507	16,469	35,976
Dry zones			
Hambantota	935	494	1,429
Jaffna	707	449	1,156
Mannar	25	13	36
Vavunia	213	81	294
Mullaitivu	181	44	225
Baticaloa	994	701	1,695
Amparai	1,549	923	2,472
Trincomalee	683	344	1,027
Puttalam	1,920	2,263	4,183
Anuradhapura	1,324	563	1,887
Polonnaruwa	1,166	360	1,526
Moneragala	2,212	1,996	4,208
Total	11,909	8,231	20,140
Sri Lanka total	31,416	24,700	56,116

Source: Department of Agricultural Statistics, Sri Lanka.

In 1978 a root and tuber crop research project was initiated with the assistance from the International Development Research Centre. Activities over 3 years were mainly concentrated on germplasm collection and evaluation. Coordinated yield evaluation experiments in various agro-climatic regions have demonstrated a vast potential for increasing production in most parts of the country, including some of the dry zone areas. However, attempts to promote large-scale cassava cultivation for industrial use have had very little success due to many constraints, such as the high cost of cultivation and transportation, and lack of an assured market.

During the past 3 years of this research project, useful data pertaining to varieties, fertilizers, intercropping, and many other management practices have been obtained in different agro-climatic zones conducive to large-scale cultivation of cassava. Findings of this research project have created an awareness among policymakers, administrators, and agricultural extension and research workers of the potential of this crop for food as well as for industrial uses. The most striking research finding was the economic potential of intercropping legumes with cassava for a short period of about 3 months. This was clearly demonstrated in a cassava/legume intercropping trial, where four different types of legumes were tried (bushitao, greengram, blackgram, and cowpea) with two cassava varieties (Lenera and MU-22). The results indicated that the combinations of the cassava variety Lenera and the legume bushitao gave significantly higher monetary returns compared to all other combinations or to cassava monoculture.

Further investigations on the effects of spatial arrangements in legume intercropping with cassava demonstrated that the double-row arrangement of cassava was more favorable for higher root yields as well as for legume yields. Intercropping cassava under coconut in the low country intermediate zone, having an annual rainfall of over 1016 mm, indicated a maximum yield of about 15 tons/ha with the variety MU-71 after 12 months.

Investigations on cassava seedlings raised from naturally cross-pollinated seeds are being carried out to select for early maturity, high yield, high starch content, and low HCN content. A total of 1098 seedlings were raised; 94 plants giving yields of 3 and 5 kg at 6 and 12 months' maturity, respectively, have been selected. All these seedlings show significant diversity and could result in the emergence of some outstanding plant types. These selections are being further evaluated for higher yield and low HCN content. Investigations on yield response of cassava to nitrogen fertilizer have demonstrated a significant production potential at higher levels of nitrogen (Table 3).

During the first phase of the research project it was realized that the cultivation of cassava could be encouraged only if technologies are developed that are compatible with village farming systems. Farmers have adapted certain types of cropping combinations which give them a regular supply of vegetables and a regular cash income. In this respect, cassava intercropping with vegetables and legumes, where farmers' income, food, and nutritional levels can be elevated, is becoming acceptable.

Table 3. **Yield response of cassava to nitrogen fertilizer.**

Fertilizer level N (kg/ha)	Yield (t/ha)
0	5.66
22.5	11.32
45	16.63
67.5	25.72
90	31.04
112.5	39.43
56.25 + organic matter (20 t/ha)	32.21
0 + organic matter (20 t/ha)	13.54

Source: *Progress report 1983*, Division of Botany, Central Agricultural Research Institute.

It is proposed to exploit the industrial potential of this crop on well identified areas after careful economic studies with particular attention to transportation and processing costs. Phase one of the project has enabled an identification of the agronomic requirements, technological needs, and yield potential in different agro-climatic zones, as well as the potential of intercropping cassava with legumes and vegetables. It is proposed to carry out phase two of the project by giving more emphasis to distinct regional needs representing different agro-climatic regions, soil types, and farming systems. The project envisages varietal evaluation, intercropping combinations, cultural practices through adaptive farm-level research, and field trial programs carried out by the major regional agricultural research centers.

Uses

In 1981 the total production of fresh cassava was 526,000 tons. Of this, 157,000 tons were lost as waste (Table 4). The balance is reported to have been used totally for human consumption as fresh food. There is no reported use in industry. Per capita consumption of cassava was 24.57 kg/yr, supplying 105.68 calories (4.8% of the total calorie requirement) per day. Food requirement statistics of the government indicate that the production of fresh cassava is just meeting the calculated food requirements of roots and tubers (Table 5). According to these estimates the requirements in the year 2000 could be met by increasing the area of cassava by 10,000 ha at present average farm yields of 10 tons/ha. The area cultivated to cassava in 1981 was 1/3 of that in 1974.

Table 4. **Food balance sheet for roots and tubers, 1981 (population 14,988,000).**

Commodity (000 t)	Source		Distribution			Per capita consumption				
	Production	Imports	Seed	Waste	Food gross	kg/yr	g/day	cal/day	g protein/day	g fat/day
Potatoes	66.04	1.00	12.70	6.70	47.64	3.18	8.71	8.45	0.14	0.01
Cassava	526.01	0	0	157.80	368.21	24.57	67.31	105.68	0.47	0.13
Yams and sweet potatoes	158.61	0	0	47.58	111.03	7.41	20.30	24.36	0.24	0.06

Source: Statistical abstracts of the Democratic Republic of Sri Lanka.

Table 5. **Food requirements of Sri Lanka (000 t).**

	1981	1986	1991	1996	2001
Rice	1,510.89	1,658.93	1,801.98	1,940.00	2,073.13
Bread, wheat, flour, etc.	404.33	544.31	595.52	646.60	696.94
Coconut	476.09	526.18	575.09	622.98	669.46
Root and tubers	471.09	511.87	549.01	580.37	607.45
Sugar	185.46	203.67	221.31	238.20	254.56
Pulses	118.87	130.61	142.13	153.48	164.59
Meat, fish, etc.	419.18	463.97	508.13	552.28	595.86
Dairy foods	776.35	836.17	893.68	946.10	997.11
Vegetable leaves	240.20	264.13	268.36	307.19	326.46
Vegetable fruits	589.22	650.03	710.02	769.50	828.10
Ripe fruits	306.29	337.18	367.57	397.56	427.05
Beverages (tea, etc.)	67.72	75.10	82.38	89.70	96.93
Condiments and spices	135.37	150.14	164.69	179.32	193.80

Source: Booklet on projections of food requirements for Sri Lanka, Dept. of Census & Statistics.

The important consideration which emerges from this discussion is whether the present consumption rate of 24.57 kg/yr is justifiable when there is a calorie deficit among Sri Lankans. Should the per capita consumption of cassava be increased, and if so, what are the factors that limit this increase? Obviously, it is the limited demand for fresh cassava in the market that is discouraging the increase in production. Low demand for cassava is influenced by the prices of rice and wheat flour and the consumer preference for these food items. Understanding demand in traditional and potential markets is necessary in promoting cassava cultivation in Sri Lanka.

Potential for Production and Utilization

The potential of cassava as a source of inexpensive starch in meeting current industrial requirements is high. Currently, industrial use of cassava starch produced locally is so negligible in Sri Lanka that it is difficult to obtain official statistics. A few private sector industries are involved in making glucose from cassava starch by enzymatic conversion, and in extraction of starch for the textile, adhesive, and paint industries. Small-scale cottage industries are producing dried chips of cassava to meet some industrial requirements, and small quantities of starch are made into tapioca pearl for human consumption.

Present industrial requirements of starch are mostly imported. In the textile industry alone, starch requirements to produce 153 million meters of cotton yarn annually are estimated to be around 2,000 tons. Cassava starch has been successfully used as sizing in the textile industry by mixing 50-60% of cassava starch with other good quality starches. Discussions with officials in the textile industry and mill owners revealed that due to a lack of an assured supply of good quality cassava starch, they were forced to depend on imports.

Use of cassava in the animal feed industry has been thoroughly investigated in Sri Lanka by relevant authorities. Cassava was used in the animal feed industry in the early 1970s. Investigations have shown very successful results in mixing cassava chips up to 10-15% in poultry and other animal feeds. However, due to lack of regular supplies of good quality dried cassava chips, the use of cassava in the animal feed industry has declined. The government Oils and Fats Corporation is the main producer of animal feed and at one time offered attractive prices for cassava chips as well as for dried cassava leaves. The Oils and Fats Corporation is the main supplier of poultry feed in the country. It supplies about 80% of the total feed requirement while the rest is supplied by two major private firms (Athula Chandrasiri and Asoka Sepala, 1980). The present production of poultry feed by the Oils and Fats Corporation is around 70,000 tons/yr. Two other private firms produce about 10,000-20,000 tons of poultry, cattle, and pig feeds.

Presently, cassava is not used directly in the animal feed industry and the main carbohydrate sources are maize, rice, and wheat flour, which is unsuitable for human consumption. Due to the undependability of cassava as a carbohydrate source,the government has offered an attractive price to maize growers. The total maize requirement for the animal feed industry is locally produced in the dry zone. The current price paid for a ton of maize is Rs 3100.00 (US $124). The price of dried cassava chips should be more than Rs 3750.00 (US $150) per ton just to give the same income to the farmer as by selling fresh cassava. In order to meet the cost of chipping and drying, the price has to be higher than this. Dry cassava chip production for direct use in animal feed is currently not economical. However, use of the cassava residue after the manufacture of starch and glucose has been investigated and was found to be very economical. Nevertheless, the present maize production has stabilized due to the attractive prices, and moreover, the cultivation of maize is undertaken by dry zone farmers under rainfed conditions without high-input levels.

Policy Implications of Research

Cultivation of cassava for direct consumption as a fresh food is very profitable at present yield levels and market prices. Higher yields could be obtained with adequate fertilizer applications and use of high-yielding varieties. Moreover, with recent increases in fertilizer prices, intercropping with legumes could increase farmers' incomes while reducing the need for more fertilizer. With the increase in prices of rice and wheat flour, the demand for cassava as a fresh food can be expected to increase. In spite of cassava's currently low prices, the demand for cassava is still not large due to the inconvenience of purchasing cassava within a day of its harvest. Therefore, use of cassava as a source of food could be increased and encouraged by developing processing technologies.

The industrial potential of cassava in Sri Lanka is totally unexploited. The problem has been the lack of coordination between market development and production expansion. The price of imported industrial starch is certainly higher than the locally produced starch from cassava. A recent price quoted for Indian starch is US $1.50/kg. Proper coordination between product utilization and expansion of cultivation combined with government incentives in the form of subsidies, as are applied to many other crops, could encourage farmers to grow more cassava. In order to reduce the cost of production and processing, hand-operated, simple machines should be introduced to facilitate harvesting, chipping, and drying of cassava. Processing of cassava should be encouraged as a cottage industry, whereby cultivation could be stabilized and employment could be provided for the village farming community. After processing at the village level to produce starch, glucose, or chips, the residue of cassava could be effectively utilized as an animal feed in combination with dried cassava leaves and leaves of other legumes such as ipil-ipil (*Leucaena leucocephala*). Therefore, attempts to promote cassava cultivation should take into consideration an integrated approach at the village level where product utilization *in situ* is encouraged.

The trade and agricultural policies of the government need revision to encourage cassava cultivation to meet the industrial requirements of the country. Liberalized import policies have turned the industrial users of cassava starch to foreign sources, mainly because of an assured supply. This situation has crippled the small-scale industries producing cassava chips for starch extraction and deprived the small cassava growers of an assured income. The recent expansion in the industrial sector in Sri Lanka has increased the demand for a cheap source of industrial starch. Demand for cassava starch in textile, adhesive, and confectionery industries has grown to such an extent that the private sector has started pilot projects to meet their own requirements. Government food, agricultural, and nutritional policies could be directed more toward the production of local food by adjusting the price structure of imported food items such as wheat flour. The current deficit in calorie requirements of Sri Lankans (about 37.4 calories per capita per day) could easily be bridged by promoting cultivation and consumption of cassava in areas where food is in short supply.

Research should be mainly directed towards evolving high-yielding varieties as a cost-reducing technology, although not at the expense of high chemical fertilizer requirements. In order to increase farmers' incomes, more research on intercropping combinations must be carried out with the idea of reducing the need for chemical fertilizers and weeding. Varietal improvement programs should be directed towards varieties with shorter maturity and reasonably high yields, so that areas with low rainfall could be exploited for cassava cultivation. In this context, a cheap source of carbohydrates is an urgent need for the small-scale, dry-zone farmer in Sri Lanka, whose calorie deficit is much greater than other segments of the population. Rainfall in the dry zone demands cassava varieties with a 6-month maturity period. In order to promote the consumption of cassava as a cheap source of food, technologies with low energy requirements to process cassava for human consumption should be developed. Programs to expand cultivation should be undertaken simultaneously with projects to promote its use in industry and as a source of food.

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Cassava in the Agricultural Economy of Thailand

Boonjit Titapiwatanakun

Introduction

Agriculture has long been a major sector of the Thai economy. In 1960, the domestic agricultural product was about 40% of the total gross domestic product (GDP). However, this percentage has been decreasing over time as the economy has developed, such that by 1981, for example, the domestic agricultural product was about 24% of the country's GDP.

In terms of total export earning, agricultural products contributed as high as 91% of the total in 1960. During the past two decades, in spite of a decreasing trend in this percentage, the export earning from agricultural products still contributed more than 74% of the total export earnings.

Among the agricultural exports, there are five principal products, namely: rice, maize, tapioca products,* sugar, and rubber. The export value of these products was more than 70% of the total. Noticeably, the export value of tapioca products increased the most rapidly, rising from 1,547 million baht in 1972 to 19,760 million baht in 1982. (The average currency exchange rate over the period was US $1.00 : 20.8 baht.) Moreover, tapioca products ranked as the second highest export-earning commodity for the past 7 years (Table 1).

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* The term 'tapioca products' is generally used in Thailand to mean products processed from cassava roots. This paper follows the Thai tradition in using cassava or cassava root for fresh roots and tapioca or tapioca products for products processed from cassava.

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Table 1. **Value of principal agricultural exports (millions of bahts), 1972-1983.**

Product	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983[a]
Tapioca products	1,547	2,537	3,836	4,597	7,527	7,720	10,892	9,891	14,804	16,447	19,760	15,311
% of total	10.03	10.99	10.57	13.92	16.31	14.89	20.01	14.39	19.13	17.46	18.38	24.74
Rice	4,437	3,594	9,778	5,852	8,603	13,323	10,424	15,592	19,505	26,366	22,470	20,125
% of total	28.78	15.57	26.94	17.72	18.65	25.71	19.25	22.69	25.20	27.99	20.90	32.52
Maize	2,085	2,969	6,078	5,705	5,676	3,345	4,275	5,644	7,281	8,346	8,313	8,168
% of total	13.52	12.86	16.75	17.27	12.30	6.45	7.90	8.21	9.41	8.86	7.74	13.20
Sugar	1,264	1,161	3,757	5,696	6,843	7,445	3,976	4,797	2,975	9,579	12,241	6,330
% of total	8.19	5.03	10.35	17.24	14.83	14.37	7.34	6.98	3.84	10.17	11.38	10.23
Rubber	1,862	4,573	5,035	3,474	5,297	6,164	8,030	12,351	12,370	10,841	9,499	11,956
% of total	12.08	19.81	13.87	10.52	11.48	11.89	14.38	17.97	15.98	11.57	8.83	19.32
Total agricultural export[b]	15,416	23,088	36,289	33,030	46,136	51,821	54,148	68,724	77,404	94,197	107,529	61,890

a) Preliminary data.

b) From Ministry of Agriculture and Co-operatives, *Selected economic indicators to agriculture*.

Source: Bank of Thailand statistical bulletin.

Average rate of exchange over the period was US $1.00 = 20.8 baht.

Production

Historical background

Cassava was first grown in Thailand sometime around 1850, primarily for human consumption. It has become quite popular in the eastern seaboard provinces during the past 50 years. Since 1956, cassava growing has spread to the provinces in the northeastern, western, and upper central parts of Thailand.

The total planted area of cassava increased from 415,200 ha in 1973 to over 1.2 million in 1982 (Table 2). Cassava production increased from 5.4 million tons in 1973 to 17.8 million tons in 1982. The rapid expansion was due to (1) on the demand side, the increasing demand for tapioca pellets in the European Economic Community (EEC) market, and (2) on the supply side, production advantages with respect to cost, yield, and low risk in growing cassava.

The local cassava market is relatively simple. The cassava growers sell their cassava roots either to tapioca factories or through local middlemen. The tapioca factories can be divided into two categories: (1) those processing tapioca products (flour, starch, and sago) for human consumption and industrial use, and (2) those processing tapioca products (chips and pellets) for animal feed.

Table 2. **Area, production, yield, farm price, and farm value, 1973-1982.**

Year	Area (ha)	Production (000 t)	Yield (t/ha)	Farm price (baht/kg)	Farm value (millions of bahts)
1973	415,200	5,443	13.12	0.34	1,850.6
1974	497,280	6,765	13.61	0.30	2,029.5
1975	475,040	7,094	14.93	0.41	2,908.5
1976	692,320	10,230	14.78	0.46	4,705.5
1977	728,160	11,840	13.99	0.47	5,564.8
1978	1,165,120	16,358	14.04	0.37	6,052.5
1979	845,760	11,840	13.13	0.77	8,547.8
1980	1,160,000	16,540	14.26	0.75	12,405.0
1981	1,270,400	17,744	13.97	0.46	8,162.2
1982	1,246,160	17,788	14.39	0.50	9,071.8

Source: Center for Agricultural Statistics, Office of Agricultural Economics, Ministry of Agriculture and Co-operatives, Bangkok, Thailand.

Average rate of exchange over the period was US $1.00 = 20.8 baht.

The starch factories started operating shortly after World War II when modern processing machinery became available. Tapioca starch was then exported to the United States for use in the paper and textile industries. Since 1973 Japan has been the most important tapioca starch market of Thailand. Tapioca starch competes with maize starch in both of these markets.

The second category of tapioca factories started around 1956 when Thai tapioca products for animal feed were introduced into the European animal feed market by European importers. This market developed rapidly and successfully into a very important market for Thai tapioca products. The trade started with the export of tapioca waste from starch manufacturing, shifted to tapioca chips, and then after 1967, following the introduction of a German pelletizing plant in Thailand, shifted to pellets. The ease in handling and shipping pellets and the cost advantages from lower bulk compared to chips and waste facilitated the rapid growth in pellet production. This coincided with the growth in the EEC animal feed market. Consequently, exports of tapioca pellets have increased since then and now dominate in the export of tapioca products.

Cassava cultivation

Generally, cassava can be planted throughout the year except during heavy rains or in the middle of the dry season. Planting is usually done either at the beginning or the end of the rainy season. At present, the cassava grown in Thailand can be classified into two types: the edible and the bitter varieties. The edible cassava is for human consumption and is grown in relatively small quantities compared to the bitter type. The bitter cassava is for processing into chips, pellets, and starch. The most popular bitter variety is the local one. This variety has been grown in Thailand for more than 50 years. In 1975, Rayong 1, a selection from the local variety, was introduced to cassava growers as being comparable to the local variety. Fertilizer use in cassava cultivation is still limited because the price of fertilizer is rather high and the fresh root price is volatile. Only some farmers in the old cassava-producing zone (eastern seaboard) use fertilizer.

Area. The area planted in cassava in Thailand increased every year from 1973/74 to 1982/83, except in1979/80 when there was a serious drought. (See Table 2.) The central plain, which includes the eastern seaboard, used to be the major cassava-producing zone, where cassava area made up 59% of the country's total in 1973/74 (Table 3). A rapid expansion of planted area subsequently took place, especially in the northeastern region, where the area increased from 130,560 ha (30% of the total) in 1973/74 to 483,360 ha (60% of the total) in 1977/78; since then, this region has been the major cassava-producing zone. The increase in cassava area came about from the

Table 3. **Area, production, and yield by region, 1973-1982.**

Year	Northeastern			Central plain			Northern			Southern		
	Area (ha)	Production (000 t)	Yield (t/ha)	Area (ha)	Production (000 t)	Yield (t/ha)	Area (ha)	Production (000 t)	Yield (t/ha)	Area (ha)	Production (000 t)	Yield (t/ha)
1973	130,560	1,574	12.06	259,840	3,531	13.59	25,120	355	14.18	20,480	208	10.14
% of total	30	28		59	62		6	6		5	4	
1974	189,600	2,335	12.31	260,320	3,522	13.53	14,720	224	15.18	15,360	159	10.38
% of total	39	37		54	56		3	3		3	2.	
1975	253,600	3,479	13.72	302,080	4,133	13.68	20,640	330	15.99	18,080	158	8.77
% of total	43	43		51	51		3	4		3	2	
1976	338,720	4,822	14.24	344,160	5,044	14.65	16,800	272	16.21	-	-	-
% of total	48	48		49	50		2	2				
1977	483,360	6,483	13.41	342,080	5,048	14.76	21,440	309	14.43	-	-	-
% of total	60	55		40	43		3	3				
1978	733,440	9,699	13.23	398,880	6,119	15.34	29,760	463	15.59	3,040	77	25.21
% of total	63	59		34	37		3	3		0	1	
1979	543,360	6,952	12.79	283,200	3,876	13.69	18,720	267	14.19	480	6	13.11
% of total	64	63		34	35		2	2		0	0	
1980	725,600	10,009	13.79	400,000	6,043	15.11	34,400	488	14.16	-	-	-
% of total	62	60		35	37		3	3				
1981	758,080	10,046	13.25	465,280	6,990	15.02	47,040	708	15.06	-	-	-
% of total	60	57		37	39		3	4				
1982	726,240	10,200	14.04	465,280	6,881	14.79	44,640	707	15.83	-	-	-
% of total	59	57		38	39							

Source: Center for Agricultural Statistics, Office of Agricultural Economics, Ministry of Agriculture and Co-operatives, Bangkok, Thailand.

substitution of cassava for kenaf and also the increasing utilization of farmers' idle land. Nevertheless, it is generally believed that the expansion of cassava area has been through or at the expense of forest destruction.

Production and yield. Total cassava production increased from about 5.4 million tons in 1973/74 to over 17.7 million tons in 1982/83, an increase of slightly more than three times. Average yield for the country fluctuated between 13.12 tons/ha and 14.93 tons/ha in this period, although a downward trend in average yield was observed after 1975/76. (See Table 2.)The northeastern region produced over 10 million tons or 57% of the total production in 1982 (Table 3). However, this region has the lowest average yield, perhaps due to the poor soil and erratic rainfall conditions, and the lack of fertilizer application.

Production costs and farm income. The total cost of production per hectare increased every year from 3151 baht/ha in 1974/75 to 5871 baht/ha in 1980/81, except in 1977/78 when the fixed cost was adjusted (Table 4). During the same period, the cost per ton also increased from 242 baht to 412 baht, almost 70%. During 1973/74 to 1979/80, net cassava income per hectare increased from 1275 baht to 5237 baht. This was due mainly to the steady increase in cassava farm prices. Moreover, net cassava income has been more attractive compared with maize, kenaf, and sugarcane. The net farm incomes of kenaf and sugarcane had been fluctuating severely; thus farmers substituted cassava for these crops, especially in the northeastern region.

Processing

Tapioca processing factories are concentrated in two regions, the northeastern and the central plain region. Generally, most of the tapioca starch factories are located in the central plain region, especially in the eastern seaboard provinces. However, sometime around 1970, there was a rapid expansion of tapioca factories, especially chip and pellet factories, in the northeastern region around Nakhon Ratchasima. Since then, chip and pellet factories have spread to almost all provinces in this region, although Nakhon Ratchasima and Khon Kaen are considered the center of the tapioca industry.

Among the three types of tapioca factories (chips, pellets, and starch), official records show that the number of chip factories increased from 90 in 1970 to 3,254 in 1978. One reason for the rapid increase in chip factories is the relatively low investment cost. For pellet factories, the number increased from 28 in 1970 to 618 in 1978. However, the number of tapioca starch factories increased only three times, from 50 to 146 factories. High

Table 4. **Average production cost (baht/ha), 1974/75-1980/81.**

Item	1974/75			1975/76			1976/77			1977/78			1978/79		
	Cash	Non-[a] cash	Total	Cash	Non-cash	Total	Cash	Non-cash	Total	Cash	Non-cash	Total	Cash	Non-cash	Total
Variable cost	1593	1065	2658	1854	1053	2907	1701	1603	3304	1550	1714	3264	1921	1683	3604
Fixed cost	-	493	493	-	621	621	-	787	787	146	401	547	138	469	607
Total cost	1593	1558	3151	1854	1674	3528	1701	2390	4091	1696	2115	3811	2059	2152	4211
Yield (t/ha)			13.00			13.73			12.56			12.92			14.90
Cost per ton			242			257			326			295			278

Item	1979/80			1980/81		
	Cash	Non-cash	Total	Cash	Non-cash	Total
Variable cost	2056	1691	3747	3046	2092	5138
Fixed cost	161	536	697	68	665	733
Total cost	2217	2227	4444	3114	2757	5871
Yield (t/ha)			10.69			14.25
Cost per ton			416			412

a) Non-cash refers to on-farm resources costed at market price.

Source: Production Economic Section, Division of Agricultural Economic Research, Office of Agricultural Economics, Ministry of Agriculture and Co-operatives, Bangkok, Thailand.

Average rate of exchange over the period was US $1.00 = 20.8 baht.

investment cost and the requirement for a steady supply of raw materials are two factors that explain the lower rate of expansion in pellet and starch factories. Data on the actual capacity of these factories were not available, but it is believed that almost all the factories are operating under their rated capacities.

In general, hard pellets or brand pellets are produced by imported machines. However, some hard pellets were produced by locally-made pellet machines in 1979. They were later developed and modified to also produce the so-called quasi-hard pellet. The quasi-hard pellet is softer than the hard pellet but harder than the native pellets. These types of factories expanded rapidly in early 1982/83, based on the remodeling of the original native pellet factories. One reason for producing harder pellets is that they are the type expected to be required by importing countries. The other reason is the comparatively low cost of investment.

The processing cost of tapioca products varies with the capacity and the operational efficiency of the plant. It is believed that economies of scale, to some extent, exist in the tapioca processing industry. For the processors, to increase output by fully utilizing the plant's capacity would decrease the per unit cost of production. However, in practice most of the processors cannot operate at their full capacity because there is a limitation in accumulating sufficient raw materials. In addition, the price fluctuations of both raw materials and output, to a great extent, cause a loss when operating at full capacity. Therefore, the processing cost of tapioca products varies drastically from plant to plant. Based on traders' estimates in 1982/83, the per kilogram processing cost of the major tapioca products are: 0.10-0.15 baht for chips, 0.15-0.26 baht for native pellets, 0.22-0.30 baht for hard pellets produced by the imported machines, and 1.00-1.25 baht for starch.

Use and Trade

Marketing flows

The present marketing flow of the Thai tapioca industry is illustrated in Figure 1. Cassava growers sell all of their cassava roots either directly to the tapioca factories or through the local middlemen or the truckers. At this level of marketing there are many truckers who operate as middlemen, buying cassava roots at the plantation or simply offering transportation and harvesting services to farmers.

The cassava roots are bought either by chip and pellet processors or tapioca starch processors (starch and pearl) within the cassava production

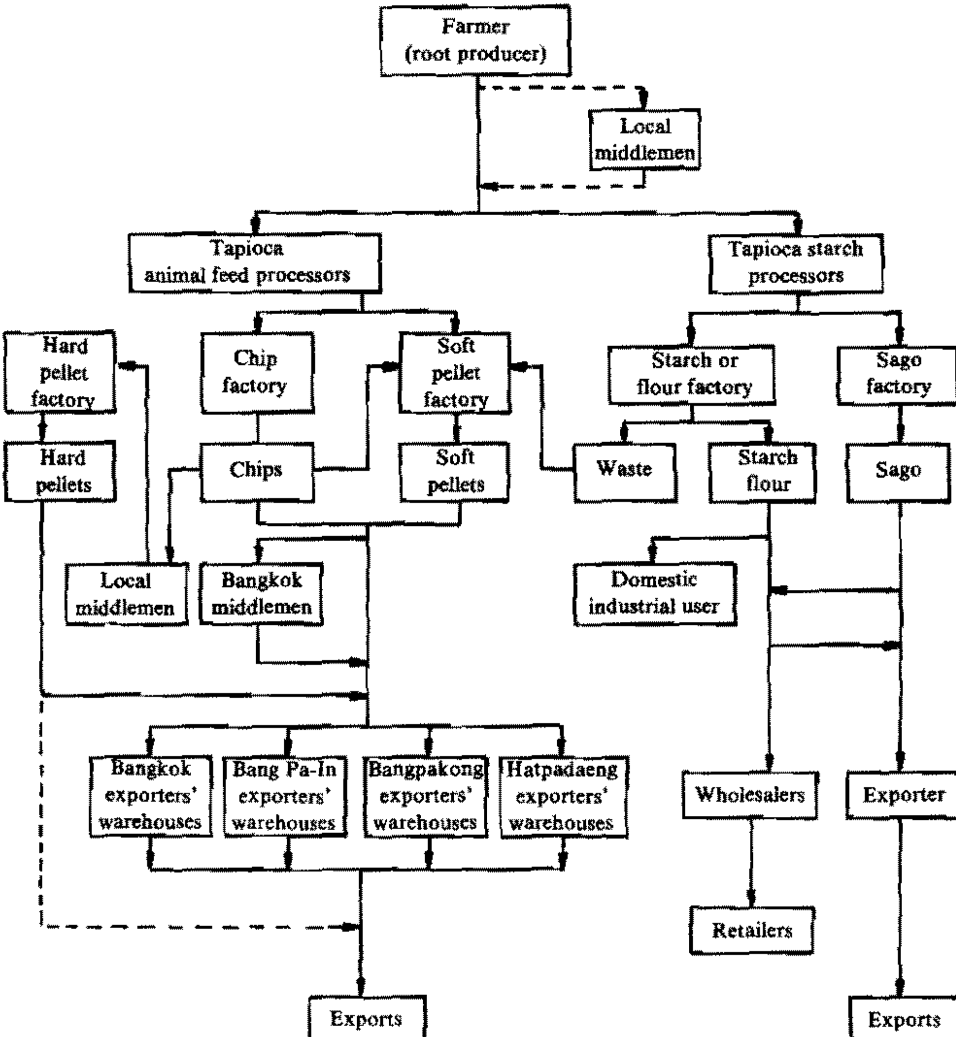

Figure 1. *Marketing flows of Thai tapioca industry.*

area. Chip factories usually sell their chips in bulk or bag directly to pellet factories within the area. Some chips are sold through middlemen or to the hard pellet factories or exporters in Bangpakong and Sriracha. All native pellets are sold in bulk to the Bangkok-based exporters and are transported to their warehouses in Bangkok, Bang Pa-In, Bangpakong, or Hatpadaeng. However, the hard pellets are not traded in the local market because hard-pellet factories are owned by the exporters. The roots bought by the starch factories are processed into starch or flour and sold directly to the domestic industrial users, wholesalers, and exporters.

In recent years, the middlemen in Bangkok have been actively involved in the trading of chips and pellets, especially those middlemen who were formerly trading in jute and kenaf. The commission of the middlemen is 0.5% of the total transaction. Sometimes these middlemen also take position in the market by buying or selling forward with processors and exporters. The existence of these middlemen has been due to: (1) the rapid expansion in pellet trading, which increased price competition among the exporters and pellet processors, thus allowing middlemen to facilitate this kind of trading; and (2) the movement of exporters to set up their warehouses far from Bangkok in order to avoid the increasing labor and exporting costs there, thus creating new terminal markets for tapioca products.

Domestic use

Cassava root is not a staple food in Thailand. Only small amounts of cassava roots are consumed, principally as dessert items. Presently domestic use of tapioca products such as waste, chips, and pellets is still limited; however, figures on the total consumption of these products are not available. Nevertheless, the domestic use of tapioca products is mainly in the form of tapioca starch, which can be divided into two categories: for industrial consumption and for human consumption. Again, official records of consumption for each category are not available.

Starch consumption. Attempts have been made to estimate the annual domestic starch consumption from 1965 to 1983 by applying a fixed coefficient of tapioca starch utilization for each industry, as well as for direct human consumption (Table 5). The industrial consumption of tapioca starch was classified and estimated for six industries, namely: monosodium glutamate, paper, textiles, plywood, other industrial uses, and food. Among these industries, the monosodium glutamate industry used the highest amount in 1983 (60,780 tons), followed by the food industry and the paper industry (48,786 tons and 44,432 tons, respectively).

Table 5. **Annual tapioca starch consumption by industry, alternate years, 1965-1983.**

Year	Monosodium glutamate manufacturing		Paper industry		Textiles industry		Plywood manufacturing	
	(t)	(%)	(t)	(%)	(t)	(%)	(t)	(%)
1965	6,163.2	13.83	1,140.42	2.56	3,945.98	8.86	562.55	1.26
1967	10,200.0	18.73	1,748.86	3.21	5,174.41	9.50	931.07	1.71
1969	20,100.0	28.27	3,796.41	5.32	6,413.92	9.00	1,013.37	1.42
1971	28,965.6	32.00	7,944.01	8.78	8,394.04	9.27	1,208.02	1.33
1973	34,629.6	32.02	10,274.31	9.50	10,143.81	9.38	1,330.26	1.23
1975	36,592.8	30.33	11,205.77	9.29	10,773.39	8.93	1,182.11	0.98
1977	37,248.0	26.24	18,914.91	13.32	13,459.96	9.48	1,611.30	1.14
1979	38,164.8	23.59	24,722.35	15.28	14,518.71	8.98	1,763.31	1.09
1981	57,720.0	29.38	31,260.54	16.78	14,310.49	7.68	1,561.37	0.84
1983	60,780.0	28.07	44,432.26	20.52	15,252.83	7.05	1,587.71	0.73

Year	Other industrial uses		Food industry		Direct human consumption		Total	
	(t)	(%)	(t)	(%)	(t)	(%)	(t)	(%)
1965	1,200.0	2.69	30,722.77	68.95	822.64	1.85	44,557.56	100
1967	1,986.0	3.65	32,673.27	60.01	1,735.40	3.19	54,449.01	100
1969	2,401.5	3.37	34,762.38	48.75	2,761.89	3.87	71,309.47	100
1971	2,968.5	3.28	37,118.81	41.00	3,926.74	4.34	90,525.72	100
1973	4,245.0	3.92	39,297.03	36.33	8,246.23	7.62	108,166.24	100
1975	6,426.0	5.33	41,455.45	34.36	13,012.82	10.78	120,648.34	100
1977	8,902.5	6.27	43,603.96	30.71	18,224.46	12.84	141,965.09	100
1979	13,081.5	8.08	45,683.17	28.24	23,847.04	14.74	161,780.88	100
1981	17,836.5	9.58	46,910.80	25.19	19,650.50	10.55	186,250.20	100
1983	25,220.0	11.65	48,786.52	22.53	20,446.40	9.44	216,505.08	100

Source: By calculation.

During the period of 1975 to 1983, the estimated annual domestic tapioca starch consumption increased from 120,648 tons to 216,505 tons. Using 2% annual growth rates, the total domestic tapioca starch consumption in 1988 is projected in the range of 239,000 to 290,000 tons. Undoubtedly, if modified tapioca starch could find new industrial uses, then total starch consumption would probably exceed even the projected maximum level.

Export

The Thai tapioca industry has been an export-oriented industry for more than a quarter of a century. Before 1963, exports of tapioca products were mainly in the form of starch sago (pearl). Since then exports of tapioca products shifted to products for animal feed, such as waste meal, chips, and pellets. Currently, the major tapioca export items are starch and pellets.

Starch exports

Exports of tapioca starch have been fluctuating in the past 25 years. The lowest quantity of exports was 34,764 tons in 1964 and the highest was 425,632 tons in 1982. The fluctuations have been due to both the fluctuating number of importing countries and the fluctuating volume by each importing country.

From 1958 to 1972 the major market for Thai tapioca starch was the U.S.A., which imported more than 50% of the total quantity exported. However, after 1972 Japan became the major importing country. Although there has been an increasing number of importing Asian countries, the total quantity exported to these countries is very unstable. Also, the quantity of starch exported to Japan and the U.S.A. has been decreasing since 1974. This decline is due mainly to the high freight cost to the U.S.A. and the import restrictions in Japan. Moreover, the starch imports of these two markets vary to some degree with the availability of maize starch in the domestic market.

Pellet exports

The quantity of pellet exports increased from over 752,000 tons in 1969 to nearly 6.7 million tons in 1982 (Table 6). Due to serious quality problems, the steady trend was interrupted in 1979. Virtually all pellets were exported to countries within the EEC. Official statistics showed that the Netherlands imported more than 85% of the total pellet exports of Thailand. However, there were transshipments from the Netherlands to Germany, France, and Belgium.

Table 6. **Export of tapioca pellets (000 t) by destination, 1969-1982.**

Year	W. Germany	Netherlands	France	Other EEC	Southeast and East Asia	All others	Total
1969	145.3	552.6	1.0	42.8	1.4	9.6	752.7
1970	307.4	843.2	0.6	0.5	1.9	10.3	1,163.9
1971	124.4	812.3	12.5	-	0.8	13.9	963.9
1972	74.6	1,066.6	33.2	2.1	0.7	0.3	1,177.5
1973	114.2	1,292.0	114.7	3.0	18.6	31.9	1,574.4
1974	112.3	1,718.7	87.9	-	86.1	26.4	2,031.4
1975	96.6	1,965.6	44.8	1.0	56.7	4.1	2,168.8
1976	89.2	3,143.3	127.7	14.4	17.7	61.4	3,453.7
1977	185.9	3,251.6	135.2	100.4	5.7	7.9	3,686.7
1978	431.3	4,059.1	429.9	788.9	45.8	40.9	5,795.9
1979	210.6	2,646.5	277.2	588.4	6.2	16.8	3,695.7
1980	198.0	3,409.9	114.9	728.6	-	1.2	4,452.6
1981	92.4	4,922.1	81.1	173.6	3.7	313.3	5,586.3
1982	176.4	6,002.6	147.1	367.4	0	.9	6,694.4

Source: Department of Customs, Bangkok, Thailand.

Almost all of the pellet exports were the so-called Thai native pellets or soft pellets. Nevertheless, the production of hard pellets, which are processed by the imported machines, has increased during the past 4 years. Export statistics from the Thai Tapioca Trade Association (TTTA) showed that total hard pellet exports increased from over 608,000 tons to nearly 1.5 million tons between 1981 and 1982. It is generally expected that the export of hard pellets will be increased gradually because of the environmental problems of the dusty native pellets, especially during unloading. In addition, some of the European ports are trying to force the importers to shift to hard pellets.

Export handling facilities

Export facilities played a major role in the development of the Thai tapioca industry and have facilitated the rapid increase in exports of tapioca products as animal feeds. Export facilities have evolved from a simple loading method at a speed of 1,000-2,000 tons per day in 1969 to 22,000-32,000 tons per day in 1982. The increase in loading speed enables the facility to handle larger vessels of up to 150,000 tons, thereby reducing per unit freight costs substantially. It is expected that the existing export facilities will continue to be used with only minor changes for better efficiency. Nevertheless, reduction of export handling costs by increasing loading speed and handling larger vessels are, to a great extent, indispensable for the Thai tapioca pellets to be more competitive with other animal feed ingredients in the world market.

Price Movement

The monthly average wholesale prices of grade A starch, pellets, chips, and roots are shown in Figure 2. In general, all these prices display similar movement, particularly those of roots, chips, and pellets. This is because most of the roots are processed into chips and pellets, while only a relatively small portion is processed into starch. Root price is determined chiefly by chip and pellet price, hence root and starch prices are not as closely correlated. The price of all four commodities showed a downward trend from mid-1976 to early 1978 and afterwards prices started moving upward until early 1979. From 1979 to late 1981, all prices for tapioca products showed a downward trend, and since then another upward trend has been observed.

Since the EEC is the major market for Thai tapioca pellets, the price movement in this market has a strong influence on the price movement in Thailand. In order to compare the price movements in both markets, the monthly price movements of Thai native pellets afloat, c.i.f. Rotterdam,

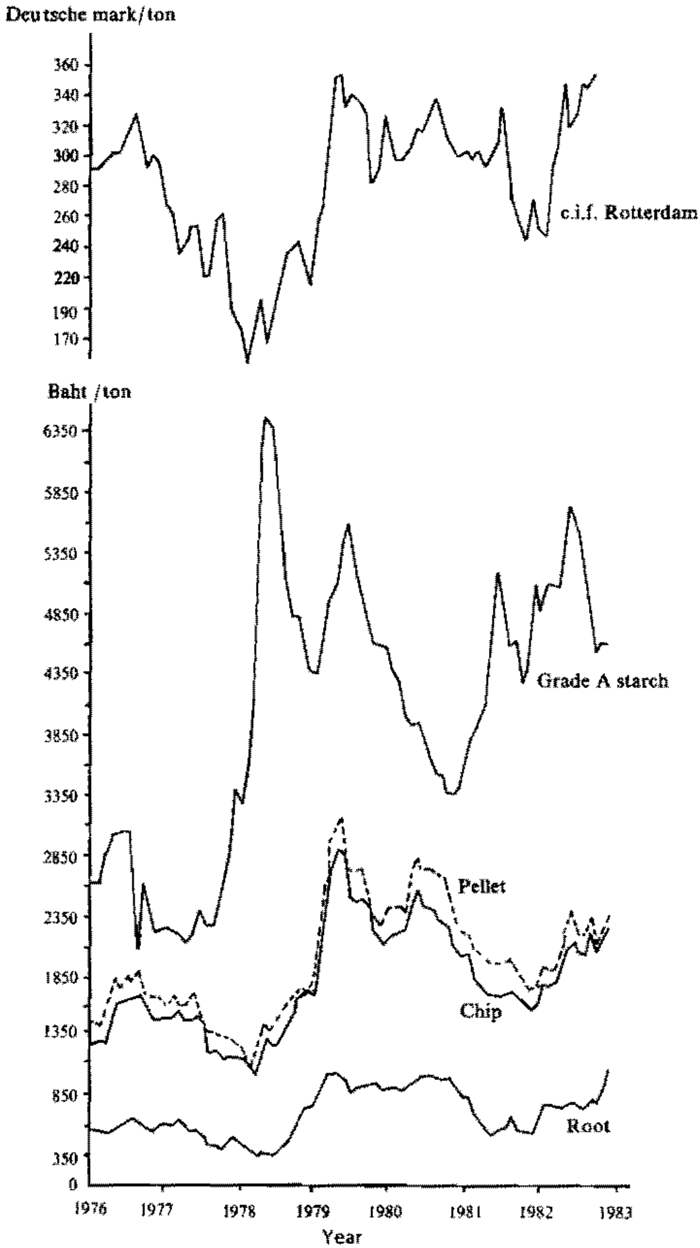

Figure 2. *Average price of Thai native pellet, afloat c.i.f. Rotterdam; Bangkok wholesale price of grade A starch; and pellet, chip, and root prices in major production areas, 1976-1982.*

shown in Figure 2, is compared with the domestic wholesale price of tapioca products and roots in Thailand. Generally, all the prices show a similar trend. However, the monthly price fluctuations differ in these two markets, perhaps due to the time lag in shipments between them.

During the period from 1975 to 1982, an analysis of marketing margins of tapioca pellets for exports revealed that the local handling margins, factory margins, exporter margins, and shipper margins were not particularly large. This would imply that tapioca pellet marketing, as well as the overall tapioca industry in Thailand, is quite competitive and efficient.

Potential Production and Use

The potential for cassava production and use in Thailand is, to a great extent, dependent upon the EEC, which has been up to the present the single market for tapioca products as animal feed. The prospects in this market will be determined by the end of 1986, when the Thai-EEC agreement is terminated. At present, it is difficult to anticipate the outcome because of the political issues involved in the negotiations. However, one may assume that the EEC will import a certain amount of Thai tapioca pellets after 1986. When this amount is known, attention can be focused on other markets, both foreign and domestic.

Domestic starch market

The domestic tapioca starch consumption in 1988 is projected to be between 239,000 and 290,000 tons. This projection is based, however, on the assumption that the existing industries will continue using tapioca starch and not switch to other higher-quality modified starches. The eventual use of modified starches is a likely possibility, and traders and tapioca starch manufacturers in Thailand expect a breakthrough in the development of modified tapioca starch. This is due mainly to the comparatively low price of tapioca starch and the wider applications for modified starch. At any rate, the development of modified starch has to be accompanied by well-trained, technical sales representatives, who are not available yet.

Domestic animal feed market

The possibility of promoting domestic use of tapioca products (chips or pellets) as an animal feed ingredient has been explored through analysis of price ratios. The monthly average wholesale prices in Bangkok of the three major high-protein feed ingredients were examined, namely: fish meal (60% protein), fish meal (50% protein), and soybean meal (45% protein). During the period from 1978 to 1983, soybean meal had the lowest price at

7.21 baht/kg, while the fish meal (60% protein) had the highest at 10.32 baht/kg. All these prices had a similar pattern of fluctuation, but with an overall increase. Soybean meal fluctuated between 5.70 and 8.26 baht/kg, fish meal with 60% protein fluctuated between 7.55 and 12.57 baht/kg, and fish meal with 50% protein fluctuated between 6.40 and 11.50 baht/kg. These are rather high and volatile prices.

It is regarded as a rule of thumb that a mixture of soybean meal and tapioca pellets or chips at a ratio of 1:4 has a nutritional feed value similar to maize. Therefore, the Bangkok wholesale price of a mixture of soybean meal and tapioca chips can be calculated by multiplying the price of soybean meal by 0.2 and adding this to the price of tapioca chips multiplied by 0.8. This calculated price of the soybean meal and chips mixture divided by the Bangkok wholesale price of maize gives a price ratio in percentage terms. These monthly price ratios from 1978 to 1983 are almost all over 100%, and the average is about 120% (Figure 3).

These analyses imply that the price of mixtures of high-protein feed ingredients (soybean meal and fish meal) and tapioca products are at least 20% higher than the price of maize. This may be one of the reasons that the use of tapioca products in domestic animal feed is still limited. Domestic maize consumption for animal feed is approximately 1.5 million tons per year. Nevertheless, there would be good prospects for increasing domestic use of tapioca products for animal feed if either the price of high-protein feed ingredients or of tapioca products could be decreased.

If the domestic price of tapioca products for animal feed remains constant, the price of high-protein feed ingredients must be decreased by more than 20% so that the price of the feed mixture could be decreased by 20% in order to be comparative with maize. The possibility of such an occurrence is not likely in the long run, unless other high-protein feed ingredients are available at a comparatively low price. However, there is a strong possibility in the short run, because the monthly price of high-protein feed ingredients is rather volatile. This, however, is not a solid basis for developing a large, stable domestic market.

On the other hand, the price of tapioca products would have to be decreased by considerably more than 20% to compete with maize in feed ingredients. If this case materialized, the potential domestic market for tapioca products as feed would be as large as 1.2 million tons per year. There is a strong possibility for this to occur in the long run, provided that the prices of tapioca products can be reduced by 40-50% which the feed manufacturers have indicated would be necessary. Such a reduction would reduce the Bangkok average wholesale price of chips from about 2,250 baht/ton to between 1,125 and 1,350 baht/ton (1983 prices). Then the farm

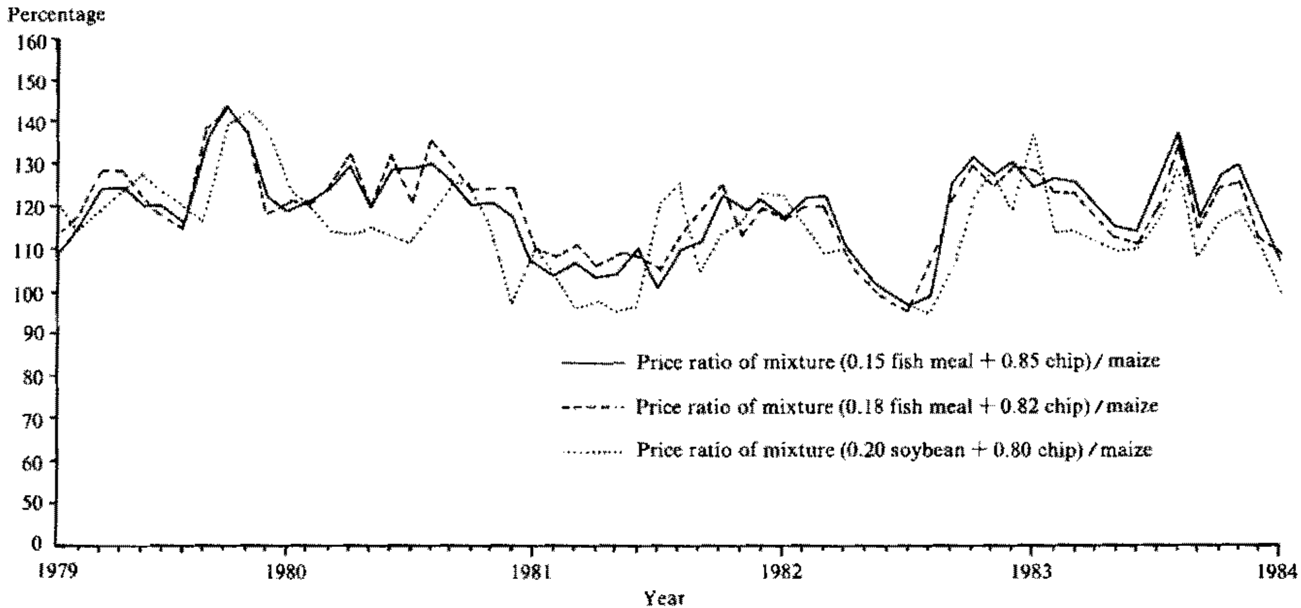

Figure 3. *Average monthly price ratio of tapioca chips mixed with high-protein feed ingredients: fish meal (60% protein), fish meal (50% protein), and soybean meal (45% protein); and maize in Thailand, 1979-1983.*

gate price can be derived by subtracting the processing cost of chips (150 baht/ton) and total transportation cost (260 baht/ton). This would result in an estimated farm gate price for roots in 1983 of about 311 to 409 baht/ton, which is lower than the average 1973-1983 price of 560 baht/ton.* Using the average price of chips from 1978 to 1982 (about 1,846 baht/ton), a 20% decrease would give an estimated farm gate price of approximately 464 baht/ton, which is slightly higher than the average country-wide production cost of roots of about 450 baht/ton.

The discussion of the above two cases implies that there is a potential domestic market for tapioca products as animal feed ingredients if the high-protein feed ingredients are available at a certain price level and the price of tapioca products can be decreased by more than 20%.

Summary and Conclusions

The rapid increase of cassava production in Thailand is mainly attributable to the expansion of planted area. The continuous planting with low rates of fertilizer application is responsible for the considerable reduction in its average yield. At present, the northeastern region is the main cassava-growing and processing area and produces more than 50% of the country's production. It is unlikely that the planted area will be expanded more unless the cassava root prices are increased substantially.

There is sufficient factory capacity to produce more than 6 million tons of chips and pellets a year. It is expected that production of hard pellets or quasi-hard pellets will be increased and exported to the EEC market while production of soft pellets or native pellet will be decreased gradually. For tapioca starch factories, the total capacity is far more than the approximate annual production of 0.5 million tons.

Cassava roots are not a staple food for the Thai people. Domestic use of tapioca products is mainly in the form of tapioca starch. At least 200,000 tons of tapioca starch were consumed domestically in 1983. The estimated annual growth rate of starch production is about 3%. Only a small amount of tapioca products was used by the domestic animal feed compounders, and this will increase only when the prices of these products are substantially lower than that of maize.

By and large, the tapioca industry in Thailand is still an export-oriented industry which is handled by private enterprises. Tapioca pellets are by far the single most important export and almost all are exported to the EEC

* Using the conversion of cassava roots into tapioca chips at a ratio of 2.3:1.

market. Tapioca starch is exported to a limited and fluctuating number of countries in which the U.S.A. and Japan are regarded as the major importers. However, all the major markets for Thai tapioca products are faced with import restrictions, such as quota restrictions in Japan and the EEC. Therefore, it may be difficult to increase the quantity of exports for tapioca products to these conventional markets.

The present marketing system for tapioca products is very efficient and very specialized, especially for tapioca pellets. Modern exporting facilities and loading technologies have been used to handle tapioca pellet exports. These technologies reduced export cost and freight cost per unit substantially, creating a comparative advantage for Thailand in comparison to other pellet-exporting countries like Indonesia.

The Thai government currently maintains a free trade policy for exports of tapioca products. However, an export quota system was applied to tapioca pellets and chips going to EEC countries in order to ensure that the quantity does not exceed that authorized by the EEC. In the meantime, a crop diversification program has been undertaken to search for new crops to substitute for cassava. In addition, experiments using cassava roots in distilling alcohol were carried out. However, significant progress from these programs is not expected soon.

The future of the Thai tapioca industry will depend more or less on the existing world market for tapioca products. At least two directions can be pursued to develop this industry. The first is to explore new markets for tapioca products, such as the animal feed markets in feed-deficient countries, and the modified starch markets. The second is to promote domestic use of tapioca products, especially those for animal feed, and to encourage development of cassava-based industries which create added value to cassava root production, for instance, the modified starch industry.

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An Analysis of the International Market Potential for Dried Cassava and Cassava Starch

Gerald C. Nelson

Introduction

The rapid growth in international exports of dried cassava from Thailand in the 1970s aroused interest in other developing countries about the possibility of increasing their own cassava exports. Because cassava is grown in most tropical countries it was hoped exports could provide a new, more profitable market for domestic cassava production.

The determinants of Thai cassava export growth are now fairly well known (for example, see Nelson, 1983). A loophole in the European Economic Community's (EEC) protection to its domestic agriculture raised domestic demand for dried cassava. As part of the EEC Common Agricultural Policy (CAP), feed grain prices were kept well above world prices with a variable levy on imports and purchases at a floor price. Dried cassava, however, faced only a 6% *ad valorem* tariff, and soybeans and soybean meal were (and are) imported duty free. In animal feed rations, a mixture of four units of dried cassava and one unit of soybean meal is roughly equal to five units of a feed grain like corn or barley. With the CAP-induced high domestic grain prices, feed manufacturers partially substituted dried cassava and soybean meal for feed grains. As a result, world prices of dried cassava increased and pulled up cassava starch prices as well (Nelson, 1982).

In 1982, as a result of the rapid growth in its dried cassava imports (from less than 1 million tons in 1970 to 6 million tons in 1978), the EEC restricted the quantity of dried cassava imports coming in under the 6% duty. Today, there is effectively a two-price system. Imports under the

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quota (currently around 5.5 million tons for Thailand and 1 million tons for Indonesia) are taxed at only 6%. EEC imports from a quota holder which are greater than its quota, or imports from new suppliers, are taxed at a much higher, variable rate. It is very unlikely that any other country will be able to exploit the EEC market to the extent that Thailand has done. Thus the potential for increased cassava exports must depend upon other markets.

Two related international markets - for starch and for energy in animal feed rations - provide the most likely sources of demand for increased trade in cassava products. The cassava root contains about 30% starch which can easily be extracted, and the starch content of dried cassava (about 75%) makes it an excellent source of energy for animal feed rations (Table 1).

There are some specialty markets for starch (such as tapioca pudding in the U.S.A.) which require chemical or physical characteristics specific to cassava starch, but this demand is small and both price- and income-inelastic. The products which currently consume most starch production (paper, textiles, food, and fructose) can for the most part use starch from any source. Any large-scale export growth will be into markets for generic starch where cassava starch must be cheaper than other starches in order to compete. Similarly, cassava used in animal feeds must compete with the

Table 1. **Nutrient values and starch content of selected animal feed ingredients, dry matter basis.**

Ingredient	Protein (%)	Kcals digestible energy/kg	Starch (%)
Dried cassava	2.84	4,000	74
Barley	13.03	3,467	65
Maize, dent yellow	8.89	3,961	72
Wheat, soft red winter	11.86	4,254	66
Soybean meal, expeller	47.33	3,870	15

Sources: Protein and caloric content for cassava from Z. Muller, K.C. Chou, and K.C. Nah (1975), "Cassava as a total substitute for cereals in livestock and poultry rations," *Animal feeds*, Tropical Products Institute. For other commodities, from the National Research Council (1979), *Nutritional requirements of swine*, National Academy of Sciences, Washington, D.C. Starch content of barley, maize, and wheat from National Academy of Sciences (1958), *Composition of cereal grains and forages*. Starch content of soybean meal fron National Academy of Sciences (1971), *Nutritional data on U.S. and Canadian feeds*.

lowest-priced energy source currently available. The most important source of both starch and animal feed energy is maize. Hence, any increase in trade in cassava products must be competitive with maize products.

The potential for increased exports of cassava products is influenced by two sets of factors - those determining domestic prices in the exporting country, and those determining domestic prices of cassava and maize products in the import markets. Despite the relatively high international dried cassava prices caused by European agricultural policy in the 1970s and early 1980s, only Thailand increased exports substantially. In other cassava-producing countries, a variety of domestic factors, such as overvalued exchange rates, inappropriate price policies, inadequate infrastructures, and more profitable agricultural alternatives, inhibited increased exports. On the demand side, domestic policies can severely limit the potential cassava market. In Japan, for example, import quotas place an absolute ceiling on increased cassava starch imports.

Both starch and animal feed markets are examined in this paper. In the next section, the discussion of international starch markets draws heavily on a report completed in 1983 by S.F. Jones of the Tropical Development and Research Institute entitled *The World Market for Starch and Starch Products with Particular Reference to Cassava (tapioca) Starch.** In the third section, the potential for growth in cassava trade for selected animal feeds is estimated with linear programming models. Domestic and international prices for a variety of countries are used to determine the price at which it would be profitable to use cassava and the quantities needed. Growth in livestock numbers is then used to project potential demand for cassava in animal feeds.

International Market for Cassava Starch

World starch production in 1980 was estimated to be 16 million tons. The U.S.A. produces about 40% of total world production, the EEC about 25%, and Asia about 22%. Starch is extracted from many materials, but maize accounts for 75% and cassava and potatoes 10% each.

Only 4% (600,000 to 700,000 tons) of world starch production is traded as starch. Considerable quantities of traded maize are used to produce starch and starch products, such as high-fructose corn syrup. Cassava

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* The reader should view the discussion of international starch markets in this paper as a summary of the Jones report unless otherwise indicated. For more details, the report may be obtained from the Tropical Development and Research Institute, 56/62 Gray's Inn Road, London WC1X 8LU, England, for £3.00.

starch accounts for about 75% of total starch exports. Thai cassava starch accounts for about two-thirds of cassava starch exports and the remaining amount comes from a number of small exporters including Indonesia, Brazil, China, and Malaysia.

Four markets (the U.S.A., Japan, Taiwan, and the EEC) import most of the internationally traded starch. Furthermore, they are also major buyers (or sellers, in the case of the U.S.A.) of maize from which domestic processors extract starch.

U.S.A.

About 6.2 million tons of starch were produced annually in the U.S. in the early 1980s, almost all from maize. Exports and imports were about equal (and were equivalent to 3% of starch consumption), but exports were two-thirds maize starch while imports were two-thirds cassava starch. Production of high-fructose corn syrup, glucose, and dextrose accounts for almost 70% of starch consumption in the U.S. The remainder is used in food manufacturing (6% of the total for convenience foods, biscuits, and canned fruits and vegetables) and industry (24% of the total for the paper, textile, pharmaceutical, and brewing industries).

Imports of cassava starch face no import taxes or restrictions, but have been steadily declining since the mid-1960s, primarily because of the rising relative price of cassava starch. According to Jones (p.52),

> In the 1960s, the U.S. paper industry, particularly in West Coast locations, could purchase tapioca starch more cheaply than U.S. maize starch, but since 1973 it is reported that tapioca starch from Thailand, delivered to the West Coast, has been in the range of $30-200 per ton more expensive than industrial grade maize starch delivered to the same customers. Tapioca [cassava] starch has therefore increasingly become a product in demand for its particular properties [a specialty starch].

Any large increase in exports of cassava starch to the U.S. will depend on price competitiveness with maize starch and regularity of supply. Jones reports (p.54),

> If tapioca starch could once more become price competitive with maize starch, it could again become a major force in the 'mass' market [for generic starch]. A number of respondents in the paper industry indicated that, given certain conditions relating to supply regularity and quality, demand for tapioca starch could be re-established to former levels...

Jones feels that it will be difficult for cassava starch imports to substitute for maize starch in the sweetener market. High-fructose syrup is made in integrated maize wet milling factories and it is impossible to introduce cassava starch directly into the process. However, processing equipment exists to make fructose directly from cassava starch which can then be exported from cassava-producing countries. As with the mass starch market, demand for imported fructose would depend upon price and regular supplies of large quantities.

Japan

In contrast to the U.S. market, Japanese starch production comes from a variety of raw materials and the domestic market for starch is highly protected. Domestic starch production was about 1.7 million tons in 1980. Despite limits on maize imports, maize starch production (from imported maize) grew rapidly from the mid-1970s, and in 1980 accounted for about 75% of starch production. White potato and sweet potato starch accounted for somewhat more than 20% of production.

Imports are restricted by both a quota (about 130,000 tons in the late 1970s) and an import tax of 0%, 2.5%, or 25%, depending on end use. Domestic regulations further reduce the desirability of imports, which have often been below the quota level. Cassava starch accounts for about 70% of total starch imports.

As long as Japan maintains its quota on imports, growth of exports to Japan is unlikely. If the quota and tariff were removed (perhaps as part of a general liberalization of Japanese agricultural trade policies, or as a trade preference specific to a country or group of countries) imports would have to compete with maize starch or its products. The majority of starch is used in sweeteners, and 80% of Japanese sweeteners is made directly from maize (via the wet milling process). It is likely that any move to liberalize imports of either starch or starch-based sweeteners would be opposed by both Japanese maize processors and potato growers, and by U.S.A. maize exporters.

Taiwan

Cassava starch has traditionally been the most important starch produced in Taiwan. Domestic production, however, declined rapidly in late 1970s, from 74,000 tons in 1975 to 15,000 tons in 1980. Maize starch production from imported maize almost tripled during the same period (from 16,600 tons in 1975 to 45,000 tons in 1980). Imports, primarily of cassava starch, increased from only 4,300 tons in 1975 to 86,400 tons in 1980.

The decline in domestic cassava starch production is the result of increased competition both from other crops for land and from maize starch. While imported cassava starch is the obvious replacement for domestically produced cassava starch, high prices for cassava starch imports, quality problems, and regular supplies of low-priced, imported maize have led to the rapid growth of a maize wet milling industry.

European Economic Community

Maize starch accounted for about 70% of the 3.7 million tons of starch produced in the EEC in 1980. About three-fourths of the maize is imported. Potato starch accounts for most of the remaining domestic production. Unlike most other starch markets, use of high-fructose syrup (called iso-glucose in Europe) has not increased much, reportedly because of government restrictions.

Starch imports into the EEC fall under the 'starch regime,' a complex set of price support regulations (including *ad valorem* import duties and variable levies on starch imports) designed to protect European farmers and starch producers. European starch prices are well above world prices, the trade taxes generally cause imported starch to be more expensive than domestically produced starch. Maize imports also face a variable levy designed to keep domestic maize prices above world prices. It is apparently cheaper, however, to import maize to produce starch (as well as other valuable by-products), than to import starch directly.

Demand growth prospects

Jones feels that while starch demand prospects are generally good, prospects for developing country exporters are quite poor unless price competitiveness improves. The impact of higher cassava root prices in developing countries, caused either by the EEC demand for dried cassava or by domestic market conditions, has been to raise prices, and force cassava starch out of many of its traditional markets.

"The underlying competitive position is determined by raw material costs and production costs which, in turn, determine ex-factory starch prices," (Jones p.78). From 1975 to mid-1981, Thai f.o.b. cassava starch prices were usually above U.S. ex-factory maize starch prices. "...final prices are considerably influenced by internal freight charges (particularly in the U.S.A.), sea freight costs, import duties, and levies...[and]... in most of the... large markets... imported starches have seldom been competitive in recent years (p.78).

> The possibility with the greatest chance of success for developing country exporters is to reduce prices through the achievement of cost reductions. Raw material costs are the biggest single production cost and therefore cost reductions must be sought primarily through lower

gate prices. So as not to reduce farm incomes this implies that substantial, even revolutionary, changes in agricultural production methods will be required... (p.79).

International Market for Cassava in Feeds

Demand for dried cassava as an animal feed ingredient is a function of three variables: the demand for meat and other animal products, the number of animals being fed commercial mixed rations, and the price of cassava relative to other feed ingredients (which determines whether or not cassava is included in the feed mixture).

A commercial animal feed is a combination of feed ingredients such as maize, soybean meal, cassava, and vitamin supplements which meet the nutritional needs of an animal of a particular species and age at minimum cost. Its composition is determined both by technical coefficients (the nutritional requirements of the animal) and prices for the various ingredients. All commercial feed formulators now use a linear programming framework to determine the feed ingredients. The problem is set up as follows:

$$\text{Min } C = \Sigma_i P_i * Q_i$$

subject to

$$N_j <, =, > \Sigma a_{ij}$$

where

C = cost of the feed

P_i = price of ith ingredient

Q_i = quantity of ith ingredient

N_j = maximum, minimum, or equality constraint on jth nutritional requirement

a_{ij} = contribution of ith ingredient to jth nutritional requirement

Two nutritional requirements - calories (energy) and protein - are basic to all animal feeds. As can be seen in Table 1, dried cassava is low in protein, but high in energy. Soybean meal is high in protein and energy. Maize, wheat, and barley have intermediate protein and energy content. Protein can provide energy and accounts for the high energy content of soybean meal. However, high-protein sources are usually more expensive sources of energy than intermediate and low-protein feed ingredients. As a result, soybean meal is often the major source of protein, and maize or other cheaper ingredients are used to supply energy. Because cassava is high in energy, it complements soybean meal, and a mixture of cassava and soybean meal is competitive with maize and other feed grains.

Statistics on current cassava use in animal feeds in Southeast Asia are rare, but it appears that only small amounts are currently used (Lynam, 1983). This is not unexpected. For cassava-exporting countries, the price of dried cassava has been effectively determined by EEC feed grain prices, and for other cassava-producing countries which do not export, domestic prices are probably higher. At the same time, countries importing maize pay world market prices which are much lower than EEC prices. As a result, domestic cassava prices would be well above the level at which it would be included in least-cost rations.

In order to examine the feasibility of using dried cassava in mixed feed, a simple cost-minimization problem was constructed for chicken and pig feed in the original five countries of the Association of South East Asian Nations (ASEAN). Feed ingredients included were copra meal, maize, palm kernel meal, soybean meal, and dried cassava. (See Table 2 for the technical coefficients used.) Technical constraints included minimum requirements of protein and metabolizable energy and maximum limits on copra meal, palm kernel meal, and dried cassava. The constraint limits were determined by the nutritional and palatability requirements of the species being fed.

Using average wholesale prices for 1975 to 1980 (with some exceptions as noted in Table 3), the analysis shows that the only countries in which dried cassava would be used are the two exporters, Thailand and Indonesia. (See Table 4.) If the price increased by 4% in Thailand and 16% in Indonesia, cassava would no longer be included. In all other countries, cassava would be too expensive to be used and the price would have to fall between 9% (Singapore) and 329% (Malaysia) for cassava to be included in the ration. For dried cassava to be used in the U.S.A., it would have to sell for at least 45% below the c.i.f. Rotterdam price ($131/ton). If the Rotterdam price is used as an approximation to an ASEAN region import price, cassava would be added only to feeds in Malaysia. In most of the countries considered, dried cassava would have to sell for less than $0.10/kg before it enters the least-cost ration.

Government trade, foreign exchange rate, and domestic marketing policies often cause wholesale feed stuff prices to differ substantially from world prices. If relative prices are altered, feed ration ingredients may also change. For cassava, two price relatives are important: between protein

Table 2. **Technical coefficients for feed rations.**

Technical limitations on feed formulations, per kg

	Swine	Poultry
Min feed requirements/kg		
Protein (kg)	0.16	0.16
Metabolizable energy (calories)	3000.0	2800.0
Max feed allowances/kg		
Cassava meal (kg)	0.30	0.10
Palm kernel meal (kg)	0.20	0.15
Copra meal (kg)	0.20	0.10

Energy and protein supplied by selected feed ingredients, per kg

	Energy (calories)		
	Swine	Poultry	Protein (kg)
Maize	3,394	3,430	.085
Soybean meal	2,822	2,249	.440
Copra meal	3,080	1,540	.180
Palm kernel meal	2,885	2,100	.173
Dried cassava	3,800	3,650	.025

Sources: Personal communication from Dr. Regalado Zamora, Department of Animal Science, University of the Philippines, Los Baños, except dried cassava from Khajarern, S., and J.M. Khajarern (1981), "The economics and public acceptance of cassava-based rations," Department of Animal Science, Khon Kaen University, Thailand, paper prepared for the Twelfth International Congress of Nutrition.

sources and the feed grains, and between other energy sources and cassava. If government policies make wholesale prices of protein sources such as soybean or copra meal more expensive than world prices and increase their price relative to energy sources, cassava is less likely to be used as feed. On the other hand, if energy sources such as maize have higher domestic prices than world prices, cassava is more likely to be used.

The difference between world prices (as represented by trade unit values) and wholesale prices for the period 1975 to 1980 has been quite substantial for many feed ingredients (Table 5). Indonesian domestic prices were 50-225% higher than world prices, except for maize, which was about 5% below world prices. In Malaysia, domestic maize prices were somewhat above world prices, soybean prices were higher yet, and domestic cassava and copra meal prices were over 250% greater than world prices. Except for soybeans and cassava in the Philippines, domestic prices in the Philippines, Thailand, and the U.S.A. were below or at world prices.

Table 3. **Wholesale prices ($/t) of feed used in minimum-cost feed rations.**

	Copra meal	Maize	Palm kernel meal	Soybean meal	Dried cassava
Indonesia	340	148	95[a]	406[b]	87
Japan	183[c]	135[c]	79[c]	242[c]	131[d]
Malaysia	377	167	112	329[b]	600[e]
Philippines	140	139	n.a.	343	238[e]
Singapore[c]	115	136	96	228	131[d]
Thailand	97[a]	120	121[a]	263[a]	92
U.S.A.	177[f]	109[g]	n.a.	218	131[d]

a) Export unit value.
b) Converted from wholesale soybean price using $P_m = (P_s - 0.165P_o)/0.817$ where P_m = meal price, P_s = soybean price, P_o = soy oil price. P_o for Indonesia is crude Dutch oil, ex-mill from World Bank, *Commodity trade and price trends*. P_o for Malaysia is export unit value.
c) Import unit value.
d) c.i.f., northern Europe.
e) Equal to three times fresh root price.
f) Calculated from $P_m = (P_c - 0.576P_o)/0.36$ where P_m = meal price, P_c = copra price, P_o = coconut oil price, P_c and P_o are c.i.f., northern Europe.
g) f.o.b., Gulf ports.

Sources: FAO production yearbooks, various issues, and relevant statistical sources from each country, average prices for 1975-1980.

Table 4. **Optimal use of dried cassava at wholesale prices and minimum-cost boundary prices.**

	Boundary price[a] ($/t)	Ratio, current price to boundary price
Indonesia	104	0.84
Japan	117	1.12
Malaysia	140	4.29
Philippines	105	2.27
Singapore	120	1.09
Thailand	96	0.96
U.S.A.	91	1.44

a) The boundary price is the price at which dried cassava would enter the feed if it is not included at the current price or at which it would leave the feed if presently included. Boundary prices for both swine and poultry feeds are identical, but feed ingredients differ. For example, the Indonesia poultry ration uses 15 kg of palm kernel meal, 10 kg of cassava meal, 56 kg of yellow maize, and 19 kg of soybean meal. The Indonesia pig ration uses 20 kg of palm kernel meal, 30 kg of cassava meal, 29 kg of yellow maize, and 21 kg of soybean meal.

Sources: Linear programming runs using technical coefficients in Table 2 and prices in Table 3.

Table 5. **Average wholesale and world prices ($/t), 1975-1980, and nominal protection rates (NPR).**

	Indonesia	Malaysia	Philippines	Thailand	U.S.A.
Soybeans					
Wholesale	428	370	408	234	218
World	232[a]	289[a]	225[a]	326[a]	206[b]
NPR (%)	85	28	81	-28	6
Dried cassava					
Wholesale	87	600[d]	238	92	n.a.
World	76[b]	131[c]	131[c]	106[b]	131[c]
NPR (%)	14	357	81	-14	
Yellow maize					
Wholesale	148	167	139	120	109
World	156[a]	146[a]	206[a]	127[b]	119[b]
NPR (%)	26	14	-32	-5	-8
Copra meal					
Wholesale	340	377	220[e]	n.a.	n.a.
World	105[b]	111[b]	350[b,e]	97[b]	n.a.
NPR (%)	223	241	-37		

a) Import unit value.
b) Export unit value.
c) c.i.f., Rotterdam.
d) Fresh cassava price times three.
e) Copra.

n.a. = not applicable.

Sources: FAO production yearbooks, various issues, and relevant statistical sources from each country.

In order to estimate the feed use of dried cassava when world prices determine feed ingredients, minimum-cost rations were constructed using export unit values for export products and import unit values for imported feed ingredients (Table 6). With these prices, cassava enters into the minimum-cost rations for Indonesia, Thailand, and the Philippines (Table 7).

The increased attractiveness of cassava at world prices occurs because most of the countries tax (implicitly or explicitly) imports of soybeans more than maize. Protection provided to domestic soybeans is several times higher than to domestic maize in Indonesia, Malaysia, and the Philippines. Furthermore, domestic prices of other protein sources, even those exported, are often well above world prices. In almost all of the rations, protein is the limiting factor and excess energy is available.

Table 6. **World prices ($/t) of feed used in minimum-cost feed rations.**

	Copra meal	Maize	Palm kernel meal	Soybean meal	Dried cassava
Indonesia	105[a]	156[b]	95[a]	134[b]	76[a]
Malaysia	87[a]	146[a]	112[a]	235[b]	131[e]
Philippines	132[a]	206[b]	121[d]	206[b]	131[c]
Singapore	115[b]	136[b]	96[b]	228[b]	131[c]
Thailand	97[a]	127[a]	121[a]	263[a]	92[a]
Japan	183[b]	135[b]	79[b]	242[b]	131[c]
U.S.A.	177[c]	119[a]	121[d]	206[a]	131[c]

a) Export unit value.
b) Import unit value.
c) c.i.f., northern Europe.
d) Thai export unit value.
e) See footnote f, Table 3.

Sources: FAO production yearbooks, various issues, and relevant statistical sources from each country, average prices for 1975-1980.

Table 7. **Optimal use of dried cassava at world prices and minimum-cost boundary prices.**

	Boundary price[a] ($/t)	Ratio, current price to boundary price
Indonesia	134	.57
Japan	117	1.12
Malaysia	131	1.00
Philippines	206	.63
Singapore	120	1.09
Thailand	104	.88
U.S.A.	104	1.26

a) The boundary price is the price at which dried cassava would enter the feed if it is not included at the current price or at which it would leave the feed if presently included. Boundary prices for both swine and poultry feeds are identical, but feed ingredients differ. For example, the Indonesia poultry ration uses 15 kg of palm kernel meal, 10 kg of cassava meal, 0 kg of yellow maize, and 10 kg of soybean meal. The Indonesia pig ration uses 20 kg of palm kernel meal, 30 kg of cassava meal, 0 kg of yellow maize, 20 kg of copra meal, and 30 kg of soybean meal.

Sources: Linear programming runs using technical coefficients in Table 2 and prices in Table 6.

Because government policies cause domestic protein prices to be high relative to domestic maize prices, maize is used in feed rather than a mixture of cassava and protein meal. In Indonesia, when world prices are used instead of domestic prices, yellow maize use drops from 56 kg (per 100 kg of feed) to 0 kg in poultry feed and from 29 kg to 0 kg in pig feed. Copra meal use increases from 0 to its maximum in both feeds, and soybean meal use also increases.

The above analysis does not take into account the impact of any currency overvaluation or changes in international exchange rates on the relative prices of feed grains. To the extent that all the feed ingredients are tradable (that is, domestic prices are determined by world prices, and there are no quantitative restrictions to trade), a devaluation will not change the attractiveness of using cassava in animal feeds relative to other sources of energy. If, however, a country decides to set the price of a feed ingredient and not allow its domestic price to move with world prices, a devaluation can change the relative attractiveness of cassava. For example, if a country decides to stimulate domestic maize production by setting a floor price above the world price, cassava becomes more attractive. If a devaluation follows, the domestic prices of imported soybean meal and exported copra meal rise, and cassava then becomes less attractive.

In the past, changes in the exchange rate between the U.S. dollar and the German deutsche mark (the $/DM rate) affected the export prices of dried cassava. Since international cassava prices were determined by EEC domestic prices, a change in the $/DM rate directly affected the dollar price of other feed ingredients. With the new two-price system for cassava imports into the EEC, new exporters will no longer experience this phenomenon.

Potential demand for dried cassava in animal feeds

If government policies or cost-lowering technical change caused sufficient declines in the cassava price for it to be included as part of mixed feeds, how much would be demanded? It is impossible to answer this hypothetical question with any degree of confidence, because the number of assumptions needed is very large and the degree of confidence about any of them is small. Nevertheless, it is useful to try to estimate the magnitude of demand given conservative assumptions. If the potential demand is large, resources devoted to reducing the relative cost of cassava will have a large payoff.

In making the forecast the following assumptions were made. Growth rates in numbers of animals between 1975 and 1980 would continue through 1990. Cassava would be used to its technical limit of 10% of poultry feed and 30% of swine feed. Where data on the number of commercial livestock (i.e., those eating mixed feeds) were available, it was assumed 10% of the population was fed mixed feed in 1980 and 20% in 1990. Commercial poultry eat 12 kg of feed per stock unit (each bird eats 4 kg and for every bird at the year's end, three birds have been raised). Commercial swine use 270 kg of feed per stock unit (one pig a year is raised for each pig at the end of the year). All livestock in Hong Kong, Japan, Singapore, and Taiwan eat mixed feeds. Potential demand in the U.S.S.R and the U.S.A. is ignored.

As expected, Japan dominates in both swine (8.6 million) and poultry (264 million) numbers in the region (Table 8). For poultry, Indonesia ranks second (98 million) while Malaysia, the Philippines, and Thailand follow with about 50 million each. For swine, the Philippines ranks second (6.9 million), Taiwan third (4.2 million), and Thailand fourth (3.7 million). Growth rates for all poultry (village plus commercial) are around 3.5% for all countries except Hong Kong and Taiwan where growth rates are over 10%, and Indonesia where growth is less than 2%. Swine growth rates vary from less than 1% in Japan to over 9% in Taiwan.

Using the assumptions, base numbers, and growth rates described above, potential animal feed demand for cassava from eight countries in the region is substantial (Table 9). If dried cassava had been used in all animal feeds in 1980, about 1.7 million tons (4 to 5 million tons for fresh roots) would have been needed. This is roughly equal to 15% of cassava production in the same countries. By 1990, use would grow to over 3.2 million tons of dried cassava (8 to 9 million tons of fresh roots). About 75% of the demand would be for pig feed.

Table 8. **Average livestock numbers and average annual growth rates, 1975-1980.**

	All poultry		Commercial poultry		All swine		Commercial swine	
	number (000)	rate (%)	number (000)	rate (%)	number (000)	rate (%)	number (000)	rate (%)
Hong Kong	5,268	11.4	5,268	11.4	478	5.9	478	5.9
Indonesia	98,458[a]	1.8[a]	2,836	4.6	2,798	4.1	n.a.	n.a.
Japan	264,446	3.6	264,446	3.6	8,591	0.8	8,591	0.8
Malaysia	46,933	3.2	n.a.	n.a.	1,499	4.1	n.a.	n.a.
Philippines	50,387	3.7	12,839	9.1	6,895	6.7	1,075	19.3
Singapore	13,638	3.3	13,638	3.3	1,139	2.0	1,139	2.0
Taiwan	34,549	10.3	34,549	10.3	4,219	9.1	4,219	9.1
Thailand	56,621	5.4	n.a.	n.a.	3,884	3.5	n.a.	n.a.

a) Non-commercial (village) poultry only.

n.a. = not available.

Sources: Averages calculated from FAO production yearbooks, various issues, and relevant statistical sources from each country. Growth rates are coefficients of log linear-fitted trends for 1975-1980.

Table 9. **Potential demand for dried cassava in animal feeds (000 t), 1980 and 1990.**

	Poultry		Swine		Total	
	1980	1990	1980	1990	1980	1990
Hong Kong	6	20	39	70	45	90
Indonesia	3	17	23	34	26	51
Japan	317	455	696	754	1,013	1,209
Malaysia	6	16	12	18	18	34
Philippines	15	99	87	600	103	699
Singapore	16	23	92	113	109	135
Taiwan	42	116	342	849	383	965
Thailand	7	23	31	45	38	68
Total	412	769	1,322	2,483	1,735	3,251

Sources: Table 8 and assumptions in text.

Japan is the largest potential market, demanding almost 60% of the cassava in 1980 and 37% in 1990. Taiwan is the second largest potential market, accounting for 22% in 1980 and 30% in 1990. For both of these countries, cassava would have to be imported. Demand from Hong Kong and Singapore for cassava is relatively small (9% in 1980 and 7% in 1990) since livestock numbers and growth are limited. However, these countries already import sizable quantities of meat and provide an additional, indirect source of potential demand for dried cassava. Potential demand in Thailand and Indonesia is a small fraction of current cassava production and can easily be met domestically. In the Philippines, however, potential demand in 1980 is more than 10% of production, and would grow rapidly if the 1975-80 growth rate of commercial swine is maintained.

The most important conclusion is that if the relative price for cassava can be lowered enough that cassava is included in animal feeds (below $0.10/kg, factory gate), the largest demand in the Southeast and Northeast Asian region will be from Japan and Taiwan (and probably South Korea). Sales to these countries will depend on a sufficiently low domestic price of protein, and on elimination of any barriers to cassava imports. Cassava imports will take the place of maize, and must therefore be competitive not only in price, but in quality and regularity of supply.

Summary and Conclusions

International demand for cassava will depend on reductions in the cost of production, changes in trade policies affecting cassava and other feed ingredients, and improved regularity of supply. The market potential for genetic starch looks good, especially in the U.S.A., but any increased trade in cassava starch must compete with maize starch. Animal feed demand also provides a potentially large market, but dried cassava must again compete with maize.

Trade barriers in two of the largest markets, Japan and the EEC, will hinder increased cassava starch imports and it seems unlikely that these barriers will be reduced. Import regulations in the EEC also constrain the growth in use of dried cassava there. EEC agricultural policy is currently undergoing substantial changes. The outcome of these changes is not clear, but it seems unlikely that the EEC use of dried cassava will grow substantially in the next few years.

Current use of dried cassava in Southeast Asia (and possibly other regions as well) is hindered by the policy of protecting domestic protein sources more than domestic feed grains. In Indonesia, for example, domestic soybean prices were 86% higher than world prices on average between 1975 and 1980 while domestic maize prices were only 26% higher than world prices during the same period. Since cassava and protein sources are complementary in feeds, cassava use is reduced by this policy.

The price at which dried cassava enters into animal feeds depends upon the prices of all other ingredients, but any large-scale increase in demand could require world cassava prices below $0.10/kg. If the social opportunity cost of dried cassava can be lowered enough for cassava to be included in animal feeds in all countries in the region, cassava-growing countries can meet their own demand with relatively small increases in production. Thus, prospects for intra-ASEAN trade in cassava are not good except possibly imports into the Philippines. (Regional trade in tropical protein sources, however, might have more potential.)

Large increases in import demand for dried cassava could occur in Japan and Taiwan. The U.S.A., U.S.S.R., and South Korean markets were not considered, but they are also potentially large buyers of dried cassava. In all of these markets, any imports of dried cassava would have to substitute for maize. In addition to competing on price terms, cassava would also have to compete in terms of regularity of supply, ease of handling, and maintenance of quality.

Acknowledgements

I would like to thank Laurian Unnevehr for comments and Marie Angeles P. Ocampo for research assistance and suggestions.

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A Comparative Analysis of Cassava Production and Utilization in Tropical Asia

John K. Lynam

Introduction

Cassava was probably first introduced into Asia during the Spanish occupation of the Philippines. It was being grown on Ambon, one of the outer islands of Indonesia, by 1653 (Nelson, 1982). Cassava was introduced from Java to Mauritius in 1740 and from Mauritius to Sri Lanka in 1796 (Greenstreet and Lambourne, 1933). Certainly by the beginning of the 19th century cassava had been effectively distributed throughout tropical Asia. Expansion of cassava production in the 19th century was hastened by colonial administrations, first by the initiation of a cassava processing and export industry in Malaya in the 1850s, followed by one in Java; and second, by the promotion of cassava as a famine reserve, particularly by the Dutch in Java and the British in southern India.

Of the New World food crops introduced into tropical Asia, cassava has become the most important in terms of volume produced. Characteristic of the crop, the development of cassava has responded to different forces in each country, as is reflected in the utilization patterns for the countries shown in Table 1. Cassava is an important food source only in India and Indonesia, an important export crop in Thailand, and an important source of starch in all countries. Just as cassava has filled a particular market niche in each country, the crop also occupies a different production niche in each country according to the type of land resource which has been exploited and the type of cropping system which has evolved. The crop's particular adaptability to upland conditions, especially where there are either soil or moisture constraints, and its multiple, end-market uses give cassava a certain malleability in adapting to quite different demand and production conditions.

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Table 1. **Production and utilization of cassava (000 t) in principal producing countries.**

Country	Production	Export	Domestic utilization: Human consumption: Fresh	Human consumption: Dried	Starch	Animal feed	Waste
India (1977)	5688	22	2610	619	1784	-	653
Kerala	4189	22	2437	619	499	-	503
Tamil Nadu	1310	-	126	-	1162	-	131
Indonesia (1976)	9686	801	3444	2212	2747	-	482
Java	6317	253	1815	1760	2134	-	355
Off-Java	3369	548	1629	452	613	-	127
Malaysia (1977)	432	66	-	-	302	43	21
Philippines (1975)	450	-	223	37	92	32	65
Thailand (1977)	13,554	9,996	-	-	745	16	2797

Sources: Unnevehr, 1982; Titapiwatanakun, 1979; and CIAT data files.

This paper compares the diversities and similarities of cassava production and utilization systems in tropical Asia and draws conclusions about the potential of the crop in this region. A dominant issue is whether principal constraints have their origin on the production or the demand side, or conversely, whether growth has been led by production or by demand. This view departs substantially from the more orthodox perspective held in Asia (dominated by the case of rice) which suggests that the restriction on increased food supplies is the lack of sufficient factors of production, especially land, and the solution is therefore improved production technology and land productivity. In the case of cassava, however, the question is whether improved technology is a sufficient stimulus for the expansion of production or whether this also needs to be integrated with market development.

A Comparative Analysis of Production

Cassava is essentially an upland crop in tropical Asia. Only in rare cases when water is a limiting factor, such as occurs with well water systems in Tamil Nadu in India or during the secondary season on sawah soils of Java, is cassava planted in irrigated areas. The agro-climatic conditions under which cassava is grown in the upland areas of Asia vary enormously, but the defining factor in major cassava-producing zones is the existence of a constraint on plant growth. In areas such as Kerala, India, the outer islands of Indonesia, or the eroded slopes of eastern and central Java, the limiting factor is soil. In the northeast of Thailand, Tamil Nadu in India, or Madura Island in Indonesia, the problem is moisture stress. Compared to other crop alternatives, cassava produces high carbohydrate yields under such conditions. Cassava has thus tended to be concentrated in those areas where it has a comparative advantage in productivity over other crops.

This, however, is too broad a generalization for Asian conditions, for cassava extensive and intensive cropping systems: On one hand, cassava is grown in upland areas where farm size is a major constraint on farmers' crop production, such as Kerala and Java (Table 2). Cassava is selected because of its high yields and yield responsiveness, even where there are agro-climatic constraints. Exploitation of the yield potential of cassava is clearest in the irrigated area of Tamil Nadu. Here, farm-level yields commonly exceed 50 tons/ha.

On the other hand, cassava is well adapted to more land-extensive production systems, such as occur in frontier areas. Cassava has been a major crop component in the re-settlement schemes in the off-Java islands of Indonesia, and where infrastructure has developed, cassava has expanded rapidly, such as the Lampung area on Sumatra. The same

Table 2. **Types of land constraint in principal cassava production zones.**

Country	Limited farm size	Marginal agro-climatic conditions	Limited infrastructure
China	Guangdong	Guangxi	
India	Kerala Tamil Nadu (irrigated)	Tamil Nadu (non-irrigated)	
Indonesia	Java (level sawah soils)	Java (eroded hillsides)	Off-Java
Malaysia		Peat soils	Land development zones
Philippines	Visayas		Mindanao
Thailand	Central plain	Northeast	Northern region

applies in the Mindanao area of the Philippines, where cassava has become a major crop. In such areas, infrastructure development is a principal stimulus in moving cassava from essentially subsistence status to a major cash crop.

In Malaysia, as compared to other Asian countries, cassava's role in the agricultural economy is defined more by access to land quality. Malaysia is by Asian standards a land surplus country and much of the unexploited land remains under control of the federal government. Cassava is the crop of first choice for squatters on federal land and apparently much of the cassava grown in Malaysia is grown by squatters. In the major producing state of Perak, a 1976 estimate indicates that 3,892 ha of cassava were planted legally while 10,240 ha were planted illegally (Hohnholz, 1980).

Given cassava's demonstrated ability to exploit the heterogeneity of the land resource in Asia, a major factor determining the production potential of cassava is its ability to compete with other crops for land in the upland areas. An important point in agricultural policy formulation emerges: on the production side cassava rarely competes for land with the same crops with which it competes on the demand side. That is, cassava rarely competes with food or feed grains. There is some competition with maize in the central plain of Thailand and to a more limited extent in Mindanao in the Philippines. The one area where maize and upland rice overlap with cassava is on Java and Lampung, and here the three are often found in an intercropping system. In areas where rainfall is a limiting factor, such as the northeast of Thailand or the non-irrigated areas of Tamil Nadu, cassava has no effective competing crop.

In most of the other cassava-producing areas cassava competes principally with tree crops: coconuts and rubber in Kerala, oil palm and rubber in Malaysia and the off-Java islands of Indonesia, and rubber in the southern part of Thailand. Southeast Asia has an international comparative advantage in these crops; over 80% of world exports of rubber, 85% of coconut oil, and 90% of palm oil originate in the region. Expansion possibilities for these crops are limited by the growth potential of world markets and, moreover, these are markets in which close substitutes exist. Cassava's ability to compete with tree crops for land, labor, and capital in these areas is an open question, but it will essentially depend on the relative importance given to expanding export markets versus meeting domestic demand for carbohydrate sources.

While it is the land issue that largely determines where cassava is grown, it is the ratio of land to labor that determines how cassava is grown, that is, in what type of cropping system. Cassava-based cropping systems vary substantially across Asia (Table 3), and the labor intensity of these systems is fairly consistent with the land/labor ratio in each country (Table 4). In the countries with the highest land/labor ratios, Malaysia and Thailand, tractors are widely used to prepare the land for cassava. In the Philippines animal traction is common, while in Indonesia and Kerala land is principally prepared by hand. Weeding intensity and the propensity to achieve a higher land productivity through intercropping and fertilizer application are also greater in more labor-intensive systems.

One common factor encountered in cassava cropping systems in Asia is the low use of chemical fertilizers (Table 3). Even in Kerala and Java, chemical fertilizer application is low, despite the fact that application levels on other crops, particularly rice, is very high. To a significant extent in Indonesia and India, farmers compensate for this by applying organic manures and wood ash. In India the green manure that remains in the field is incorporated into the soil below the planted stake. Although many fertilizer experiments have shown a yield response of cassava to fertilizer application, the fact remains that few farmers utilize chemical fertilizer in significant quantities. A better understanding of the fertilizer response issue at the farm level is needed, but it does appear to offer one potential avenue for significant yield gains.

These differences in cropping systems lead to significant differences in labor input, per hectare production cost, and yields across Asian cassava production zones (Table 5). Labor is consistently the largest cost component in cassava production. Differences between countries in total

Table 3. **Characteristics of cassava cropping systems in major production zones.**

Characteristic	Thailand, northeast	Malaysia, Perak	Indonesia Java	Philippines, Mindanao	India	
					Kerala	Tamil Nadu
Principal power source	Tractor	Tractor	Manual	Bullock	Manual	Bullock
Intercropping	Monoculture	Monoculture	Maize and upland rice principal intercrops	Monoculture	Peanut recent intercrop	Monoculture
Labor input for weeding (man-days/ha)	37.6	13.3	high	12.8	high	96.7
Fertilizer use						
organic (t/ha)	-	-	0 to 8.6	none	high	18.5
inorganic (kg/ha)	9.6	198	21.7	none	19	200
Seasonality in planting	50% planted April-June	slight	75% planted Nov-Jan	Moderate	60-65% planted April-June	Major portion planted Jan-March
Average yields (t/ha)	13.8	27.2	9.7	4.7	13.6	24.5
Subsistence consumption (%)	none	none	27	17	60	neg.

Sources: Thailand Ministry of Agriculture and Cooperatives, 1982; Tunku Yahaya, 1979; Roche, 1982; Mejia et al., 1979, and Uthamalingam, 1980.

Table 4. **Land-labor ratios and average farm size for various Asian countries.**

Country	Land-labor ratio[a] (ha person)	Average farm size (ha farm)
India (Kerala)	0.12	0.49 (1971)
Indonesia	0.22	1.05 (1963)
Java	n.a.	0.4 (1973)
Malaysia	0.65	2.19[b] (1970)
Philippines	0.44	3.59 (1960)
Thailand	0.51	3.72 (1978)

a) Arable land and land in permanent crops divided by rural population, 1980.

b) Does not include large estates, which make up 31% of cultivated area.

n.a. = not available.

Sources: FAO, 1981, and agricultural censuses of different countries.

per hectare labor cost are substantial. However, once differences in yields are taken into account, there is significantly reduced range of production costs per ton. Expressed on a dried equivalent basis,* these production costs must be seen as low, compared to per ton production costs of grains.

However, in most cases, it is yield rather than per hectare production costs that is the principal variable in the determination of costs per ton. Cassava, as compared to the grain crops, has a potentially high yield variance. Yields as low as as 2 tons/ha are not uncommon in many parts of the Philippines while farm yields reaching as high as 80 tons/ha have been recorded in Tamil Nadu, India. This very large yield potential has always been the hallmark of the crop, and it is in Asia that this yield potential has been most exploited. Compared to Africa or Latin America, yields in Asia are high. Part of this is due to significantly lower disease and insect pressure, since Asia is outside cassava's center of origin. The other factor is the more intensive cassava cropping systems found in Asia.

* As a gross approximation, 2.5 tons of fresh roots produce 1 ton of dried cassava, expressed on a 14% moisture basis. This will obviously vary depending on the dry matter content of the roots.

Table 5. **Labor use and cost structure ($US) in cassava production systems.**

	Indonesia, Gunung Kidul 1979/80	Indonesia, Kediri 1979/80	Thailand, Cholburi 1977/78	Thailand, Nakornrajsima 1977/78	India, Salem 1978/79	Philippines, Central Visayas 1976/77	Malaysia, Perak 1977/78
Labor (man-days/ha)	345.8	237.2	74.8	67.2	138.5	65.0	62.2
Land cost/ha	0	233.7	28.9	74.8	121.3	46.4[a]	17.3
Variable costs/ha							
Labor	97.8	227.0	76.2	64.0	90.9	50.1	116.4
Land preparation	0	106.7	59.2	33.5	13.4	5.1	38.9
Fertilizer	0	114.9	16.6	0	59.8	0	25.9
Pesticides	0	0	2.7	0	0	0	12.1[b]
Seed	2.6	4.8	16.6	1.9	0	0	3.5
Total	100.4	453.4	171.3	99.4	164.1	55.2	196.8
Yield (t/ha)	2.6	17.5	10.9	13.7	10.7	5.5	27.2
Variable costs/t	38.6	25.9	15.7	7.3	15.3	10.0	7.2

a) Share tenancy - 33% of gross value

b) Herbicides.

Sources: Roche, 1982; Tinprapha, 1979, Uthamalingam, 1981, Mejia et al., 1979, and Tunku Yahaya, 1979

Yield differences due to differences in agro-climatic conditions and cropping systems of the major production areas (Table 6) have not been studied extensively. No systematic work has been done which specifically relates differences in agro-climatic conditions, input levels, varieties, and management practices to variation in yield levels.* Without this information, it is very difficult to assess the principal constraints on cassava yields, and in turn, the potential for increasing cassava productivity. The potential yield gains from new technology, and in a large measure, the definition of that technology, still remain rather amorphous. Nevertheless, the range of yields presented in Table 6 are at least suggestive of the substantial scope for yield improvement in many countries.

A Comparative Analysis of Consumption

The food economies of tropical Asia are dominated by rice; any other starchy staple is only of secondary importance in the regional diet. Within this context cassava has achieved a significant role in the food economies of Indonesia and Kerala, and only maize is as significant a calorie source in tropical Asia. The impetus for the early expansion of cassava in Kerala, the Philippines, and Indonesia was to supplement inadequate supplies of rice, and it was in land-scarce Kerala and Java that cassava production expanded most significantly. In Thailand and Malaysia, on the other hand, the incentive for production expansion came from non-food markets.

The locus of cassava consumption in Indonesia and Kerala is in the rural sector and among the lower income strata. Moreover, because cassava is significantly less preferred than rice in the diet, cassava is very much a secondary staple in the food economy of these countries. Cassava's role in such food economies is as a cheap calorie source which supplements shortfalls in the availability of rice, whether due to insufficient supplies or restricted purchasing power. Cassava has thus come to play a significant role in the calorie intake of that population most at risk in the region (Figure 1). While food policy in these countries will still have rice as its central component, cassava can add a certain flexibility to these rice-based policies. Unfortunately, it is rare that policies on secondary staples are integrated with those on rice in developing an overall food and nutritional policy.

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* The research by Roche (1982) on cassava cropping systems on Java is the one exception. Apart from age at harvest, fertilizer, and labor input, the other explanatory variables were regional or land system variables.

Table 6. **Comparative yields derived from national statistics and production surveys.**

Country region	National statistics		Production surveys	
	Year	Yield (t/ha)	Year	Yield (t/ha)
India	1978-79	16.7		
Kerala	1978/79	14.6		
Tamil Nadu	1978/79	31.2	1978-79	13.6 and 23.0[a]
Malaysia	1978	17.4		
Perak			1978	27.2
Indonesia	1977-79	12.9		
West Java	1977-79	10-12	1979-80	6-20
Central Java	1977-79	9-11	1979-80	5-12
South-Central Java	1977-79	7-9	1979-80	2-10
East Java	1977-79	10-11	1979-80	10-40
Philippines	1977-79	10.3		
Central Luzon	1977-79	2.4	1977-79	5.8
Bicol	1977-79	9.6	1977-79	2.5
Central Visayas	1977-79	3.5	1977-79	5.5
Eastern Visayas	1977-79	4.2	1977-79	2.2
Western Mindanao	1977-79	14.7	1977-79	5.4
Northern Mindanao	1977-79	4.6	1977-79	4.0
Thailand	1980-81	13.1		
North	1980-81	17.0	1980-81	14.2
Central	1980-81	15.5	1980-81	15.1
Northeast	1980-81	13.3	1980-81	13.8

a) Non-irrigated and irrigated conditions.

Sources: Uthamalingam, 1980; Tunku Yahaya, 1979; Roche, 1982; Mejia et al., 1979; Ministry of Agriculture and Cooperatives, 1982; and national statistical sources.

The role of cassava in nutrition planning has been analyzed most rigorously in Indonesia (Dixon, 1982; Timmer and Alderman, 1979; Timmer, 1980). Cassava's low cost relative to rice, the very skewed distribution of consumption toward the low income strata, the existence among the poor of calorie intake well below recommended standards, and, among the lowest income strata, the significantly positive income elasticity for cassava (Dixon, 1982) create a situation where increased cassava production and lower prices will almost exclusively affect the poor consumer.

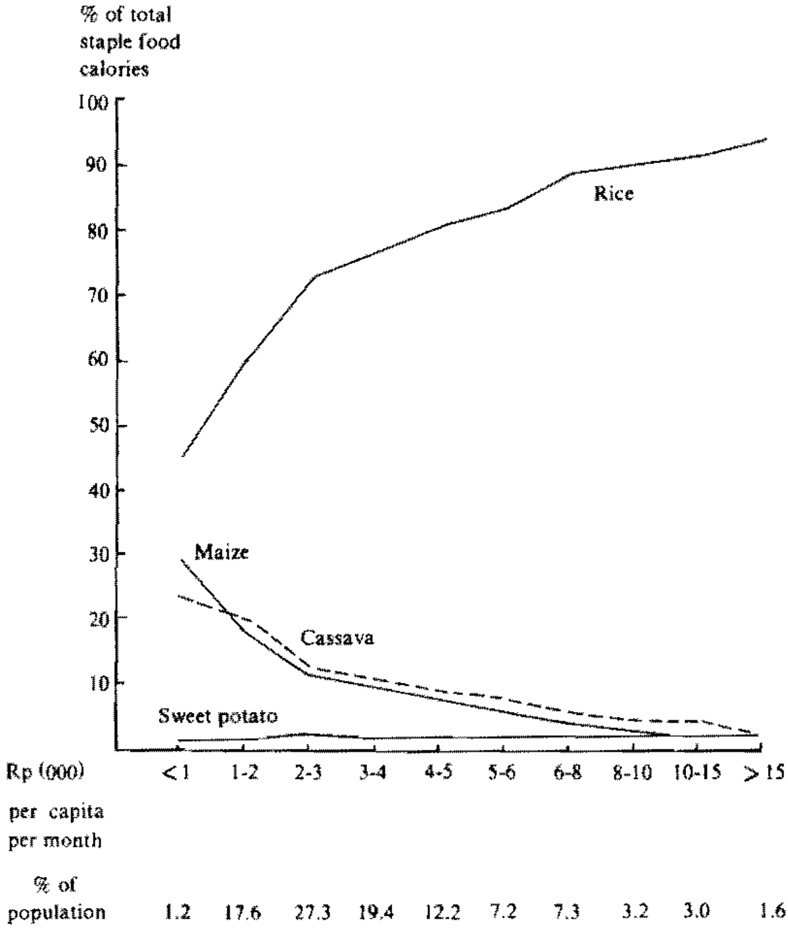

Figure 1. *Type of staple food consumption by income group, Java 1976.*
Source: Dixon, 1982.

Overall inelasticity in food markets, while providing substantial benefits to consumers when improved technology is introduced, does not provide much scope for increasing farm incomes. Cassava is a cash crop in Asia. Even in Indonesia and India, where there is some subsistence food consumption, most cassava moves into market channels. Areas of expanding cassava production have been associated with dynamic markets. Thus, if cassava is to play a role in food policy, there must be a means of maintaining incentives to producers. Cassava's role in generating increases in farm incomes is, therefore, associated with markets other than traditional food markets. Where traditional food markets are important, development of these alternative markets provides something of a price floor to sustain farm incomes. Moreover, some of these alternative markets, such as composite flour, can be more elastic than traditional food markets.

The economies of Southeast Asia have been changing rapidly in the last two decades (Table 7). Industrialization, rapidly rising income, and significant rates of urbanization have created changes in domestic demand for food. Food demand within the region is being driven principally by changes occurring outside the agricultural sector; yet it is this sector which must continue to generate both the bulk of employment in the economy and continued increases in marketable surpluses, and in many cases the major portion of foreign exchange earnings. Increasing demand in the quantity and variety of food products can be a stimulus to the agricultural sector, but greater demand can also cause internal food prices to rise, thus affecting the nutrition levels of the poor and/or food imports. This situation is potentially aggravated by the winding down of the production gains achieved by the dwarf rice varieties and by the significant portion of resources devoted to export, mainly tree crops.

One of the dominant trends in Asian food economies is the rising demand for livestock products and the derived demand for carbohydrate and protein sources for concentrate feeds (Table 8). This growth in demand for livestock products has been most apparent in the poultry sector, that is, for meat and eggs. The poultry and feed concentrate sector has developed rapidly over the last decade in the cassava-producing countries of Thailand, the Philippines, and Malaysia, and in the non-producing countries of Taiwan, Japan, and the Republic of Korea. The sector is only in a very formative stage in Indonesia. However, per capita consumption levels remain low, although the FAO (1983) anticipates annual growth rates to the year 2000 of 8.8% for poultry meat and 6.3% for eggs in the Far East.

Maize is universally the principal grain used in the feed concentrate industry in the region. Only Thailand, the Philippines, and Indonesia are significant producers, and of these only Thailand is in a net export position. Undoubtedly Southeast Asia will have a continuing deficit in production versus consumption of feed grains. However, only very insignificant amounts of cassava presently enter into animal feed rations in the region. Malaysia is apparently the largest user of cassava for feed concentrates, using around 15,000 tons annually. A large and growing domestic market thus remains unexploited in most countries.

After direct food use, starch is by far the largest form of domestic cassava use in the region. As in the case of livestock products, consumption

Table 7. **Selected economic indicators of principal cassava-producing countries.**

Country	GNP per capita		GNP of industrial origin		Population in urban sector	Growth in urban population	
	1980 ($US)	Growth 1960-80 (%)	1960 (%)	1980 (%)	1980 (%)	1960-70 (%)	1970-80 (%)
India	240	1.4	20	26	22	3.3	3.3
Indonesia	430	4.0	14	42	20	3.6	4.0
Malaysia	1620	4.3	18	37	29	3.5	3.3
Philippines	690	2.8	28	37	36	3.8	3.6
Thailand	670	4.7	19	29	14	3.5	3.4

Source: World Bank, 1981.

Table 8. **Production of feed concentrates in relation to coarse grain imports.**

Country	Feed concentrate production 1980 (000 t)	Growth in concentrate production 1970-80 (%)	Coarse grain imports 1980 (000 t)	Growth in coarse grain imports 1970-80 (%)
Cassava producers				
Thailand	1350	28.6	-2,175	-
Philippines	936[a]	12.9[b]	351	27.5
Malaysia	549	12.2[c]	431	7.4
Indonesia	410	n.a.	34	3.5
Non-cassava producers				
Republic of Korea	4775[d]	5.2[e]	2,364	27.2
Taiwan	n.a.	n.a.	3,618	n.a.
Hong Kong	n.a.	n.a.	270	4.4
Japan	19,876[f]	n.a.	17,165	5.7
Singapore	n.a.	n.a.	552	14.0

a) 1979
b) 1970-79
c) 1972-80
d) 1981
e) 1972-81
f) 1977

Sources. FAO, 1975 and 1982; and CIAT data files.

levels of starch have increased rapidly in most countries in the last decade (Table 9). In countries such as Indonesia and Malaysia, and regions such as Tamil Nadu in India and Mindanao in the Philippines, starch processing dominates the market for roots. These similarities contrast with the significant heterogeneity across countries in the end market for cassava starch, competition with other starch sources (principally maize), and the scale of processing technology within the starch industry. These latter factors determine, to a large extent, the future growth potential for cassava starch in each of the countries.

The other major cassava market is the export market; exports are dominated by chips/pellets, although a significant volume of cassava starch is exported as well. While all of the major cassava-producing countries in the region have exported cassava products in the recent past, only in Thailand is production principally directed to export markets. In all other countries the export market is minor when compared to the domestic market. India and China have been intermittent exporters, while Indonesia has been a consistent exporter but has had large fluctuations in quantities. Malaysia has been a consistent, but declining exporter. For these latter countries the export market serves as something of a surplus vent, which usually is operational only at relatively high world market prices. This was particularly the case in 1979-80, and demonstrates the role that the export market can play in setting a price floor under domestic markets, even though at historically low to moderate world price levels, domestic prices in most countries make cassava exports uncompetitive.

A multiple market structure has developed for cassava in most countries in the region, with each country having its own particular utilization patterns. Yet, as has been noted, significant untapped potential exists for cassava in undeveloped markets, such as the domestic feed concentrate markets. Other markets include the composite flour market (especially where the wheat flour is used principally in noodles), and the fructose syrup market in sugar-importing countries such as Indonesia.

A natural question is what has been constraining the development of these alternative markets and in turn, whether improved production technology could be a motivating factor in their development. To answer this question, the issue of price formulations must first be analyzed.

Marketing and Price Formulation

In a multi-market situation it is essentially price which allocates the cassava roots between the different end uses. It is axiomatic that the price must be able, on the one hand, to cover the farmer's costs of production

Table 9. **Characteristics of the cassava starch industry in the principal producing countries.**

Country	Cassava starch production 1980 (000 t)	Growth in cassava starch utilization 1970-80 (%)	Growth in total starch utilization 1970-80 (%)	Two largest end uses	Modal scale of processing
India	415	n.a.	n.a.	Tapioca pearl Cloth sizing	Medium
Indonesia	662	8.9[a]	8.9[a]	Krupuk Other food industries	Medium to large Large
Malaysia	50	9.9[b]	9.9[b]	n.a.	Large
Philippines	17[c]	-2.9[d]	7.9[d]	Glucose Monosodium glutamate	Large
Thailand	416	7.7	7.7	Food industry Monosodium glutamate	Large

a) 1974-79
b) 1972-80
c) 1979
d) 1970-79

Sources: Nelson, 1982; and CIAT data files.

and, on the other hand, to compete with substitutes in the various markets. Forces on the supply side, such as increasing input or factor costs, or the advent of more profitable crops, may drive the production cost of cassava out of line with the market price of substitutes. Vice versa, forces on the demand side, such as inelastic output markets or falling prices of substitutes, may drive the market price out of line with cassava production costs, at least for more high-cost producers. At issue in this section then is delineation of the principal factors determining cassava price in the different countries and the mechanisms influencing the allocation of cassava between different end uses.

The cassava products in the different cassava markets tend to compete with different substitutes. This sets up something of a market hierarchy in which cassava in some markets can be competitive at higher prices than in other markets. Thus, in Kerala, India, the fresh food market is the principal demand-side factor regulating price formulation. Since there are severe supply-side constraints on expanding cassava production, cassava prices set in the food market tend to be higher than are profitable for the operation of the starch industry, which absorbs seasonal surpluses and roots of inferior quality. In the Philippines, the fresh food market also usually sets a higher root price than the starch market, but because the size of the food market is so limited, the starch factories tend to be the major market force in their supply area. However, expansion in this starch market has been apparently constrained by competition with maize starch. There is potential for expanding cassava area and production for the animal feed market, but yields need to be higher than their current average of around 5 tons/ha, thereby reducing costs of production.

Factors determining cassava prices as well as constraints on further development of the crop vary markedly between countries (Table 10). In Thailand and the Philippines the constraint is on the demand side, while in India, Malaysia, and Java the constraint is very much one of production. Where cassava production has expanded rapidly in Asia, such as Thailand and the Lampung area of Indonesia, both an expansive market and land to support area expansion were present. In the other areas, apart from the possible case of Malaysia, growth in production will depend on increasing yields, either to make cassava competitive in alternative markets or to make up for a scarcity of land.

For a crop where, in most countries, prices are so dependent on forces within domestic markets and market structures are so diverse, cassava prices would be expected to vary markedly across countries. Evaluated at current exchange rates, farm-level prices are consistently lowest in Thailand and highest either in India or Indonesia (Table 11), although the

Table 10. **Cassava markets and constraints to expanded production.**

Country	Major market	Principal secondary market	Principal constraint in development of alternative markets		Dominant constraint in expansion of production and utilization
			Supply side	Demand side	
Indonesia	Starch and food (fresh root)	Food (gaplek)			
Java			Small farm size	Existing growth market	Supply side
Off-Java			Competition with tree crops	Infrastructure	Demand side
India					
Kerala	Food (fresh root)	Starch	Small farm size	High prices in food market	Supply side
Tamil Nadu	Starch	Food (fresh root)	Small farm size	Existing growth market	Supply side
Thailand	Export (pellets)	Export (starch)	Price distortions relative to grains created by EEC export market		Demand side
Malaysia	Starch	Animal feed	Land use policy	Competition with imported maize	Supply side
Philippines					
Mindanao	Starch	Food (fresh root)	Lack of integration of appropriate production and processing technology		Demand side
Rest of country	Food (fresh root)	Starch	Lack of integration of appropriate production and processing technology		Demand side

Table 11. **Farm-level prices of cassava roots: constant (1975) domestic currency prices and US dollar prices, 1970-81.**

Year	India[a]		Indonesia[b]		Malaysia[c]		Philippines[d]		Thailand[e]	
	Real price (rupee/t)	Dollar price ($US/t)	Real price (rupiah/kg)	Dollar price ($US/t)	Real price (M$/t)	Dollar price ($US/t)	Real price (pesos/kg)	Dollar price ($US/t)	Real price (baht/kg)	Dollar price ($US/t)
1970	n.a.	n.a.	19.7	22	n.a.	n.a.	.25	20	.79	24
1971	391	29	17.7	19	83	20	.27	23	.82	25
1972	406	31	21.5	23	56	15	.25	22	.72	23
1973	446	40	28.3	40	65	22	.30	31	.38	14
1974	423	47	16.1	32	79	32	.31	42	.30	14
1975	400	48	17.6	42	78	30	.29	40	.40	19
1976	449	44	23.4	67	73	29	.26	37	.44	22
1977	376	37	21.9	70	76	33	.26	40	.43	23
1978	353	39	19.9	64	58	28	.26	43	.29	18
1979	411	49	19.4	53	67	36	.25	50	.56	36
1980	n.a.	n.a.	20.3	67	89	51	.25	58	.47	37
1981	n.a.	n.a.	19.7	73	72	43	n.a.	n.a.	.30	25

a) Kerala, farm level.
b) Java and Madura, rural village level.
c) Perak factory buying price.
d) Average Philippines, farm-level.
e) Average Thailand, farm level.

n.a. = not available.

Source: CIAT data files.

latter are probably inflated because the series is based on village-level prices. Clearly, however, the competitive position of Thailand in the world market is firmly established, while the other countries remain either minor or intermittent exporters. Moreover, only in Thailand has there been any clear trend in real, farm-level prices over the last decade, and this has been a downward trend, which is consistent with the very rapid expansion in production. In the other countries, farm prices have been relatively stable, implying a relatively stable supply-demand situation. The case in Indonesia is more complex, but certainly for the other countries there has been little incentive to develop lower-priced markets.

Different end markets and different forms of marketing cassava affect how price allocates the cassava roots and dried products between the different markets. As has been noted, only a relatively small part of cassava production remains on the farm for subsistence consumption, and this occurs only in Indonesia and Kerala; the greater portion moves into marketing channels. Farmers market the major part of their production as fresh roots and it is generally the assembly agent who decides on the end market to which the cassava will go. However, farmers also have the option of producing *gaplek* (the peeled, quartered, and dried root). This practice predominates in Indonesia and is utilized to a much more limited extent in Kerala and the southern region of the Philippines. Gaplek plays a fundamental role in Indonesia in integrating cassava markets across different forms, locations, and time.

Various demands are made on cassava marketing systems due to the bulkiness and extreme perishability of the roots, the different end uses and forms, and in most countries, the seasonality of production. Seasonality is a problem in only the major cassava-producing countries of Thailand, Indonesia, and India. In Thailand, about 50% of cassava area is planted in the April-June period; in Kerala 60-65% is planted in the same 3-month period; and in Java, 75% of area is planted in the November-January period. The seasonality problem in Thailand is overcome by processing all the cassava roots and by large storage facilities. In India and Indonesia, where consumption of fresh roots as food is important, there is a definite seasonality in consumption, as can be seen in the case of Indonesia (Table 12). In Indonesia, and to a much lesser extent in India, gaplek, although a less preferred food, serves to extend the consumption period. The seasonality problem is thus resolved not by adjustments in the production system but through adjustments in marketing, processing, and consumption form.

Gaplek provides the storage capability in cassava markets and thus tends to integrate them through time. Gaplek also permits economical transport of cassava and thus tends to integrate cassava markets across

Table 12. **Seasonality in consumption and prices of fresh cassava and gaplek, Indonesia, 1976.**

	January-April	May-August	September-December	Annual average
Consumption (kg/capita)				
Rural Java				
Fresh cassava	33.7	25.1	15.8	24.9
Gaplek	24.7	31.6	33.9	30.1
Indonesia				
Fresh cassava	33.3	27.0	17.0	25.7
Gaplek	19.7	25.3	23.0	22.6
Prices (rupiah/1000 calories)				
Indonesia				
Fresh cassava	21	24	26	23
Gaplek	14	13	20	16

Source: Dixon, 1979.

locations as well. That is, consumption points for fresh roots normally draw on only a very small supply area, due to the high transport cost and the perishability constraint. This situation tends to create relatively independent markets in which prices vary significantly between areas. These independent markets are most likely to occur in countries where food markets for fresh cassava dominate, that is, the Philippines and Kerala. Widely traded commodities, such as starch and gaplek, where arbitraging is possible, have more of a national market where prices are determined more by aggregate rather than by local supply and demand situations. Because farmers and/or assembly agents have the option of supplying roots to these markets, gaplek and starch prices will tend to integrate fresh root markets within the economy, as occurs in Thailand and Indonesia (Unnevehr, 1982).

Price integration across markets, space, and time is critical in fostering growth in cassava production and utilization. Integration provides incentives for cassava to be grown in areas where production is most efficient, it maintains competitive price formation, and it provides the necessary information, implicit in nationally determined market prices, to motivate investment in processing capacity for which there is greatest market potential. Fragmented markets, in a crop such as cassava, can significantly inhibit investment in processing plants by making cassava appear too costly in price terms in relation to its actual production cost.

This is certainly one factor in explaining the lack of growth in Philippine cassava production compared to that in Thailand and Indonesia.

Finally, an observation arises on the role that gaplek can play in price integration between different end markets. Gaplek is in many ways like a grain. If properly dried it can be stored, providing food supplies in non-harvest seasons. Because it is peeled, it can be ground for composite flour production or used in domestic or export animal feed markets. Starch plants in India and the Philippines occasionally use gaplek for starch processing, especially for glucose production, when fresh root supplies are limited. Apart from *kokonte* in Ghana and *farinha de raspa* in Brazil, dried cassava chips of this quality are only produced in Asia, almost solely in Indonesia. Interestingly, Indonesia has the most diverse end markets for cassava and is probably the most fully integrated cassava market where the bulk of production is for domestic use. Establishing a gaplek market of a certain minimum, critical size would appear to give the cassava economy a large degree of flexibility in responding to changing economic and market conditions.

Cassava's Future Role in Asia

Beyond the central role that rice plays in the food economies of tropical Asian countries, the agricultural sectors of these countries are very diverse. Cassava production and utilization has adapted to this diversity. As shown in the previous analysis, it is the differences rather than the similarities that are most striking in comparing cassava sectors across countries. Cassava has developed within different types of land constraints, and multiple markets have evolved around the crop, with the particular market structure reflecting the overall development of the economy. The rate of development of most of these economies has accelerated over the past two decades, creating a potential demand for further expansion of cassava production and utilization.

Rapid development of the crop in most cases will depend on increased yields, either to relieve land constraints or to be competitive in these emerging markets. It is natural in an Asian context, where expansion of crop area is frequently constrained, that there should be a bias toward crops with high-yield potentials, especially under upland conditions. Very high productivity is already being achieved in certain areas, but in general, average yields remain below the known potential of the crop. The means of achieving this high-yield capability across tropical Asia remain largely undefined. Obviously, the type of technology necessary will vary and will require a continued commitment of research resources in order to

Table 13. **Potential role of cassava in agricultural policies of selected Asian countries.**

Agricultural policy objectives	Contribution according to country				
	Indonesia	India	Thailand	Philippines	Malaysia
Food and nutritional policies					
Flexibility in rice policies[a]	X	X			
Nutrition of the poor	X (gaplek)	X (fresh)			
Farm income and land use					
Higher small-farm income in upland areas	X	X	X	X	X
Exploitation of frontier areas	X (except Java)		X (in the NE)	X (in Mindanao)	X (peat soils)
Balance of payments					
Increased export earning			X		
Import substitution	X (sugar)			X (feed grains)	X (feed grains)

a) Indonesia has a price policy on rice and in India rice comes under a food rationing system maintain the Asian cassava research capacity that has emerged over the last two decades since the founding of the Indian program in 1963. Governments, however, require some justification for research investment, which follows from the role cassava could play in the policy arena.

Cassava's adaptation to a wide range of upland conditions and its multiple-use characteristics give it a substantial flexibility in agricultural policy. As has been stressed, cassava's role in each country's agricultural economy will differ (Table 13), but in each case cassava can be a basis for meeting multiple policy objectives. In India and Indonesia cassava can play a clear role in nutrition policy. In all countries, even in India and Indonesia, cassava, because of its multiple-market potential, can play a major role as a source of income generation for small-scale farmers in upland areas. A further advantage in satisfying growing domestic markets by increased domestic production is the positive impact on balance of payments. Further market diversification of cassava, however, will require both improved production technology and appropriate processing technology, together with, in some countries, better integrated markets.

The Green Revolution that swept Asia in the late 1960s and 1970s was limited to the irrigated areas. The next major challenge is to raise crop productivity and farmer incomes in the upland areas. With probably limited prospects for further major growth in world demand for rubber, palm oil, and coconut oil; with growing domestic markets that could absorb cassava products; and with a growing regional market for carbohydrate sources for livestock, cassava is a major, if not *the* major, crop in a position to foster income growth in the upland areas of tropical Asia.

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Rapporteur's Summary of Discussions

John K. Lynam

This first session dealt quite appropriately with the market potential for cassava, both the domestic prospects within each country as well as the major factors affecting international markets for cassava production. A major theme that ran through the discussion was whether domestic or alternatively international market forces were the dominant factor influencing both the present status as well as the future potential of cassava in the region. Because of cassava's multiple end uses, the linkage to international markets depended on whether food or feed demand was the driving element in domestic markets. The dominance of one of these alternative markets then, in large part determined the production trends in each country and in the region as a whole.

The trends paper by Sarma clearly demonstrated on the one hand, the very high rate of growth in cassava production in Asia in the last decade and, on the other hand, the very great differences between each country's rate of growth. The increase in Asian cassava production was principally due to Thailand. Nelson stressed that Thailand was the only country to respond to the rising international cassava price brought on by the "loop hole" in the EEC's variable levy system. Nelson felt that other countries did not respond because domestic dried cassava prices were higher than world prices because of either lack of infrastructure, inappropriate agricultural price policies, inappropriate macroeconomic policies (especially exchange rates), or loss of comparative advantage, (for example, rising labor costs in Malaysia).

Discussions reflected the current uncertainty in international cassava markets after more than a decade of relatively buoyant growth. This uncertainty grew out of increasing trade barriers in import markets, especially the dried cassava quotas negotiated by the EEC with the principal exporting countries. The retrenchment in international markets currently affects only Thailand, but Welsch's four future scenarios highlighted the point that should Thai cassava be forced to compete in the world grain market, Thailand's apparent comparative advantage in cassava will put competitive pressure on the cassava industry in neighbouring countries, especially Malaysia and potentially the Philippines. There was a concensus that linking international cassava prices to the world grain market rather than the EEC grain market, opened up significant growth potential, especially in the Asian regional market. However, Thailand should not forsake the significant rents it currently earns in the European market. Capturing these rents while competing in the world market obviously argued for some form of two-tier pricing structure.

Inherent in such a scenario is the question of whether cassava can compete in the world grain market. There were a broad range of opinions on the question with the only concensus being that there does not yet exist a rigorous empirical analysis of the question. How large a drop Thai cassava farmers could absorb was debated, leading to the conclusion that improved, cost-reducing, production technology was needed to cushion this crop. Also, cassava's ability to compete depended on world grain prices. There was agreement that these prices were currently low, but disagreement prevailed over future prospects. Welsch argued that feed grain prices were likely to rise, while Nelson argued that continued technological change in feed grain production would most likely keep prices constant in real terms. Rising grain prices would obviously favor cassava, particularly in the Asian regional market where rising demand for livestock products was leading to very rapid increases in course grain imports.

Outside of Thailand, the discussions focused almost exclusively on demand potential in domestic markets. The country papers highlighted first, the multiple uses for cassava and, second, the diversity between countries in the relative weights of the different end markets. In the direct use of cassava as food, the cumulative evidence suggested that overall demand for cassava was inelastic. However, cassava consumption was high in the low income strata, particularly in Indonesia and India, and cassava consumption increased with rising incomes in these strata. Lynam made the point that the benefits of improved technology would be largely directed to poor consumers under such circumstances, but that overall inelastic food markets provided little scope for significant growth. Most of the discussion, therefore, focused on the prospects for cassava in more elastic markets and concensus emerged that the domestic animal feed concentrate market offered the most immediate growth prospects for cassava in the region. Nelson argued that domestic price policies significantly influenced cassava's potencial in these markets, and in particular, protein prices were kept artificially high in most countries, undercutting cassava's competitive position *vis-a-vis* grains.

The discussion concluded on the theme that cassava had demonstrated sufficient potential to warrant more in-depth economic studies to evaluate the future potential of the crop in each country. These studies would aid in defining a future role for cassava in each country's agricultural economy and would be critical in generating consistent policy support for the crop. Investment in research leading to improved, cost-reducing technologies would go a long way to guaranteeing this future; but, in the interim those markets where cassava would be approximately competitive with grains needed to be identified and the current, though limited, backlog of technology, tested. The very basic lack of data existing for cassava reflected the historic neglect of the crop. Basic economic studies were now needed to overcome this neglect.

III. New Technology as the Basis for Increased Production

The Agronomic Potential of Cassava for the Upland Areas of Tropical Asia

James H. Cock

Introduction

The cassava plant is relatively new to Asia. It is probable that it was first introduced to the Philippines by the 17th century galleon trade from Acapulco, Mexico, to Manila. After that date a series of introductions were made by the Portuguese to Goa and Indonesia and by the British to Malaysia and India. By the end of the 19th century it was widely grown throughout Asia.

The agriculture of Southeast Asia is now, and has been for several centuries, based on rice culture. The overriding importance of rice in Southeast Asian agriculture is well illustrated by the fact that in Indonesia, crops are generally referred to as either rice or non-rice (*palawija*) crops. Most rice is produced under irrigation or as rainfed bunded rice, with smaller quantities produced as upland rice. Chandler (1979), in his authoritative work on rice, states that " many authorities recommend that upland areas that cannot be economically bunded, or that have sandy soils, be converted to the growing of [other] crops." It is exactly under these conditions that most cassava is presently grown.

Under non-irrigated conditions cassava has tended to be relegated to the less favorable areas that are often considered marginal for crop production. Thus, in northeast Thailand and southern India much of the cassava is grown under the poorest conditions in soils with very low fertility that are often subject to severe erosion problems. Apart from a small number of large plantations that produce the raw material for starch production in the southern Philippines and south Sumatra, Indonesia, most cassava is produced by small farmers using traditional production systems.

Average yields in Asia of about 12 tons/ha are above the world average of 8-9 tons/ha. Yields, however, vary considerably. Average yields in

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Tamil Nadu, India, where cassava is grown under irrigated conditions, are over 24.5 tons/ha, and much lower in Sri Lanka where cassava is grown as a subsistence crop under rainfed conditions.

Characteristics of the Crop

The cassava crop contrasts markedly with most field crops in its development. In the majority of crops the reproductive organs, that is, the seeds, are the economically useful parts, whereas in root crops (including cassava) the vegetative organs are of economic significance. In cereal grains, the crop passes through a vegetative phase when the photosynthetic source is formed and then into a reproductive phase when photosynthate from the source is utilized to fill the grains. In this process the plants pass through certain critical phases. For example, initiation of the reproductive organs, flowering, and grain filling when the plant is stressed for even short periods can lead to severe reduction in yield, and even complete crop failure. In the development of cassava, the roots are filled and the leaves are formed simultaneously throughout most of the growth cycle. For this reason, the crop has no critical period after establishment. This difference was amply illustrated several years ago in northeast Thailand when maize and cassava were planted at the commencement of the first monsoon. The second monsoon came late in that particular year and a 2-3 week dry period occurred when the maize was at a critical period of its development. Maize yields were disastrous, but cassava yields were only slightly reduced.

In its early growth the cassava plant covers the ground relatively slowly. When cassava is grown in monoculture this characteristic often allows substantial weed growth to occur before the canopy closes about 3 months after planting. Many growers utilize this early growth period to intercrop cassava with short-season crops such as grain legumes, thus obtaining good yields from the intercrop with very little adverse effects on cassava yields.

Apart from lack of critical periods in its development, cassava has several other mechanisms that make it highly tolerant of stress conditions. The cassava plant has a special stomatal reaction to humidity that allows it to conserve water during dry periods. This mechanism reduces plant growth during periods of water stress but enables the plant to survive under such conditions.

This ability to tolerate dry conditions gives the crop extreme flexibility in terms of planting date because the crop can be planted in the rainy season up to about 1 month before the beginning of the dry season. This characteristic coupled with the lack of a fixed maturity date means that cassava can, in most conditions, be harvested throughout the year, thus guaranteeing a continuous supply of roots. It should be noted, however, that significant quality changes may occur depending on the conditions prior to harvest. In areas with marked seasonal temperature changes, the starch content of roots is greatest in the cool winter months with a short photoperiod and least in the summer months, irrespective of planting date. Similarly, the starch content of roots tends to drop markedly at the onset of the rains. This drop is sufficiently large in many areas to cause starch factories to close at the beginning of the rainy season.

Although cassava is very tolerant of dry conditions it will not tolerate waterlogging of the soil, and consequently should not be planted in poorly drained soils. It also does not tolerate high pH associated with sodium salts.

Cassava is particularly well adapted to acid soils of low fertility. Cassava will give a yield, albeit low, under fertility conditions where other crops fail to produce at all. However, cassava does respond to fertilizer, as shown in Figure 1. An interesting aspect of cassava response to fertilizer is that maximum root yield is achieved at fertility levels considerably below those required for maximum biomass yield. Hence, although cassava responds to fertilizer, it does not require as high fertility levels to give good yields as do many other crops.

Cassava is naturally tolerant of very acid soils and the associated high levels of aluminum in the soil solution. Nevertheless, cassava does respond to lime applications, with levels up to 0.5-1.0 tons/ha being necessary when the crop is heavily fertilized. The use of dolomitic lime is normally recommended in order to supply magnesium as well as calcium. The main effect of lime is probably due more to these two elements than to altered soil pH and aluminum levels.

Cassava is generally considered a hardy crop with few disease and pest problems; however, when cultivation methods are intensified and area is expanded, disease and pest problems may become very severe. The lack of critical periods and the continuous production of new leaves allow the crop to recover from damage. In addition, most local cultivars have some resistance to the endemic problems of the area. The resistance in cassava tends to be stable multigenic resistance rather than gene for gene resistance, which is considered more likely to break down.

In Latin America, the center of origin of cassava, many natural enemies of the crop's pests have evolved. The long growth cycle of the crop is an important factor contributing to effective biological control. In Asia, the

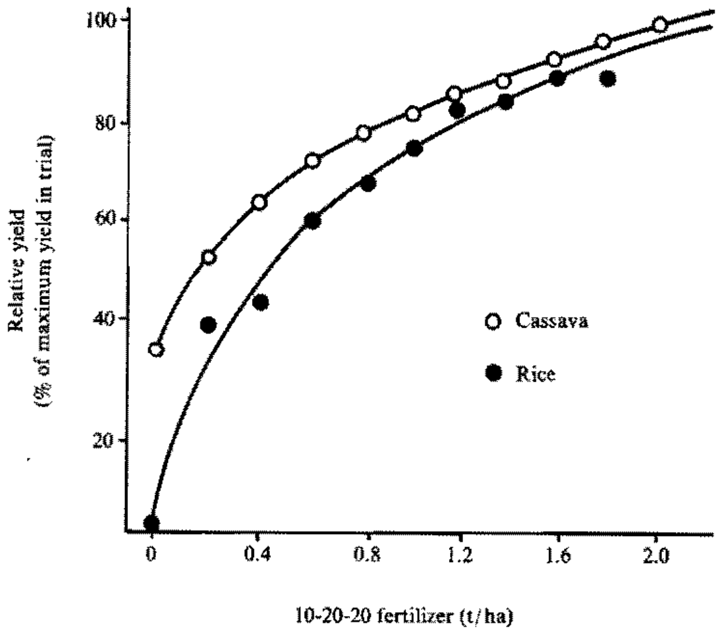

Figure 1. *Response of cassava and rice to fertilizer.*

disease and pest complex of cassava is not as large and few cases of biological control occur naturally. The major diseases and pests of Latin America and Asia are compared in Table 1. The reduced number of problems in Asia is a major factor contributing to the high yield potential in the region.

Yield Improvement

Cassava yields of around 12 tons/ha in Asia are still far below the potential. In experimental stations throughout Asia, yields of 30-40 tons/ha are frequently obtained. The yield gap is partially due to the many experimental stations that are situated on the more fertile soils of tropical Asia. But it is also due to the use of varieties with higher yield potential and improved management practices in most experimental stations. In the following sections various aspects of the crop are discussed with a view to showing how yield in farmers' fields can be increased.

Varieties

In their paper in this volume, Kawano *et al.* show guarded optimism about the potential of new varieties to increase yields. It is unlikely that

Table 1. **Distribution of selected diseases and pests in Asia and the Americas.**

	Americas	Asia
Cassava bacterial blight	+	+
Superelongation disease	+	-
Cercospora leaf spots	+	+
Frogskin disease	+	-
African cassava mosaic disease	-	(India only)
Mononychellus mites	+	-
Tetranychus mites	+	+
Thrips	+	-
Hornworms	+	-
Mealy bugs	+	-
Scales	+	+

extraordinary yield jumps will be made like those resulting from the introduction of semi-dwarf rice into the irrigated rice sector in Asia. Nevertheless, it does appear that with a continuous concerted breeding effort, yield improvement can be expected above and beyond the generally acceptable level of most widely grown local lines.

Improving yield potential is, however, only one aspect of breeding and selection programs. Preliminary results reported by Kawano *et al.* in this volume have clearly shown that breeding for characteristics such as high starch content and early maturity is extremely promising. In Asia, where land is scarce and cropping systems are intensive, earliness can be an extremely important factor in determining whether cassava can fit into the systems. If, as appears probable, acceptable yields can be obtained in 7-8 months, then cassava can be planted towards the end of the rainy season, after other short-season rainfed crops have been harvested. It can then be harvested in the dry period with enough time left to prepare the land for planting other crops at the beginning of the next rainy season.

Planting methods

In order to obtain a good yield of cassava, it is essential to have planting material of good quality. In Asia this is one of the most neglected management practices. In Colombia, careful visual selection of cuttings with no signs of disease or physical damage has been shown to greatly increase yields. It is unlikely that the effect will be as marked in Asia, as there are less disease problems. Similarly in Colombia, selection of high-yielding plants with no virus symptoms, coupled with visual selection of cuttings has been shown to double yields in certain circumstances. Once again, results in Asia are likely to be less dramatic as there are no reported virus diseases outside India. Nevertheless, the use of good quality cuttings should increase yields in Asia.

In regions having a definite dry period, the harvesting time frequently does not coincide with the planting time, hence, cuttings are stored for periods of up to 4-5 months. During traditional storage there is large loss of planting material due to dehydratation of the cuttings. Furthermore, germination and early vigor of stored cuttings is normally much lower than that of fresh cuttings. If planting material is cut into long sticks (1 m or more), treated with a fungicide and insecticide mix, and stored vertically with the base of the cuttings in moist soil under shade, the quality of the cuttings at the end of the storage period is greatly enhanced.

A novel manner of storing cassava planting material is being used in Cuba and could effectively be transferred to Asia. About 10% of the area planted to cassava is maintained in the field as a living storage bank in areas where land availability is not a major production constraint. These plants are used to supply the cuttings for the next planting, after which their roots can still be used. The seed banks receive special care to ensure that the quality of planting materials is excellent.

Irrespective of how the planting material is produced, it is recommended that stakes be treated with a fungicidal and insecticidal dip before planting. This treatment is particularly effective in preventing early infestation of the crop with such pests as spider mites and scales, as well as in protecting the cuttings if adverse conditions occur immediately after planting.

Cassava grown in monoculture is most frequently planted on the square with plant populations ranging from 7,000-20,000 plants per hectare. Lower plant populations are normally used for vigorous heavy branching types on fertile soils, while higher populations of erect plant types are used on less fertile soils. Cassava can also be planted with a large degree of rectangularity, as long as total population per hectare is maintained, with little adverse effect on yield. This makes it possible for the farmer to intercrop between wide rows of cassava. In addition, wide-row spacing may enable the farmer to leave permanent cover plants between cassava rows as an erosion control measure.

Soil Conservation and Fertility Maintenance

Cassava has somewhat undeservedly gained the reputation of being a soil-depleting crop. As already stated, cassava has the ability to grow on poor soils. Under such conditions a cassava crop is bound to lead to soil depletion if reasonable yields are obtained. However, the nutrients extracted by cassava per ton of harvested dry matter are no greater than that for other crops (Table 2).

Cassava growers have traditionally maintained soil fertility by letting their fields lie fallow. The effects of previous cropping history on cassava yields can be dramatic (Table 3). As land becomes scarce and fallow periods are shortened, yields decline. In most cases yields can be maintained by application of fertilizer to replace the nutrients removed by cassava. If however, several crops are harvested consecutively and the soil becomes degraded, yields cannot be returned to their original level by a single application of fertilizer; it is necessary to apply fertilizer every year, even in the first years after fallow or land clearing when fertilizer response may be small, in order to maintain yields in subsequent crops. Potassium fertilization is of particular importance in maintaining yield levels over time.

Table 2. **Nutrients extracted by various crops.**

	N	P	K	Total
	(kg/t harvested dry matter)			
Cassava (roots)	6	1	11	18
Potatoes (tubers)	17	3	26	46
Maize (grain)	19	3	4	26
Rice (grain)	16	3	3	22
Beans (grain)	37	3	22	62

Table 3. **Yields of cassava after different fallow/cropping systems in three regions of Colombia.**

Region	Previous cropping/fallow system	Yield (t/ha) Non-fertilized	Fertilized
Mondomo	Long-term fallow	10	24
	Two or three cassava crops	6	13
Media Luna	Fallow	20	24
	One to two cassava crops	18	20
	Three or more cassava crops	14	17
Piedemonte	Pasture	30	33
	Three or more years of crops	12	20

Source: John Lynam and Rafael Orlando Diaz, pers. comm.

Table 4. **Erosion control methods in cassava.**

Treatment	Soil loss (t dry soil/ha/yr)	Cassava yield (t/ha)
No fertilizer	36	7
Standard*	23	14
Maize mulch	15	16
Double row of cassava (60 x 60 cm) with 1-m strips left unprepared	14	16
No soil preparation	10	18

* Standard treatment was: soil preparation by oxen, fertilizer, and 80 x 80 cm spacing.

Source: R. Howeler and L.F. Cadavid, pers. comm.

Soil erosion is also a severe problem when cassava is grown on steep or long slopes. In experiments conducted in Colombia, good erosion control has been obtained on very steep slopes by using a variety of methods such as mulching, reduced land preparation, and plant covers. Effective control measures include planting cassava in widely spaced rows (1.5 to 2.0 m) and leaving a strip of natural vegetation cut to just above soil level, as well as planting a fast-growing intercrop in the alley between the cassava rows. Erosion control is also enhanced by good management of the cassava crop, especially fertilization, which encourages rapid ground cover. The results of several erosion control measures are summarized in Table 4. Erosion control will be of fundamental importance as cassava moves into more marginal sloping areas in Asia, for example, in southeast India, the hilly areas of Java, and northeast Thailand.

Disease and Pest Control

In Asia the disease and pest pressure is less than in the Americas. Perhaps the most important aspects of control in the future is to maintain this situation through adequate quarantine procedures. Care should be taken to make these sufficiently stringent so as to minimize the possibility of introducing new diseases and pests, but not so strict as to prevent the importation of valuable genetic material. The best control of the major diseases and pests of cassava in Asia [cassava bacterial blight, anthracnose, cercospora, and *Tetranychus* spp. (mites)] is through varietal resistance. Less important pests, such as scales, can readily be controlled by stake treatment.

Cropping Systems

Cassava is grown extensively in Asia as a monocrop in areas of lower soil fertility, but in more fertile soils it is grown in complex cropping systems, often as an intercrop. In traditional systems where no fertilizer is applied yields of cassava and the intercrop are generally low. In the last 10 years a large amount of research data has been obtained on cassava intercropping, particularly with the short-season grain legumes which are high in protein. When cassava and a grain legume are planted simultaneously using wide spaces between cassava plants with 2-3 rows of grain legumes between them, and are fertilized, good yields of both crops can be obtained. On the average, yields of both cassava and the intercrop are reduced by about 15-25% when intercropped, but land equivalent ratios are consistently greater than one. (Values of more than 1 indicate that intercropping is more efficient in terms of land use than sole cropping.) The potential for obtaining a rapid cash return from grain legumes with little reduction in cassava yield is particularly attractive to the resource-poor small farmer.

Conclusions

Cassava is well adapted to the light, well-drained soils with low fertility that are found in the tropics. It is very tolerant of dry periods and irregular rainfall patterns, but also grows well in areas with rains throughout the year. Both types of areas are found extensively in the tropics, and a tremendous potential exists for expanding cassava production in them.

The potential yield of cassava under commercial conditions will obviously depend on the level of management and the level of inputs. With the technology currently available for cassava, the main purchased inputs are very small quantities of fungicides and insecticides for the treatment of planting material and fertilizers.

Table 5. **Potential commercial yields of improved cassava varieties under good management.**

Rainfall	Soil fertility	Potential yield (t/ha/yr)
Well distributed	High	Over 35
3-6 dry months	High	30-35
Well distributed	Medium	25-30
3-6 dry months	Medium	20-25
Well distributed	Acid infertile	20-25
3-6 dry months	Acid infertile	15-20

Under good management with improved varieties and optimum conditions, yields of over 35 tons/ha should be possible; however most cassava will not be grown under such ideal conditions. Even under the most difficult conditions of acid, infertile soils and a long dry season, yields of 15-20 tons can be expected, with yields increasing as the dry season is shorter and soil fertility increases (Table 5).

Acknowledgements

The author wishes to express his indebtedness to the large number of people with whom he has had contact over the years who have given information that greatly facilitated writing this document.

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Improving the Productivity of Cassava in China

Lin Xiong
Zhang Weite
Tang Xuecheng

Introduction

Cassava in China is a widely grown crop and plays an important role in agriculture, sugar manufacturing, food, and the animal feed industry. The area under cassava is about 400,000 ha distributed mainly in the region south of latitude 30°N. With the development of cassava production, more interest has been focused on cassava research. Although some research progress has been made, it has been hindered by lack of continuity and systematic methods.

Research Activities

Experiments on biennial cultivation, flour production, analysis of root nutrient composition, and application of N-P-K fertilizers date back to 1914-1919. During 1940 and 1941, varietal observations, cultural experiments, and studies on cassava cyanide detoxification were carried out by Professors Li Youkai and Huang Ruilun. Later, in 1957, Professor Liang Guangshang collected several cassava varieties and began work on crossbreeding. Unfortunately, lack of continuity has made any breakthrough impossible in this field. During 1958 and 1964 extensive cassava research was carried out by the Tropical Crops Cultivation Research Institute at SCATC and some progress was made in the following areas:

1. Collection and evaluation of indigenous germplasm. Comparative trials with local varieties were conducted and root characteristics (yield, dry matter, starch, hydrogen cyanide) were analyzed. The high-yielding bitter varieties SC205, SC201, and SC202 listed in Table 1 are

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Table 1. **Characteristics of major cassava varieties in China, 1962.**

Cultivar	Yield (t/ha)	Dry matter (%)	Starch content (%)	HCN content in peeled roots (mg/100 g)
SC101	15.2	38.5	29.2	4.1
SC102	13.6	41.6	29.0	3.8
SC103	13.3	38.4	31.3	7.6
SC104	18.5	41.2	30.5	5.4
SC201	23.5	34.5	23.7	10.5
SC202	22.7	33.8	27.7	14.8
SC203	21.5	32.7	28.2	21.1
SC204	12.1	42.4	28.8	8.4
SC205	26.2	36.4	28.1	9.1
SC206	18.4	41.2	35.6	15.0
SC207	21.1	38.2	29.6	19.5
SC208	13.9	34.7	21.5	10.7
SC209	15.8	39.1	23.0	19.3
SC210	14.4	45.3	36.8	6.0
SC211	10.0	39.6	26.8	4.9
SC6068	22.8	43.6	37.9	5.0

suitable for starch production, and the high-yielding sweet varieties such as SC104 and SC101 are suitable for human consumption.

2. Breeding and selection of superior varieties. Crossbreeding was begun on the basis of germplasm collections and evaluations. Results of comparative tests, regional trials, and quality analysis revealed SC6068 to be the best sweet variety. It is a precocious variety with low hydrogen cyanide (HCN) content, high dry matter content (about 43%), high starch content (about 38%), and a high tolerance to infertile soils. It is presently used in commercial production.

3. Research on cultural practices. Past investigations showed that the best length of cassava stem cuttings for planting material was about 13-16 cm. The root yield decreased if the cutting was longer or shorter: 10-cm and 20-cm stem cuttings produced root yields 10% and 14% less, respectively, than those from 16-cm cuttings. Ridge planting compared favorably with flat planting, having a yield increase of 17%. The best spacing for ridge planting was 1 m x 0.8 m. In order to maintain soil fertility, groundnuts or jack beans can be intercropped with cassava, planted at a spacing of 1.5 m x 0.8 m. With respect to the N-P-K fertilizers, P gave the best root yield response with an increase of 104.8% over the control, while N increased root yield by 24.4%, and K by 11.3%. The best yields were obtained by applying N-P compound

fertilizer, which raised the root yield to 161.5% over that of the control. Fertilizer application should be based on plant nutrient diagnosis and specific soil fertility.

4. Cultural experiments to expand the agronomic growing area. Experiments to delineate practical regions suitable for cassava cultivation in the northern subtropics of China were conducted by the Cassava Research Group of SCATC in coordination with organizations in Hebei, Liaoning, Shandong, Jiangsu, Anhui, Hubei, Sichuan, and Shanxi provinces. Results from testing SC101 and SC102 in these northern latitudes showed that commercial cultivation of cassava is possible in the Yangtze River Valley south of the Huai River and Qin Ling Mountains, where the climatic conditions favor earlier maturity (Table 2). These experiments have provided a scientific base for expanding cassava-growing areas in China.

Breeding

An active cassava research program was resumed in 1979 and has continued since then. The current major agronomic research task is to collect germplasm and launch crossbreeding. A number of good cultivars for crossbreeding are kept at the Tropical Crops Research Institute. These include SC201, SC205, SC104, SC101, SC102, SC6068, SC7901, SC7924, SC7903, SC7908, and SC7945. Presently, 30-40 hybrid combinations are made annually. From these, 4000-5000 flowers are pollinated artificially to

Table 2. **Yields of cassava at high latitudes, 1962.**

°N	Growing season (days)	Cultivar	Yield (kg/ plant)	Yield (t/ha)	Highest yield (kg/plant)	Starch content (%)
29°30'	214	SC102	2.2	26.4	-	33.00
29°30'	214	SC101	1.3	15.6	-	26.00
30°00'	210	SC101	1.4	16.8	-	-
31°53'	205	SC101	1.4	16.8	4.3	21.56
32°04'	180	SC101	1.2	14.4	2.3	-
32°04'	180	SC102	2.7	32.4	4.5	-
33°55'	172	SC102	2.8	33.6	6.0	24.41
34°21'	162	SC102	1.2	14.4	2.0	-
34°21'	169	SC101	0.39	4.6	0.6	-
36°41'	180	SC102	-	-	1.5	-
38°54'	170	SC102	-	-	1.3	-
38°54'	170	SC101	-	-	0.9	-
39°20'	163	SC101	-	-	2.5	28.66
39°20'	163	SC102	1.2	14.4	3.0	29.80

yield 2000-3000 hybrid seeds and 800-1200 seedlings, from which 60-80 promising individual plants are selected annually.

So far, several superior lines have been selected from the hybrid progenies developed in 1979 and 1980. Among them, SC7924 and SC8013 are the most promising. Regional trials with SC7924 showed that this strain is highly recommendable because of its low HCN content and tolerance to cold weather. SC8013 is the progeny of SC101 x SC201 and several years of tests and observations have demonstrated that this is also a most promising line, possessing the characteristics of high yield and likely resistance to cassava bacterial blight (CBB).

A variety of breeding materials with different characteristics has been chosen to enrich the germplasm collection. The cumulative number of hybrid combinations developed during 1979-1982 is 187, the number of artificially pollinated flowers is 15,000, and the fruit success rate is 25-38%, with 68.1% being the highest and 5.4% the lowest. The average seed-setting rate is 70.6%, the highest being 92.3% and the lowest 38.3%. Although the optimal time for assisted pollination is between September and October in order for the seeds to fully develop before the onset of colder weather, the peak flowering period appears in October and November.

Experiments and observations indicated that the seed-setting ratio of hybridization is related to the affinity between varieties. Maternal superiority exists and in general, a highly fertile female crossed with any male would give a higher seed-setting ratio. Maternal superiority also appears in the compatibility of hybrid combinations. A high-yielding female parent tends to produce a larger number of high-yielding individuals among its hybrid progeny, and low-yielding females also produce a preponderance of low-yielders among their progeny. For example, high-yielding individuals (above 1.5 kg/plant/yr) from the hybrid of SC201 (high-yielder) x SC102 (low-yielder) make up 60% of the total, while high-yielders from the hybrid of SC102 x SC201 account for only 8.3%. Open-pollinated hybrids from high-yielding female parents also produce more high-yielders among their progenies, e.g., open-pollinated hybrids of SC201, SC102, and SC101 gave 18.9%, 7.9%, and 2.8% high-yielding individuals (over 1.5 kg/plant/yr) respectively, while top-yielders (over 2.5 kg/plant/yr) occupy 4.9%, 1.3%, and 0% respectively of SC201, SC102, and SC101. The recommended line SC7924 is an open-pollinated hybrid of the high-yielding variety SC205.

Intercropping

Agronomical research emphasizes intercropping or interplanting, and crop rotation systems. Through this research, better planting methods and intercrops are expected to be found to help conserve water, enhance soil fertility, check soil erosion, and increase economic benefits. So far, experiments have been conducted on multi-storied cultivation, interplanting *Leucaena leucocephala* with cassava intercropped with legumes. Experiments of this sort will be extended to provide a basis for recommendations by the extension services. The present plan is to recommend that the early maturing, improved variety, SC6068, be planted on about 33,300 ha (in addition to the 667 ha currently planted in it). Root yields of SC6068 in the region south of the Tropic of Cancer are usually 25-50% higher than those of local cultivars.

Production Constraints

Cassava research to increase yields should be appropriate to local agricultural conditions and practices. The main constraints on yield increase are:

1. A shorter growing period due to low temperature and frost injury. In China, cassava is largely grown in the subtropics. The low temperature in winter and early spring often reduces the growing period to 8-10 months. Cassava has to be planted in March or April and harvested before December. The plant is usually affected by low temperature in its later growing period and its yield decreases due to lower rates of starch accumulation and root bulking.

2. Lack of better cultivars. Presently, the two high-yielding varieties, SC201 and SC205, are the most commonly used in commercial production in China. However, due to their longer growth period, neither of them can be used to full extent in terms of yield in areas having a short growing period. Since early maturing varieties have low yields, they are not suitable candidates for increasing production.

3. Lack of systematic planning and technical assistance in production, processing, and marketing. Local farmers normally fail to introduce improved varieties and advanced cultural techniques. In many places cassava is planted and then left untended, causing low yields. On the other hand, low marketability of cassava products also reduces the farmers' incentive to increase production.

4. Occurrence of CBB (cassava bacterial blight). This disease has recently appeared in the experimental fields at the Tropical Crops Cultivation Research Institute of SCATC and the hazard of it spreading exists. This is the most serious potential factor affecting cassava production in China.

5. Need for further research on processing and uses of cassava. The importance of multipurpose use of cassava has not yet been fully realized. This is another major constraint on cassava development.

Future Research Directions

Considering the climatic characteristics, cultivation practices, level of processing and utilization, and existing problems in cassava-growing areas in China, future research should aim at producing high-yielding cultivars, low-input management, and diversified, high-profit utilization. Areas of concentration should be genetic breeding, physiology, cultural techniques, prevention and control of plant diseases and pests, and processing and integrated use of cassava produce. The chief objective of cassava breeding is the selection of superior varieties which have the following characteristics: early maturity, high yields, low HCN content, good root quality (rich in starch and with increased protein), winter hardiness, disease resistance, easy harvesting, reduced perishability, and suitability for biennial cultivation (including high ratooning ability and less lignified tissue in the roots harvested the following year).

Domestic and foreign germplasm will be collected in order to establish well planned germplasm banks. Furthermore, an attempt will be made to develop a pattern of genetic improvement based on crossbreeding. Cassava-growing areas will be demarcated and regional tests will he standardized with improved varieties recommended for specific locations. At the same time, technical cooperation with other institutions, e.g., CIAT and CGPRT, will be strengthened and contacts will be established with other cassava-growing countries for mutual exchange of technology and experience.

In the next few years, attempts will be made to set up 40-50 hybrid combinations annually. These will provide 5,000-6,000 seeds (including natural hybrids). These hybrid seeds will be distributed to different ecological regions for selection. It is expected that about 100 promising individuals will be singled out for comparative tests at various levels.

Multipurpose uses of cassava will be undertaken principally by light industries, mainly the feed, food, and sugar industries. Agronomic research will stress the multistoried cultivation systems of cassava/oil crops and forest trees/cassava interplanting. Studies on the physiological characteristics and ecotypes of different crop populations will aid in water conservation and maintenance or enhancement of soil fertility, and in turn in the building of a more prosperous cassava industry.

Improving the Productivity of Cassava in India

S.P. Ghosh
R.G. Nair

Introduction

Cultivation of cassava in India is confined mostly to southern states like Kerala, Tamil Nadu, Karnataka, and Andhra Pradesh. It is grown to a limited extent in the northeastern parts of the country and in the tribal belts of Orissa.

The average root yield in Tamil Nadu is 29.5 tons/ha compared to 14.8 tons/ha in Kerala. While in Kerala and in certain parts of Tamil Nadu, like the Kanyakumari district, cassava is a rainfed crop, in other parts of Tamil Nadu, particularly in the Salem-Dharmapuri belt, it is an irrigated one. In the northeastern hill region of the country cassava is mostly grown in a mixed stand of shifting cultivation plots as a purely rainfed crop.

Within a 10-year period yields almost doubled in Tamil Nadu, from an average of 12.3 tons/ha in 1970-71 to 29.5 tons/ha in 1980-81. This indicates the vast potential for the development of cassava. Progress was partly due to switching to certain high-yielding varieties released by research institutes and partly to improved cultivation practices by farmers. A steady demand from the starch and sago (pearl) industries acted as a stimulus for the cultivation of the crop.

Prevailing Production Practices

Cassava is generally grown in marginal areas having poor soils, with few inputs such as fertilizers, pesticides, and irrigation. In Kerala it is generally grown on hilly slopes having red laterite soil with little addition of fertilizers and manures. The average yield of 15 tons/ha can therefore be considered impressive under such circumstances. Cassava also grows well

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in light sandy loams that are moist and deep. The soil texture in Kerala is not friable enough to allow full development of the root system but planting on ridges, mounds, or hillocks, and substantial deep digging of soils do result in higher yields. Most farmers in Kerala grow some cassava, mostly on homesteads and small holdings. There are a few large growers who specialize in supplying the produce to processing units, particularly in the Salem district of Tamil Nadu.

In Tamil Nadu the crop is grown mostly in the Kanyakumari district and the Salem-Dharmapuri region. In the former area the cultivation practices are somewhat similar to those practiced in Kerala where cassava is grown as a rainfed crop in small holdings. The produce is mostly used for human consumption. In the Salem region, however, the crop is grown as an irrigated crop and roots are mostly used as raw material for about 700 small- and medium-scale starch and sago factories. The average root yield under irrigated conditions is about 30 tons/ha.

Cassava has traditionally been grown on a small scale as a backyard crop for home consumption. Cassava production on a large scale as a cash crop is a relatively new phenomenon in two or three states of the country. To a great majority of individual farmers, who cannot afford optimum field preparation or other improved cultural practices, stability of yield is more important than a package of new cultural techniques. The entire thrust in cassava development is towards achieving optimum stable yields under low-input management conditions. Additionally, in a vast country like India, selection of desirable genotypes for different agro-climatic zones through adaptive trials can help achieve yield stability in the face of the widely different environments in which cassava is grown.

Production Constraints

The factors responsible for low production levels in the country as identified by the Central Tuber Crops Research Institute (CTCRI) are described below.

1. The prevalence of inferior varieties which are adapted to low fertility conditions. Although certain high-yielding varieties (HYVs) have been developed which performed well in regional adaptive trials, present coverage with HYVs is still very low due to the absence of aggressive extension programs.

2. Low adoption level of improved production technology by the farmer.

3. Prevalence of diseases, particularly the cassava mosaic disease (CMD) in local varieties, and the use of diseased planting materials which further spread the diseases.

4. Lack of awareness of higher income earning capacity through improved cultivation practices.

5. Absence of a stable price stimulus due to unorganized marketing channels. Short shelf life of roots leads to distress sale of the marketable surplus.

6. Limited product diversification and lack of exploitation of the produce for alternate uses. Raw material demand is limited only to starch and sago industries; the vast potential in the animal feed sector remains altogether unattended.

Research Activities

Taking into consideration the above constraints, the activities of research organizations, particularly the CTCRI at Trivandrum, focus on:

1. Evolving high-yielding, disease-resistant crop varieties through a global collection of germplasm and hybridization.

2. Developing optimum cultural and fertilizer management practices for the different crops and cropping systems.

3. Maintaining and evolving control measures for pests and diseases.

4. Extending the newly evolved high-yielding varieties and their production technology to a large number of farmers throughout the cassava-growing region of the country.

5. Providing a research base which would ensure increased use of roots for industrial and other uses through the development of postharvest technology.

Breeding

Germplasm collection. A total of 1320 cassava accessions were collected and are now being evaluated and documented.

Varietal improvement. A cassava breeding program aimed at evolving high-yielding and disease-resistant cultivars is in progress. Breeding has been streamlined to emphasize objectives like high yield, high starch content, freedom from pests and diseases, early maturity, ideal plant type, low hydrocyanide content, and good culinary quality. The Institute's breeding activities have resulted in the evolution and release of three outstanding hybrids (H-97, H-165, and H-226) in 1971 and another two hybrids, H-1687 (named Sree Vishakham) and H-2304 (named Sree Sahya) in 1977.

H-97. A hybrid incorporating the high-starch content derived from its Brazilian parent and developed primarily for industry. It has a mean yield of 28 tons/ha, while registering a potential of 84.7 tons/ha.

H-165. An early variety that matures in 7 to 8 months, while other varieties mature in 10 months. It has a mean yield of 30 tons/ha. Its early maturing ability has helped in fitting this hybrid into intercropping systems.

H-226. A variety of good culinary quality which yields an average of 29 tons/ha. It is suitable for the irrigated areas of Tamil Nadu.

H-1687. This variety has recorded mean yields of 40 tons/ha with a consistent yield above 30 tons/ha in farmers' fields. The presence of carotene, a precursor of vitamin A, makes it an ideal table variety.

H-2304. A high-yielding multiple hybrid having 30% starch content, which makes it suitable for industry and for making dried chips.

Early-maturing varieties. Included in the breeding programs is the identification of early-maturing varieties which can be harvested 6 to 7 months after planting. These varieties can thus be used for raising more than one crop per year from the same area and can also be fitted into the multiple cropping systems. Under this program, varieties like OP 1/81, Ci 856, Ci 206, and Ci 129 have shown some promise. Some of the released varieties like H-165 and H-1687 are also capable of giving reasonably good yields if harvested early, although the full yield potential can only be obtained by harvesting after 8-9 months.

Shade-tolerant varieties. Cultivation of cassava under multiple cropping systems is popular in many areas. It is often grown as an intercrop in coconut plantings. Hence the breeding program is oriented towards developing and identifying types suited for such conditions. Varietal differences for root yield under shade were observed, with clones like H-97/2, H-165, H-2304, and Ci 590 accumulating more dry matter in the roots.

Cultivation practices

Time of planting. Cassava is generally grown as a rainfed crop and planting under such conditions coincides with the onset of rains in May-June. Planting can be advanced if pot-watering of the stakes is provided.

Length of stake. Although there was no significant yield difference when stakes of 15 cm, 20 cm, 25 cm, and 30 cm long were used, stake length of 20 to 25 cm was found to be the optimum.

Spacing. Results of spacing trials with spacings of 60 x 60 cm, 75 x 75 cm, 90 x 90 cm, and 120 x 90 cm indicated that 90 x 90 cm spacing is ideal for branching type varieties, while for non-branching types 75 x 75 cm spacing is best.

Planting method. The method of planting varies with the type and topography of the soil. The mound method may be adopted in soils having high clay content and poor drainage, whereas the ridge method can be used on slopes to check soil erosion. The flat method of cultivation may be followed in level lands having good drainage. The 'pit-followed-by-mound' method has been found to be superior to all other methods in level lands. In this method pits 30 x 30 x 25 cm are first opened and the soil is mixed with cattle manure and reshaped into a mound. Fertilizers are applied in a furrow opened at a 15-cm radius from the top of the mound. This method of cultivation is more labor-intensive but a yield increase of nearly 10% over the conventional method of mound preparation has been recorded.

Gap filling. The use of poor quality planting material or adverse weather conditions result in a high degree of stake mortality. Replacing the unsuccessful stakes 15 days after planting is better than waiting until a later date.

Thinning of shoots. Removal of excess sprouts at the initial stages of establishment (10-15 days after sprouting) helps to prevent mutual shading and competition between plants.

Fertilization

Recommended rate. The recommended rate of fertilizer for high-yielding varieties is 100 kg each of N, P_2O_5, and K_20 per hectare, along with an application of 12 tons/ha of cattle manure or compost, which is applied at the time of land preparation. The fertilizer containing N and K is applied in two split doses, half as basal and the remaining half with the first cultivating operation at 45 to 60 days after planting. The P is applied as a basal dose.

Alternative fertilizer sources. The citrate-soluble forms of phosphorus (basic slag, ultraphosphate, and Ammo-phos) were compared with water-soluble superphosphate in acid laterite soils. Basic slag and ultraphosphate were better than superphosphate and increased the root yield by 10% and 9%, respectively.

Effects of calcium. Application of 2000 kg CaO/ha was beneficial in increasing the yield of cassava. The yield increase was about 25% over the untreated control. Liming also improved the quality of roots by increasing the starch content and decreasing the HCN content.

Sulphur nutrition. The relative influence of sulphur-containing fertilizers (ammonium sulphate, superphosphate, and Ammo-phos) and fertilizers without sulphur (urea, diammonium phosphate, muriate of potash, 17:17:17 N-P-K complex, and 28:28 N-K complex) on cassava were studied and it was found that sulphur-containing fertilizers were significantly superior to fertilizers without sulphur. Sulphur at 50 kg/ha gave significantly higher yields (18% more than the control) than other levels. Application of sulphur resulted in an increased starch content and a decreased HCN content in the roots.

Micronutrients. In laterite soil cassava responded significantly to soil application of zinc, boron, and molybdenum. Zinc (12.5 kg/ha) as zinc sulphate, boron (10 kg/ha) as borax, and molybdenum (1.0 kg/ha) as ammonium molybdate applied along with 100 kg/ha of N, P_2O_5, and K_2O increased root yields 15%, 12%, and 11%, respectively. Application of zinc improved the quality of roots by increasing starch content and decreasing HCN content.

Irrigation

Although cassava is generally grown under rainfed conditions, its full yield potential can be achieved through good water management. By providing irrigation at 25% of the available moisture depletion level, the yield of cassava can be doubled compared to no irrigation. The effect of supplementary irrigation was investigated and it was observed that by providing irrigation during drought months at 20 mm per week, the root yield increased 64% over non-irrigated plots. The yield of intercropped cassava was doubled by providing irrigation at 25 mm every 10 days during the drought period.

Intercropping

Trials with a large number of short-duration crops to make use of the solar energy and moisture between cassava rows have identified groundnuts and French beans as profitable cassava intercrops. Intercropping groundnuts with cassava gave an additional income of Rs 1500-2000/ha (approximately US $150-200) over a pure crop of cassava.

The fertilization rate formulated for such an intercropping system is a basal application of 12 tons/ha of manure or compost along with 50 kg N, 100 kg P_2O_5, and 50 kg K_2O for high-yielding varieties, and half the above rate for local cassava varieties. These are applied at the time of planting cassava stakes, which are spaced at 90 x 90 cm. The seeds of intercrops are sown in between rows immediately after planting the stakes. The seed rate of groundnuts is about 60-65 kg/ha using a spacing of 30 x 20 cm. In the case of French beans, the seed rate is 25-30 kg/ha at the same spacing.

For a sole crop of cassava, the top dressing is applied 45-60 days after planting along with cultivating and weeding. But when an intercrop is raised with cassava, the top dressing of fertilizer is half the rate of N and K applied immediately after the intercrops are harvested, along with hoeing and earthing up.

Multistoried project. Initial observations recorded in a multistoried cropping project with coconut, banana, *Eucalyptus*, and *Leucaena* as the first tier perennial species, cassava as the second tier species, and French beans and groundnuts as the third tier bottom species showed no adverse shade effect on cassava in the first year of the perennials' growth. The light transmission ratio was minimum in banana plots (58%) against 71% in pure cassava stands at 6 months. Cassava adversely affected the growth of banana and *Leucaena*, but there was a marginal (12.7%) increase in height in the case of *Eucalyptus*. Groundnut and French bean intercrops reduced leaf production in cassava by 12.7% and 4.6%, respectively. Root growth in all perennial species, except *Leucaena*, was adversely affected by cassava. Soil loss was reduced considerably through intercropping cassava with groundnuts and French beans. Similarly, cassava intercropping helped in reducing the soil loss in banana plots. The population buildup of whitefly, the insect vector of cassava mosaic disease, was minimum when grown in association with *Eucalyptus*, while cassava thrips were found to infest *Leucaena*.

Plant protection

Cassava mosaic disease (CMD). Although CMD infects cassava in India, its nature and identity have not been well established. Recent work suggests that the CMD of southern India shows a good correspondence with the CMD of Africa. It has been observed that the improved cultivars released by the CTCRI show a degree of tolerance to the disease.

In the field the disease is spread by the whitefly (*Bemisia tabacii*), the extent depending on the varieties of cassava cultivated. Use of disease-free plants as the source of planting material and careful roguing of infected plants can considerably reduce the disease incidence.

Since most cassava cultivars appear to be affected by virus diseases, a tissue culture unit was set up at CTCRI in 1980 to take up meristem cultures for developing virus-free plants.

Red spider mites. Four species of spider mites belonging to two distinct groups cause damage to cassava in India. The first group includes *Eutetranychus orientalis* and *Oligonychus biharensis*, which prefer to feed on the upper surface of leaves, causing severe browning or tarring and curling of leaves. The second group comprises *Tetranychus cinnabarinus* and *T. neocaledonicus*, which attack the lower surface of the leaf. A fall in relative humidity from 70 to 30% and an increase in temperature over 31°C are conditions leading to rapid multiplication of these pests. The yield loss due to severe infestation ranges between 17 to 33% in different varieties. Spraying the crop at the time of incidence and subsequently at monthly intervals with dimethoate or methyl demeton at 0.05% is highly effective in reducing mite infestation. Alternatively, thorough spraying with water alone at a runoff level at 10-day intervals is equally effective as chemical spraying.

Scale insects. Cassava scale insects (*Aonidomyteleus albus*) infect the standing crop in the fields and also the stem in storage. They multiply rapidly and completely cover the stem and suck the sap. Severe infestation often leads to drying and death of the plants, and roots become unpalatable. The infestation becomes severe in stems in storage if they are not properly stored. Higher humidity and poor aeration in storage encourage rapid multiplication of scale insects. The infested planting materials dry up quickly and do not germinate. For effective control, only scale-free stems should be selected for storing and planting. The stems should be stacked in vertical positions and kept in shade to get diffuse light and aeration. As a prophylactic measure, the stems should be sprayed with 0.05% dimethoate or methyl demeton.

Future Research Directions

Cassava research is mainly being conducted at the Central Tuber Crops Research Institute, Trivandrum, and in its regional center located in the state of Orissa. While the main institute, through its research and rural development program (like the Lab-to-Land Project and Operational Research Project) could make considerable achievements in the southern states like Kerala and Tamil Nadu, little research and development could be attained in other parts of the country. Taking into consideration the research needs in other areas, a coordinated project, the All India Coordinated Tuber Crops Improvement Project, was launched by the ICAR. This project has research centers in state agricultural universities and national institutes located in states like Kerala, Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, West Bengal, Bihar, Assam, and Meghalaya. The project attempts to resolve local problems such as identification of varieties for different agro-climatic zones and development of suitable farming technologies. Most of the centers have already developed agronomic schedules suitable for their respective regions. However, considering the ambitious developmental program as envisaged by the National Commission on Agriculture and the economic utilization of cassava and its products, priority areas for future research have been identified.

The projections made by the National Commission on Agriculture include 40 million tons of cassava from an area of 1 million hectares by the year 2000. Currently, 5.8 million tons are produced from 0.35 million hectares. The projections require two- to three-fold increases in average yields as well as substantial expansion of areas.

The Commission felt that the present average production of 16.81 tons/ha could be increased to 40 tons/ha to achieve the targeted production level of 40 million tons. The total number of hectares to be planted in cassava by 2000 is shown below by states.

State	Area (000 ha)
Kerala	325
Tamil Nadu	200
Karnataka	125
Maharashtra	50
Andhra Pradesh	125
Orissa	75
Northeastern region including Assam	100
Total	1000

While Kerala and Tamil Nadu in the south have good rainfall and a more or less tropical climate, the northeastern region of the country and the eastern states are predominantly subtropical in climate with moderately good rainfall. Due to cooler winter temperatures and a delay in the break of monsoon rains in major parts of these eastern states, the duration of the crop is restricted to 6-7 months, instead of 9-10 months as experienced in the south. Varieties with early root growth and bulking characteristics may be more desirable for such situations. In the states like Karnataka and Andhra Pradesh in the southcentral zone, the rainfall is much less, with certain parts even falling in semiarid and dry farming zones. For achieving economic yields, a major thrust in research for such areas may be directed to watershed management to improve water conservation and use. Research on limited and supplementary irrigation is to be intensified.

The package of practices so far formulated is intended primarily for rainfed conditions such as in Kerala, which receives more than 1500 mm annual rainfall, 75% of it during the southwest monsoon (June-September).

In summary, future directions of cassava research and development will focus on the areas listed below.

- High-yielding varieties with acceptable cooking quality.
- Varieties suitable for industrial use.
- Varieties suitable for cultivation in partial shade that can be fit into multistoried cropping systems.
- Early maturing varieties (6-7 months) to suit northern sub-tropical climatic conditions.
- Production physiology under normal and stress situations and identification of suitable physiological parameters contributing to drought tolerance and adaptation to shaded conditions. Environmental influence on root development for crop models suitable for different cropping systems.
- Biochemical basis for resistance to pests and diseases and biosynthesis of cyanogenic glucoside.
- Multiple cropping systems including multistoried cropping and mixed and relay cropping for optimum land use.
- Water management involving investigation of critical stages of irrigation, water catchments, and moisture conservation.
- Nutrient budgeting and studies on the effect of micronutrients.
- Survey of major production zones for nutrient status, disease-insect associations, and use and marketing patterns.
- Cassava mosaic disease: etiology, epidemiology, cleaning through tissue culture, certification, and production of healthy planting materials.
- Biological control of pests.
- Development of technology for cassava utilization in food and animal feed products.
- Market analysis for assessing investment potential in cassava-based industries, and analysis of diffusion and adoption of new technologies.

Improving the Productivity of Cassava in Indonesia

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J. Hardono Nugroho

Production

Cassava, *Manihot esculenta* Crantz, ranks as the third most important staple food crop in Indonesia, after rice and maize. From 1969 to 1983, the annual harvested area averaged over 1.4 million hectares, and the mean production was over 12.3 million tons annually. Cassava covers about 11% of the total area planted to food crops in Indonesia. The average yield during the Pelita I period (First Five-Year Development Plan) from 1969 to 1973 was a low 7.5 tons/ha. However, during Pelita II (1974-78) the average yield rose by 20% and total production increased by 17.7%. During Pelita III these increases were not as great, 5.60% for yields and 7.05% for production. The increase in the average total production during the overall period (1969-1983) was mainly due to increases in yields (Table 1).

The main cassava-producing areas are mostly in Java and Madura, which contain about 77% of the total harvested area. The other islands account for the remaining 23%, with Sumatra having 7%, eastern Indonesia including West Irian 8%, Sulawesi 6%, and Kalimantan only 2%.

Constraints

The low production and productivity levels are due to several reasons, particularly poor cultural practices. Farmers generally apply little or no fertilizer. Many grow cassava in multiple cropping systems, leading to lower yields. The wide range of cultivars planted have low productivity,

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Table 1. **Cassava production in Indonesia during Pelitas I-III (1969-1983).**

Period/year	Harvested area (millions of hectares)	Production (millions of tons)	Yield (t/ha)	Trend (%)[a] Prod.	Yield
Pelita I					
1969	1.47	10.92	7.4		
1970	1.40	10.48	7.5		
1971	1.41	10.69	7.6		
1972	1.41	10.38	7.1		
1973	1.43	11.19	7.8		
Mean	1.42	10.73	7.5		
Pelita II					
1974	1.51	13.03	8.6		
1975	1.41	12.55	8.9		
1976	1.35	12.19	9.0		
1977	1.37	12.49	9.2		
1978	1.38	12.90	9.3		
Mean	1.40	12.63	9.0	17.70	20.00
Pelita III					
1979	1.44	13.75	9.6		
1980	1.41	13.73	9.7		
1981	1.40	13.67	9.8		
1982	1.44	12.64	8.8		
1983	1.45	13.80	9.5		
Mean	1.43	13.52	9.5	7.05	5.60

a) Average % increase over the preceding 5-year period.

Sources: CBS, Jakarta, 1982; SP. Bimas, 1983.

and are susceptible to a major pest, the red spider mite (*Tetranychus* sp.) and a principal disease, cassava bacterial blight (CBB), caused by *Xanthomonas campestris* var. *manihotis*. CBB and cassava wilt disease (*Pseudomonas solanacearum*) may reduce yields by up to 90% (Nishayama et al., 1980, and Wargiono et al., 1981). Other important diseases are brown leaf spot, *Cercosporidium henningsii* and *Cercospora caribaea*. The fungal disease caused by *Fomes lignosus* is also present in areas previously planted to rubber trees.

Low and fluctuating prices influence farmers' attitudes towards new packets of technology that include improved cultivars and recommended cultural practices. Prices at the factory level have varied from Rp 22-54 per kg of fresh root (US $0.22-0.54) in the last 2 years. The price received by farmers is generally 30% less than the factory price because of the cost of transport and the middlemen's profit.

There is no price guarantee or floor price for cassava root and its products. Prices can fall so low that farmers may not even bother to harvest their cassava crop.

Research Objectives

The Central Research Institute for Food Crops (CRIFC) is one of the research institutes under the Agency for Agricultural Research and Development (AARD) of the Indonesian Ministry of Agriculture. CRIFC is responsible for research and development of food crops, including rice, maize, sorghum, legumes, and root crops. CRIFC has six research institutes (Figure 1), each with a specific national mandate related to its regional environment.

The major activities of CRIFC's root and tuber crops program are breeding and agronomy. Other activities are still very limited due to lack of manpower and financial support.

The main objectives of the breeding program are to develop superior cassava clones that, combined with improved production methods, give higher yields and maximum profit to farmers. Ideal cassava cultivars are characterized by these attributes:

- High yield per unit area; high proportion of roots to total plant weight
- Relatively early maturity with considerable yield
- Tolerance to major pests and diseases
- High starch content in the root
- Good root shape
- Broad adaptation to various soil and climatic conditions

CRIFC's agronomy program studies fertilizer use and application in relation to recommended clones, and aims to develop agronomically sound cultural practices for different soils and climatic regions.

CRIFC's breeding activities include the introduction of foreign germplasm, the collection of existing domestic cultivars, and population improvement by using breeding methods suggested by Hahn (1975), as shown in Figure 2.

Figure 1. *CRIFC research institutes in Indonesia.*

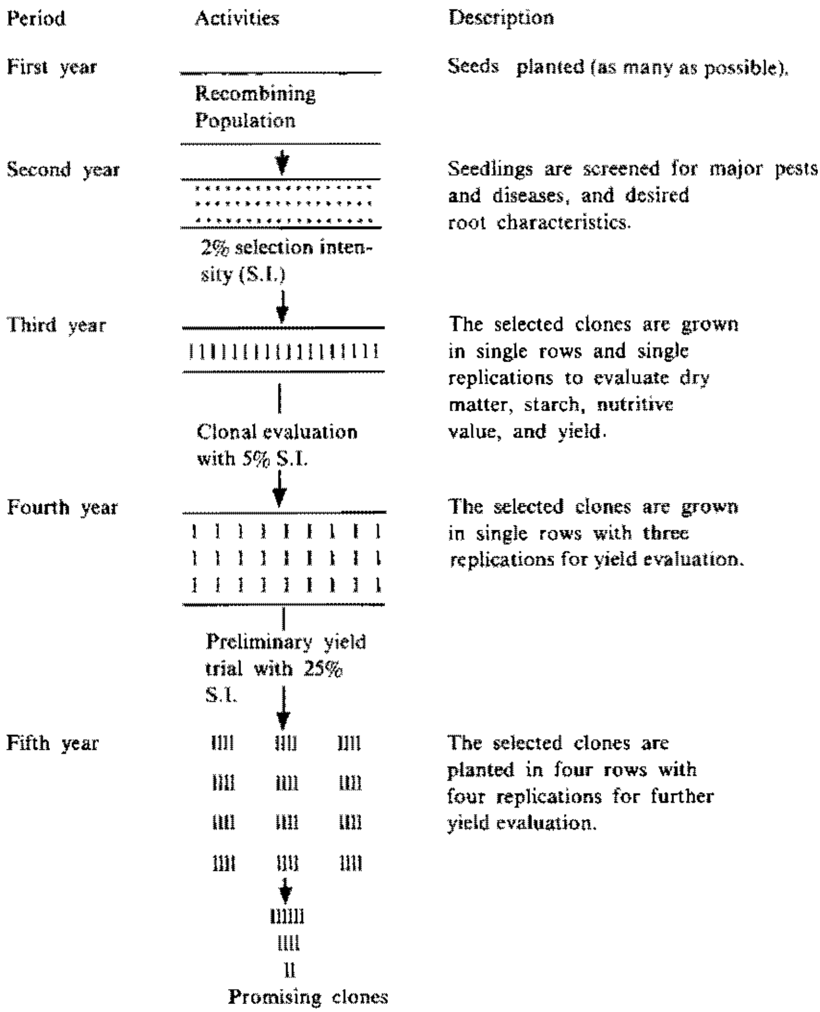


Figure 2. *Breeding procedures for cassava, Indonesia.*

The introduction of foreign cultivars, especially from Africa and Latin America, has been done very carefully to avoid introducing new cassava diseases into Indonesia. International cooperation has been good and has helped develop the cassava breeding program in Indonesia.

The collection of both exotic and domestic germplasm is essential to enrich the genetic variability of the existing materials. About 130 local cultivars and over 700 clones are maintained in the collection. Maintaining and conserving this collection has been a major problem, since a large area of land, a considerable budget, and experienced personnel are required to avoid genetic loss and reduction in genetic variation of the existing materials.

Hand pollination and natural crossing have been carried out at Pacet Experiment Farm, West Java, at an altitude of 1100 m above sea level. Selection has been carried out in a limited number of environments, but the selected material will ultimately be tested in widely varying locations. Testing for adaptability in a reasonable number of seasons and locations representing major cassava-growing areas is very important for the evaluation and release of selected clones to farmers.

Research Results

During the past 10 years two new CRIFC cassava clones named Adira I and Adira II have been released, and six local cultivars have been recommended to farmers. The recommended cultivars are those which provide good yields and are accepted by farmers, but are not officially released by the Ministry of Agriculture due to limited supporting data.

Adira I was released in 1978; it now covers over 25,000 ha. It has high starch content, moderate yield, high harvest index, early maturity, tolerance to cassava bacterial blight, and low HCN content. It has a firm texture after cooking and is very good for making fermented cassava. Adira II has medium starch content, high yield, medium maturity, tolerance to CBB and mites, drought tolerance, and high HCN content.

Research indicates that cassava yields can be increased by 22% above the present national average (7.5 tons/ha) through the application of improved cultural practices alone. When improved, high-yielding varieties are also considered, the increase amounts to 73%; and when appropriate plant nutrients are added, yields can be increased up to 247% of the present average (26 tons/ha).

The breeding program during the past 4 years has shown progress. New clones such as M-30 and M-31 offer 30% to 40% higher yields than Adira I, and 50% to 70% above local cultivars.

In regional yield trials conducted at three different locations representing poor soils, and two different locations representing fertile soils, M-30 and M-31 gave higher yields than Adira I and the local cultivars (Table 2). A regional yield trial at Maguwoharjo in 1982/1983 showed that clones W-236-28, W-236-31, M-30, and M-31 gave significantly higher

Table 2. **Results of cassava regional yield trials, 1980/1981 and 1981/1982.**

Clone	Average yield (t/ha)	
	1980/81 Fertile soil[a]	1981/82 Poor soil[b]
M-30	30.9	17.7
M-31	25.8	16.7
G-168	-	12.4
I-107	-	11.9
WV-43	22.9	10.8
WL-54	22.0	12.3
W-1705	-	6.5
GL-8	20.4	9.8
Adira I (check)	22.8	13.2
Local (check)	16.4	12.0
Average	23.0	12.3
LSD 0.05	10.9	1.1

a) Two sites: Muara and Lampung.
b) Three sites: Ciamis, Sukadana, and Wonorigi.

— = not tested.

yields than Adira I. Clone CM-84 introduced from CIAT in 1978 produced a lower yield than Adira I, and was not significantly different from the local check (Table 3).

Another regional yield trial conducted at Tamanbogo, Lampung, in 1983/1984 showed that M-30 and M-31 produced significantly higher fresh root yields than the local check (Table 4). These two superior clones also had good root shape and CBB tolerance. They are ready for harvest at about 8-9 months after planting.

Agronomic studies indicate that split applications of one-third of the nitrogen and potash at planting and two-thirds at 3 months after planting could increase yields by 20% as compared to a single application at 3 months after planting.

The effect of fertilizer on cassava yields in different types of soils has also been studied during the past 5 years. The results indicated that cassava gave a better response in latosolic soils than in red-yellow podsolic soils (Figure 3).

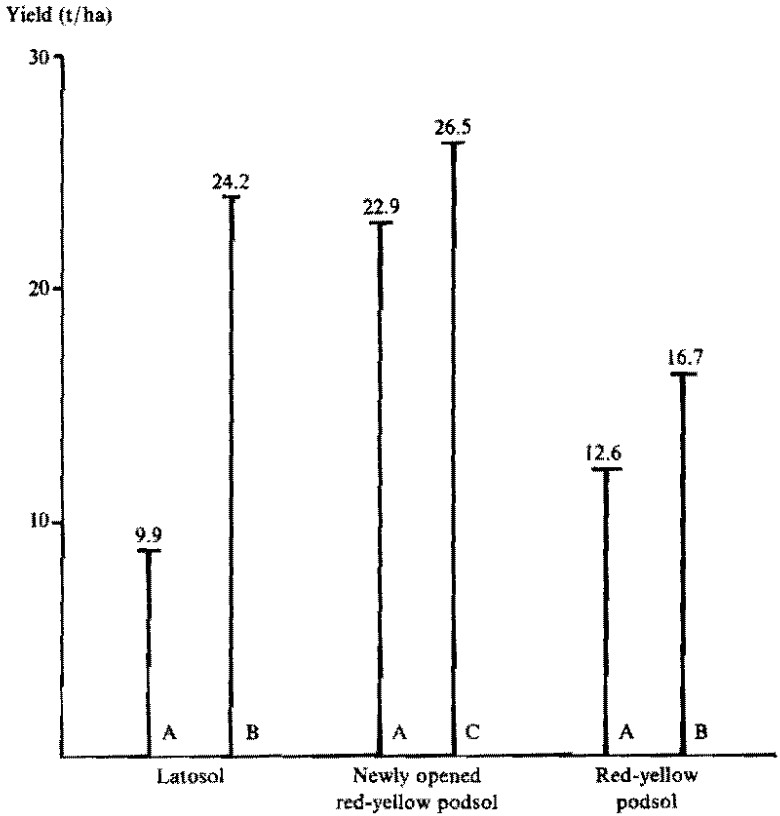
Appropriate methods of fertilizer application could also increase yield. Researchers found that dibbling application gave 11% more yield than band application, and 7.4% more yield than application in a circle around the plant (Figure 4).

Table 3. **Results of cassava regional yield trial at Maguwoharjo, Yogyakarta, 1982/83.**

Clone	Yield (t/ha)	Harvest index (%)
W-236-28	46.2	64.0
W-236-31	45.9	59.7
I-130	26.2	47.0
M-30	46.0	68.8
M-31	47.5	60.2
G-168	38.7	57.9
H-7	39.0	57.7
WL-54	34.6	54.0
W-1548	29.6	48.5
CM-84	30.6	49.6
Local (check)	24.1	46.7
Adira I (check)	31.2	62.1
Average	36.5	56.4
LSD 0.05	9.8	5.4

Table 4. **Results of cassava regional yield trial at Tamanbogo, Lampung, 1983/84.**

Clone	Yield (t/ha)	Harvest index (%)
M-30	60.5	63.5
M-31	44.5	46.1
CM-1371-6	23.4	31.6
I-130	30.7	40.4
K-8	35.8	51.2
GL-8	29.1	37.6
WV-43	23.6	29.5
WL-54	16.1	24.2
Adira I (check)	38.8	52.2
Local (check)	29.2	38.6
Average	33.2	41.5
LSD 0.05	7.3	6.1



Treatments:
A. Control
B. 90 kg N, 30 kg P_2O_5, 50 kg K_2O/ha.
C. 60 kg N/ha.

Figure 3. *Effect of fertilizer on cassava yield in different soil types.*

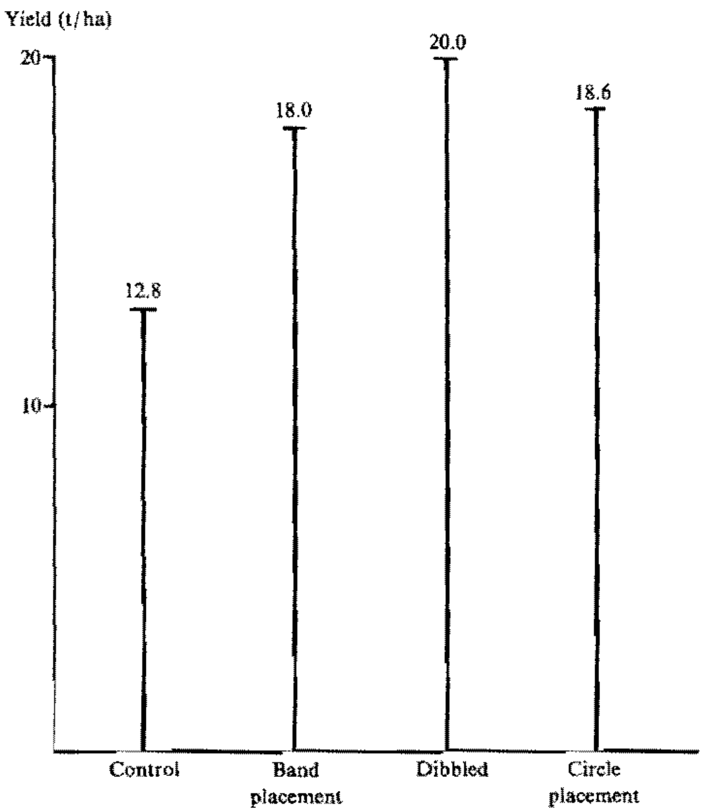


Figure 4. *Effect of method of fertilizer application on cassava yield.*

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Improving the Productivity of Cassava in Peninsular Malaysia

Tan Swee Lian
Chan Seak Khen

Introduction

Cassava is the principal root crop cultivated in Malaysia, occupying an area of 9599 ha in 1981 in Peninsular Malaysia (Malaysia, 1981). (Reliable data for Sabah and Sarawak are not available.) It is grown primarily for the starch extraction industry, with only about 10% of current production destined for the animal feed industry (Chan et al., 1983). Cassava for human consumption is grown on a comparatively smaller scale since it is not a staple food. It is mainly a backyard crop, and is used in various culinary preparations, such as desserts, cakes, and fried chips.

Agro-climatic Zones

Much of the cassava cultivation is located in the state of Perak, in the central western part of Peninsular Malaysia. The state of Kedah in the northwest, although ranking second in area, accounted for only 614 ha in 1981 (Figure 1). The rest of the states of the peninsula had 1237 ha in cassava, or 12.9% of the total. As information and data on cassava cultivation in Sabah and Sarawak are somewhat scarce, and because research on cassava as conducted by MARDI is directed only towards conditions in Peninsular Malaysia, this paper is relevant only to Peninsular Malaysia and not Sabah or Sarawak.

In terms of soil groups (as classified by the FAO, 1968, and quoted by Wong, 1971), cassava in Perak is cultivated largely on red and yellow latosols and podzolic soils on terrains ranging from flat to gently sloping. Developed over raised terraces and platforms of older alluvium and sub-

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recent alluvium, these soils are of variable fertility. Some others are derived either from acid igneous rocks or from a variety of sedimentary rocks (Wong, 1971). Depending on their parent material, soils of red-yellow latosols include a wide range of textures: free-draining, friable sandy, sandy clay or silty clay loams, and moderately well-developed clay loams and clays (Siew, 1970).

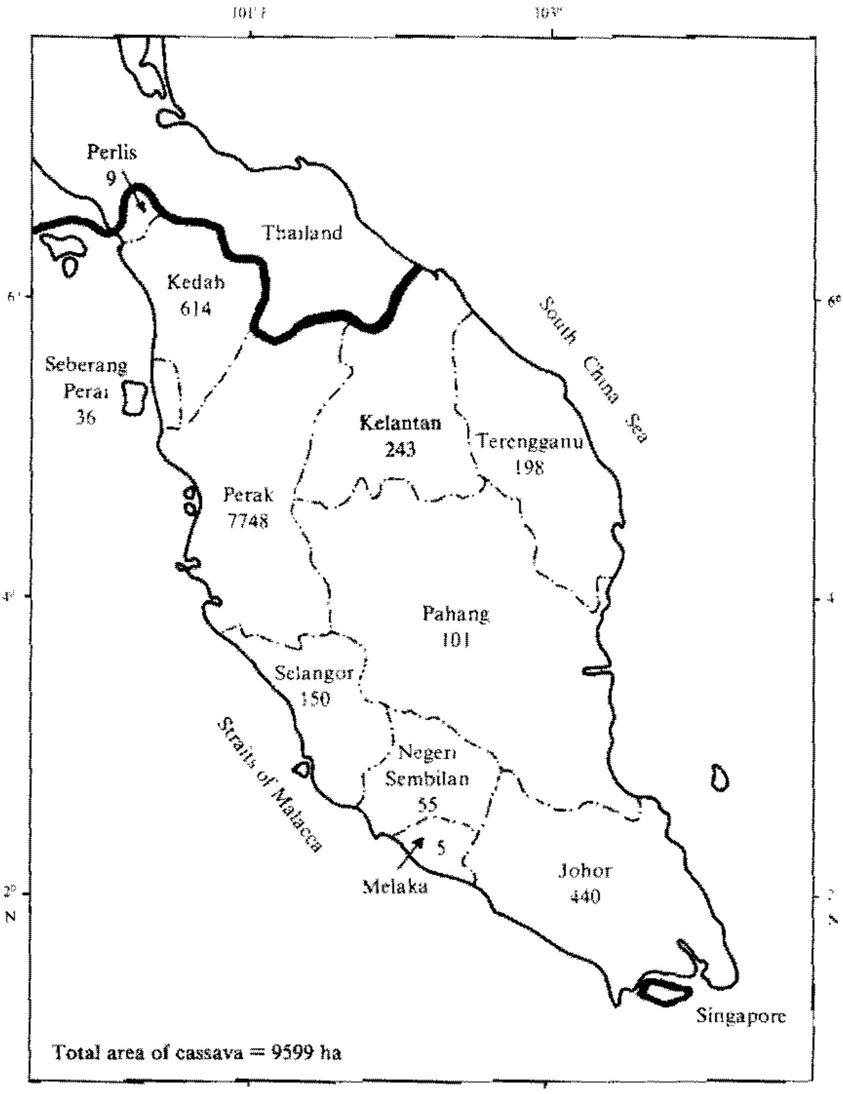

Figure 1. *Distribution of cassava cultivation by state (ha), Peninsular Malaysia, 1981.*

In Kedah, however, land occupied by cassava comprises mainly lateritic soils on gently sloping land which are derived from shales, phyllites, and schists. These soils are often of average or below average fertility. In texture, lateritic soils are moderately or strongly structured clay loams or clays with consistence varying from friable at the top of the profile to firm at depth (Wong, 1970). They are characterized by iron-rich concretions present within 45 cm of the surface.

It is clear from the foregoing descriptions that cassava is planted on a range of soil types. Indeed, the soil type has less bearing on the decision to plant cassava than other socioeconomic factors.

The soil types on which cassava is grown do not usually impose serious constraints on crop productivity except where they are heavy and poorly drained. Most fertility problems may be surmounted by sound agronomic and nutritional practices. Where cassava is cultivated on sloping land, soil erosion may become a significant problem. Current land preparation practices strip the soil of vegetative cover. This, coupled with the considerable time the cassava crop canopy takes to achieve cover over the bare soil and the general practice of subsequently weeding the crop, can lead to severe erosion and loss of top soil and fertility in the wet climatic conditions of Malaysia.

Notwithstanding the traditional practice of planting cassava on mineral soils in Peninsular Malaysia, the potential for significant expansion on these soils is somewhat limited. The rapid expansion in cultivation of the more lucrative plantation crops, such as oil palm, rubber, and cocoa, represents strong competition to cassava expansion on these same soils. As stated in the Malaysian paper in a previous section of this volume, an estimated 72% of the cassava area in Perak is planted by squatters on land to which they hold no legal rights. The stepped-up enforcement against these squatters that is currently taking place will certainly lead to further reduction of the traditional cultivated areas. There is, however, an alternative area for future cassava cultivation and expansion. Preliminary research has shown the ability of cassava to adapt to the acid conditions of drained peat, of which large tracts may be found in the country. Although cassava faces less competition with other crops on peat soils, it must still confront agronomic constraints such as optimal crop growth, low pH, fluctuating and high water tables, nutritional limitations and deficiences, and the low-bearing capacity of these organic soils.

The climate of Malaysia is typically equatorial, with rain falling throughout the year, a mean annual temperature fluctuating within a very narrow range (26-28° C), and high relative humidity, usually in the range of 82-86% (Wong, 1971). Nevertheless, there are five distinct rainfall distribution patterns in Peninsular Malaysia resulting from the influences of the northeast and southwest monsoons, physiographical features of the country, and, to a lesser extent, the small changes in latitude from south to north. These five rainfall regions are the northwest, west, Port Dickson-Muar coast, southwest, and east (Dale, 1959).

The production zone for cassava in Perak falls within the west region, which is characterized by a two-maxima, two-minima pattern of precipitation, with the maxima occurring in April and in October/November (coinciding with the monsoons), and the minima in February and July. Dry spells, if they occur at all, do not last for more than a week or two.

The Kedah production zone falls within the northwest region. Although the rainfall pattern here still shows two maxima and two minima, the maxima occur during the intermonsoonal periods. Low rainfall, with dry spells lasting from 2-3 months, is common in the months from December through February.

Peat tracts are found within the western, southwestern, and eastern regions. Cassava cultivation in the east is hampered by heavy rainfall (up to 60% of the annual total) during the northeast monsoon, which is accompanied by strong winds and gives rise to flooding. More likely potential areas would therefore be in the west. The climate of the west region has already been described in relation to Perak. The southwest region is characterized by a relatively even distribution of rainfall throughout the year.

Production Systems

Cassava is traditionally a smallholder crop in Malaysia, usually planted in holdings less than 3 ha in size. Attempts to plant the crop on a plantation scale have met with little success. Most farmers practice monocropping of cassava combined with rotational cropping involving short-term field crops (such as groundnut and maize), vegetables after several crops of cassava, or fallowing. In rubber, coconut, and fruit tree small holdings, the inter-row spaces are often cropped with a variety of annual crops, including cassava, when the main crop is in its juvenile unproductive stage. Less frequently, cassava planted as a main crop is intercropped with other short-term field crops and vegetables (MARDI, 1982).

Cassava is planted year-round in Perak and generally harvested after 12-14 months. However, some farmers delay harvesting until 16-18 months if the market situation is unfavorable and prices are low. In more coastal areas where flooding is common, farmers may be forced to harvest earlier, 8-10 months after planting, to avoid total or substantial crop loss. However, as the varieties used are Black Twig, and, less commonly, Green Twig, harvesting after 12-14 months leads to deterioration in root quality, whereas earlier harvesting does not give maximum yields.

Kedah, with its climate of long dry spells, requires that cassava planting be restricted to months with sufficient rainfall. Extreme dry weather can pose a constraint to early establishment and growth of cassava, and can also stunt crop growth in mid-season. Farmers often choose to plant at the end of the dry season, around March, 1 or 2 weeks after the onset of rains (MARDI, 1982). Land preparation can therefore be carried out during the dry months. Harvesting takes place any time from 10-18 months after planting, depending on the variety and the market price for fresh roots. Red Twig is favored because of its longer durability in the ground. Even if it is harvested after 1 year, there is little decline in starch content. Black Twig is planted less frequently.

Black Twig, Red Twig, and Green Twig are all bitter varieties, grown for the starch and animal feed industries.

Land preparation preceding planting consists of two to three rounds of plowing in Perak, sometimes with one round of rototilling and/or ridging. Ridging is practiced in areas where soils are heavy and prone to floods and waterlogging. An alternative to ridging is the building of wide cambered beds on which three rows of cassava are planted. In Kedah, the practice is to plow the land once or twice, followed by one round of rototilling or harrowing.

While most Perak farmers use cuttings between 10 and 15 cm long, Kedah farmers go by node number rather than length, preferring cuttings with at least three to four nodes. These may vary from 7.5 to 13 cm long. Horizontal planting with one cutting per planting hole is the general rule, although some farmers in Perak practice inclined planting. Depth of planting can range from 5 to 10 cm, the depth of a *changkul* (hoe) scoop. Some farmers believe that deeper planting (at 15 cm) helps to prevent desiccation of the cuttings in dry months and lodging of plants.

Plant spacing generally ranges from 0.60 m square to 0.90 m or 1.00 m square. Some rectangularity in spacing is practiced, e.g., 0.60 x 0.90 m, 0.45 x 1.20 m, 0.75 x 1.20 m. Wider spacing, e.g., 1.20 x 1.20 m or 1.50 x 1.50 m, is used in new plantings and in subsequent croppings as yields decline. There is a tendency to compensate by closer spacing (0.30 x 0.30 m, or 0.45 x 0.45 m) in land of low fertility. Lodging, however, is often associated with close spacing.

Lime applications are uncommon in cassava cultivation, and when it is practiced in Perak, it is only applied to the first planting at a rate of 600 kg/ha. Chemical fertilizers are supplied by farmers' associations as a subsidy to cassava farmers, the most widely used being a commercial formulation of 12 N: 6 P_2O_5: 22 K_2O: 3 MgO recommended for cassava. Rates of application in Perak vary around 200-300 kg/ha, although the recommended rate is 500 kg/ha. Less knowledgeable farmers use other commercial formulations such as 15:15:15 and 14:14:14 at 200-400 kg/ha, or the formulations 12:6:22:3 and 15:15:15 in mixtures, and even urea alone. Squatters, for whom the cassava crop is a supplementary source of income, do not generally apply any kind of fertilizer or any other inputs except the labor to plant and harvest. The crop is planted in burnt jungle clearings for a couple of seasons if undetected, and then new sites are used in a shifting cultivation system.

Although farmers also receive fertilizer subsidies in Kedah, most distrust chemical formulations. The prevailing preference is for wood ash (comprising about 30-40% CaO, 4-15% K_2O, and 0.6-3.4% Mg), of which about three-quarters to one-and-a-half lorryloads (six-wheelers) are applied per hectare in the course of land preparation. Some farmers supplement wood ash with chemical fertilizers. Various formulations are used, such as 12:6:22:3, 14:14:14, 15:15:15, and 11:18:4:3, the last three being fertilizers recommended for young rubber trees and probably obtained as subsidies for rubber. Some farmers do not use any fertilizers at all for new plantings.

Although chemical fertilizers are generally applied within the first 2 months after planting, in some cases the applications are delayed until the 3rd or 4th month. Fertilizers are normally placed near the plants but broadcasting is also fairly common.

Weed control is achieved by both chemical and manual methods. A number of farmers are familiar with the use of pre-emergence herbicides using alachlor, diuron, or fluometuron, usually in cocktail mixtures with paraquat. Paraquat is the most widely used post-emergence herbicide, sprayed once or twice during the crop season, usually a couple of months before harvest to facilitate access to the crop and the harvesting operation itself. A round of manual weeding is usually done within the first 2 months just before fertilizers are applied. Farmers generally realize the importance of keeping weeds in check, especially during the early stages of crop growth. With squatters, however, weeding is not always practical if as little attention as possible is to be drawn to their holdings.

Among farmers in Perak, root yields average around 12-20 tons/ha (Aw-Yong & Mooi, 1973; Chung, 1976; Tunku Mahmud, 1979; MARDI, 1982). In Kedah, yields average around 20-35 tons/ha (MARDI, 1982). Farmers in Perak and Kedah claim yields as high as 45-60 and 50-52 tons/ha, respectively, in the first seasons of cropping newly opened land.

Principal Constraints on Cassava Productivity

Constraints on cassava productivity in Peninsular Malaysia may be grouped into three principal areas: technical, managerial, and socio-economic.

Technical constraints

Since a major portion of the cassava in Perak is cultivated by squatters, it is to be expected that these farmers receive no extension services to enhance their technological knowledge in cassava production. Most of them acquire this knowledge from their peers, and generally they try to cultivate with minimal inputs, which often means little or no fertilizer use and weed control.

Bona fide cassava farmers do not, however, always fully adopt technical advice and inputs supplied by extension agencies. This has been the case with farmers in Kedah who persist in using wood ash rather than the recommended chemical fertilizers. Inadequate amounts of fertilizer and late applications lead to less than optimal yields. Insufficient fertilizers and lack of technical knowledge in correcting nutrient imbalances in the soil soon result in declining yields and starch content, particularly where cassava is monocropped over a long-term period.

Cultural practices such as length of cutting, planting distance, and weed control measures do not usually coincide with those that are recommended. For instance, in an effort to improve yields by planting closer, a farmer will in fact cause further declines in productivity. Similarly, weeding might be delayed until it is too late, i.e., initial establishment and plant vigor are gravely undermined and will never fully recover. As has been mentioned before, soil erosion creates problems where there is a lack of conservation practices.

Inadequate drainage in low-lying areas during periods of heavy rains can result in substantial losses in yield and root quality. Varieties suited to the different agro-climatic conditions are not always available or known to the farmers. For example, in coastal areas of Perak which are flood-prone from 2-3 months a year, short-term varieties would save the crop from destruction and deterioration in root quality. In Kedah where long dry spells are characteristic, varieties are required which are tolerant to the dry spells, capable of rapid recovery in growth when moisture becomes available, and durable in root quality even when harvesting has to be delayed beyond the normal 12-14 months.

Although leaf diseases such as cercospora leaf spot and cassava bacterial blight frequently occur, they do not seem to depress cassava productivity to any significant extent. White root disease (causal organism: *Ridigoporus lignosus*), which occurs sporadically in cassava planted on newly cleared land that is incompletely destumped of rubber or jungle trees, causes lodging, root rot, and quality deterioration, and thus yield loss. The frequent practice of plowing the harvest debris under during land preparation probably aggravates the disease incidence.

Arthropod pests such as red spider mites and scales often appear during dry spells, and may cause defoliation or stunting of plant growth. In severe cases, scales cause stem desiccation and damage to lateral buds. Various leaf-eating caterpillars have also been reported, the best known being *Tiracola plagiata* Walker which caused severe damage in a cassava plantation in 1977. Termites also occur where there is a lot of old and rotting wood in the soil, e.g., in peat areas where complete destumping is impractical. Termites can cause dieback symptoms, severe yield reductions, and complete destruction of the plant.

In cassava holdings adjoining secondary or primary jungle, the most destructive pests are mammalian. Monkeys cause some damage to shoots, but wild boars can cause considerable crop loss due to their routing habits. Measures such as fencing, trapping, and shooting these pests are less than satisfactory in achieving complete control.

Managerial constraints

Managerial problems are often encountered where cassava is cultivated on a plantation scale. Plantations in Malaysia have long been associated with perennial tree crops, and there has been little local experience and expertise in the management of annual crops on a large scale. For this reason, there have been difficulties in coping with a schedule of frequent management operations. A limited labor pool is not always efficiently managed to ensure that essential operations, such as fertilizer application and weed control, are carried out on time for maximum effectiveness. Unfortunately, there are often delays because these operations have been considered to be of lower priority than harvesting, which is a labor-intensive undertaking. Such delays can ultimately lead to poorer yields.

Recently, as a result of the increasing labor shortages in the agricultural sector (because of competition for labor in the industrial sectors), one cassava plantation switched to contracting out lots of land to be planted with cassava. One problem arising from this practice is the lack of uniformity in agronomic practices among different contractors, leading to uneven crop productivity.

Productivity in plantation-scale cassava may also be undermined when the debris from the previous harvest has not been adequately cleared. This provides a source of volunteer plants, and, more seriously, a source of inoculum of root diseases such as white root in the next season. In addition it prevents good germination and establishment of the crop.

Socioeconomic constraints

The attitude of farmers towards cassava itself may indirectly form constraints to crop productivity. For instance, cassava has acquired a low status because of its poor income-earning capacity, relatively high costs of production, long-term nature (compared to other field crops), and therefore slower rate of return. For these reasons, many farmers consider cassava cultivation suitable as a part-time enterprise, not worth too much time and effort, and certainly deserving of the minimum of inputs. The belief that cassava is soil-impoverishing has caused the best land to be reserved for other more profitable crops and for cassava to be grown in marginal areas. Such circumstances have resulted in lower yields than would otherwise be expected under more favorable conditions of growth and management.

Socioeconomic attitudes may only be changed by effective extension, which until now is far from satisfactory because of higher priorities given to other crops.

Research Activities

Objectives

The objectives of the cassava research program at MARDI concentrate on overcoming productivity constraints and on expansion of production. These objectives are:

1. To increase the productivity of cassava in small holdings and in plantation-scale cultivation in various important and potentially important production regions through:
   - the breeding and selection of superior varieties adapted to these regions, and
   - the development of appropriate production technologies.

2. To improve postharvest processing and storage technology, and to develop new end uses for cassava.

Strategies

The research program covers various aspects of production, processing, and product utilization, including use as animal feed. A core group of cassava scientists from the Miscellaneous Crops Research Division is involved in programs to develop production technologies such as breeding and selection, nutrition, cultural and management practices, and pathology. This multidisciplinary team approach gives due emphasis to on-location experimentation in production regions (including peat) to ensure that technology developed on-station is both viable and adequate.

Contributions to other aspects of research from scientists working part-time on cassava cover fringe areas such as mechanization, economics, tissue culture, postharvest technology (including processing, storage, and end-product development), and utilization as animal feed.

In view of the increasing competition for arable land between cassava and other more lucrative crops, cassava cultivation is unlikely to expand much further on mineral soils under current agronomic and economic circumstances. To render cultivation of the crop more attractive and profitable, at least one of the following conditions must be met: increased productivity, reduced costs of production, or government incentives, e.g., price supports. Research efforts aim at achieving the first two conditions. Breeding and agronomic research are the means of attaining increased productivity, while reduced costs of production (and therefore a larger profit margin) may be accomplished through the development of more efficient systems of management and input utilization, including exploring mechanization possibilities to reduce labor requirements of certain management operations.

Practical technologies in mechanization will aid in eliminating labor limitations which have thus far hindered production systems associated with large-scale cassava cultivation. Commercial-scale cultivation might in this way become more attractive, especially if there is an assured market for cassava.

The potential for future expansion of cassava production exists in peat tracts in the western and southwestern areas of Peninsular Malaysia. Cassava adapts well to the acid conditions of peat, giving it an immediate advantage over many other crops. Also, because peat has a light and friable texture, the labor requirements for harvesting are much less than on mineral soils. Nevertheless, cassava is suitable only for cultivation on shallow peat which places it in competition with crops such as vegetables, pineapple, oil palm, coffee, and cocoa. Research to improve cassava productivity on peat would give cassava an edge over its competitors.

To date, most of the production technologies for cassava have been developed for mineral soils. Similar multidisciplinary research programs for cultivation on peat have to be formulated in the future. Emphasis will be given to breeding and selection for high-yielding cassava varieties adapted to peat and agronomic studies on nutrition and cultural practices suited to maximizing productivity on peat. If large-scale planting of cassava on peat is envisaged, appropriate machinery has to be developed given the limitations of the low-bearing capacity and slightly waterlogged conditions of the soil.

Cercospora leaf spots are more prevalent on peat, hence resistance to these diseases, particularly brown leaf spot, will be a necessary trait in clones developed for peat if yield loss to this cause is to be minimized.

Priorities of research needs are based on which are considered most pressing in order to promote future cassava production. Under this premise, the need for greater research emphasis on peat would take precedence over research on mineral soils. Technologies for cassava production on mineral soils have been developed to a satisfactory level and more efforts should be made to disseminate these technologies to the current cassava farmers.

Agronomic research on peat should concentrate primarily on nutritional studies, taking priority over studies on breeding and selection of clones. (The selection and development of clones suitable to cultivation on peat is already an integral part of the existing breeding and selection program.)

More emphasis should be given to mechanization because it provides the means of overcoming labor shortages in the agricultural sector and of reducing production costs, particularly in large-scale cultivation.

The development of cultural practices to solve problems such as soil erosion on mineral soils and loss of fertility, and as a means of developing more profitable cropping systems involving cassava, would be conducive to improving productivity and production.

Proposed research directions

The research directions proposed here are areas which require the most immediate attention. Whether they are fully adopted and implemented depends on MARDI's policy decisions regarding the best use of its research resources, which must be apportioned to the many commodities and research fields under its jurisdiction.

Agronomic research. There are two major components to agronomic research: nutritional studies and development of cultural practices. Of the two, the former has greater potential in eliminating productivity constraints.

The objectives of nutritional studies are:

1. To maintain soil fertility for optimal yields

2. To develop efficient diagnostic measures to aid in recommending effective fertilizer applications

Since emphasis will be given to cultivation on peat, research will cover liming, micronutrient availability, efficient fertilizer practices (including method and time of application), and studies on the relationship between the water table and nutrient uptake.

On both peat and mineral soils, studies will continue on mycorrhiza and cassava nutrition, exploring avenues for reducing fertilizer inputs, and monitoring nutrient levels in the soil and plant to diagnose fertilizer requirements.

The objectives of research on cultural practices are:

1. To maximize income through the development of efficient systems of production and management

2. To improve systems of soil management and crop protection

Cover-cropping and intercropping systems on mineral soils will be developed as a means of conserving soil fertility and preventing soil erosion. Intercropping studies will also aim at providing short-term returns to farmers while waiting for the cassava crop to mature. The maceration of crop debris from harvest and its incorporation into the soil will be examined as a possible way of returning nutrients to the soil. This would require close collaboration with agricultural engineers who will develop suitable machines for the maceration and incorporation processes, and with pathologists who will closely monitor any disease buildup associated with returning crop debris into the soil.

Breeding research. In response to industrial needs, cassava clones will continue to be selected for high starch content to maximize conversion rates to starch as well as to chips for animal feed milling. The principal goals in the breeding program will be:

1. High root yield and high harvest index
2. High starch yield (through high starch content)
3. Adaptability to peat and to the different ecological regions of current production
4. Early harvestability
5. Resistance to major diseases (cercospora leaf spots, cassava bacterial blight, white root disease)

Wide adaptability in clones may not be a practical goal because of the contrasting characteristics of peat and mineral soils. Even for mineral soils, the wide variation in weather conditions between production regions suggests the need to select clones for specific adaptability to some extent. For example, clones destined for Kedah should have a degree of tolerance to long dry spells.

Early harvestability, on the other hand, provides earlier returns, opportunity for a short-term crop to follow in rotation with cassava, and enables cassava to be cultivated in areas where the growing season is shortened by annual occurrences of floods (e.g., coastal areas in Perak).

The breeding and selection program will encompass introduction of hybrid seed for local testing and selection, hybridization among introduced and local germplasm materials, and introduction of varieties as aseptic meristem cultures for possible direct use or for incorporating desired characteristics into local varieties. Clonal evaluations will be carried out on-station in the earlier stages of selection, and increasingly on-location in the advanced stages of selection.

Mechanization research. Harvesting requires a major portion of the labor in cassava production (anywhere from 50-65% on mineral soils and probably 30-40% on peat). It is therefore a significant cost item and a production constraint where labor is in short supply. Even in small-scale production where family labor may be used in other operations such as planting, weeding, and fertilizing, contract labor is almost always employed for harvesting. In plantation production, labor is limited since planting is staggered throughout the year, and in addition to the tremendous pressures put on a labor pool for harvesting the crop, the same pool has to cope with a fixed schedule of weeding and fertilizer applications.

The objectives of mechanization research must take into account both smallholder and plantation cultivation of cassava, and must also investigate the possibility of mechanization in large-scale cultivation on peat. In-field transportation of roots constitutes a primary problem as heavy machinery or vehicles tend to sink in peat. Mechanization will serve not only to reduce labor requirements for various field operations but also to alleviate the drudgery of back-breaking operations such as harvesting. This will involve the development of tractor-driven machines (for large-scale cultivation or group farming in smallholder situations) as well as mechanical aids or implements (to be used by small farmers) for various field operations.

Other research areas. Other research areas meriting attention are physiology, crop protection, and end-use development.

To obtain a better understanding of crop performance and productivity, and of interrelationships between crop and environment, physiological studies will support and guide both breeding and agronomic research.

Crop protection studies comprise aspects of weeds, pests, and diseases. Research on weed control will give attention to determining effective herbicides and their rates in relation to different soil types. Disease control will give emphasis to cercospora on peat and white root on mineral soils, and devise effective management practices to keep them in check.

Postharvest research will help in developing various end uses for cassava to boost its market demand. Available technologies will be improved or adapted for practical application. At the same time, new cassava-based products may be developed.

Research findings

While considerable progress has been made in cassava research at MARDI to date, only the major technological findings in production research are reported here.

Black Twig and Medan are endorsed as high-yielding varieties suitable for industrial use and human consumption, respectively. C5 was developed from an open-pollinated local selection, and is endorsed as an early variety, harvestable after 9 months when a root yield comparable to that of Black Twig at 12 months may be achieved.

Various promising clones are in advanced stages of regional testing, having outyielded Black Twig and C5 in on-station trials. Prominent among these are CM 942-28, CM 621-24, CM 378-17, Silon 128-3, and Bengkang Bengkok 247.

The optimum cutting length for horizontal planting is 20-24 cm at a planting depth of 10 cm, while 60 cm is optimum for vertical planting. Although vertical planting produces higher root yields than horizontal, it requires greater harvesting efforts since deeper planting is involved.

Hence, vertical planting has greater application on peat because of its light and friable texture.

Only mature portions of stems from plants between the ages of 7 and 17 months are suitable as planting materials. Optimal plant spacing for root yield is 1 x 1 m, giving a density of 10,000 plants/hectare. For maximum starch yield in Black Twig, the crop should be harvested between 12 and 14 months.

Long-term fertility studies on mineral soils show that a fertilizer rate of 60 kg N, 30 kg P_2O_5, and 160 kg K_2O per hectare is required to maintain high cassava yields. At a fresh root yield of 40 tons/ha, a cassava crop is estimated to extract 126 kg N, 46 kg P, 259 kg K, 56 kg Ca, and 23 kg Mg from the soil. Mg plays an important role in cassava nutrition and should be supplied when its deficiency symptoms are detected.

K requirements may be estimated by the analysis of soil K content using water-soluble extracts. In soils deficient in specific micronutrients, dipping cuttings into micronutrient solution prior to planting is effective in producing good growth and high yields.

Mycorrhizae have been identified as being instrumental in enhancing P absorption in cassava. In the absence of mycorrhizae, 1-1/2 to 6 times as much P as is normally required is necessary for high yield.

On peat, cassava requires minimal liming of about 3.5 tons/ha to correct low soil pH. The recommended fertilizer rate on peat is 250 kg N, 50 kg P_2O_5, and 150 kg K_2O per hectare. The inherent Cu deficiency in peat must be corrected with the application of 15 kg/ha of $CuSO_4 . 5H_2O$ to achieve high yields. Rotational systems on peat involving cassava-groundnut and cassava-sorghum-groundnut sequences appear to have potential. In intercropping studies, satisfactory yields were obtained from groundnut planted 2 weeks before the cassava crop was due to be harvested.

Several clones and varieties have been identified as having field resistance to cercospora brown leaf spot (causal agent: *Cercospora henningsii*), notably C3, and also to cassava bacterial blight (causal agent: *Xanthomonas manihotis*). Black Twig has been found to be relatively susceptible to both diseases.

Cool temperatures in the Cameron Highlands appear to be effective in inducing early flowering in selected germplasm varieties which flower infrequently or tardily in the lowlands. This provides the means for hybridization between varieties which otherwise do not flower readily at sea level.

Physiological studies have determined the strong relationship between starch and dry matter contents in roots, facilitating the estimation of starch content by oven-dried samples or by specific gravity measurements. Leaf area index (LAI) and leaf life are of critical importance to cassava productivity. An optimal LAI of around 3.5 maintained for as long as possible coupled with a long leaf life are desirable for high root yields.

Weed control practices involve a combination of pre-emergence and pre-harvest chemical control methods and one round of manual weeding.

Mechanization possibilities in planting and harvesting have been investigated, and a harvesting implement has been adapted to aid manual extraction of roots.

Rapid propagation techniques were adapted for producing cassava planting materials, while tissue culture methods were developed to aid in the production of disease-free materials and multiplication and transfer of germplasm.

Assessment of Yield Gap and Production Potential

Current farm-level yields and experimental yields are given in Table 1. The mean yields obtained by farmers in Perak are lower than those reported by farmers in Kedah. The mean cassava yield for all of Peninsular Malaysia falls within the range for Perak, which accounts for an overwhelming proportion of the national production. It may be seen that the yield gap on mineral soils between experimental and farmers' yields based on improved agronomic practices is somewhere in the region of 20-35 tons/ha for most farmers. However, the more progressive farmers may be assumed to have adopted at least some of the recommended agronomic practices. Here, yield improvement attained through further sharpening of their skills would be 10-20 tons/ha. It has been reported that farmers who practice crop rotation and adequate fertilizer applications to their cassava crop regularly achieve yields around 30-33 tons/ha (Aw-Yong & Mooi, 1973; Chung, 1976).

The yield gap between experimental yields obtained on-station and yields in farmers' fields is estimated at about 15 tons/ha. Using new clones, most farmers may expect yield increases of about 30-40 tons/ha, whereas progressive farmers will achieve roughly a 15-25 ton/ha improvement, as their yields are already high.

Many progressive farmers (including plantations), have adopted recommended agronomic practices such as planting density, horizontal planting, weed control and fertilizer practices, and harvesting at 12-14 months. This

Table 1. **Current cassava yield levels, Peninsular Malaysia.**

Farmers' yields		
Progressive farmers	Perak	22.5-37.0 t/ha
	Kedah	37.0-45.0 t/ha
Mean yields	Perak	12.0-20.0 t/ha
	Kedah	20.0-35.0 t/ha
Best yields	Perak	45.0-60.0 t/ha
	Kedak	50.0-52.0 t/ha
Worst yields	Perak	6.0-10.5 t/ha
	Kedah	7.5-15.0 t/ha
Plantation yields		
Mean (over 6 years)		26.8 t/ha
Best (on an individual field basis)		49.6 t/ha
Worst (on an individual field basis)		10.5 t/ha
Experimental yields (on-station)		
Using traditional varieties and improved agronomic practices	Mineral soils	45.0-55.0 t/ha
	Peat	40.0-50.0 t/ha
Using new improved clones and recommended agronomic practices	Mineral soils	60.0-80.0 t/ha
	Peat	50.0-70.0 t/ha
National yields		
Range over 6 years		11.1-22.0 t/ha
Mean		16.1 t/ha

has probably been the reason for the yield difference between the average farmer and the progressive one.

In both Perak and Kedah, the difference is around 13-14 tons/ha. By far the most significant impact on yields has been the adoption of sound weed control and fertilizer practices. A conservative figure of yield loss through uncontrolled weed growth is 15% (Chan et al., 1983), although situations of profuse weed growth, especially in the early crop growth stages, would undoubtedly depress yields more drastically.

Failure to apply any fertilizers can account for up to 45% reduction in root yield. At the same time, applying fertilizers too late during crop growth can cause yields to decline by as much as 30% (Chan et al., 1983).

Unskilled cassava farmers who know little about planting cassava (see worst yields, Table 1), many of whom do not apply any form of fertilizer, can suffer a yield depression of as much as 8-16 tons/ha under that of the average farmer. The potential yield improvement for these farmers, bringing them to the level of progressive farmers, would be 21-29 tons/ha.

Yield potential

How rapidly yield gaps will be bridged depends on the degree of importance the government gives to cassava cultivation in the future. Without active government support, there will be no corresponding extension efforts, nor ready access to input subsidies and credit specific for cultivating cassava.

There are some favorable indications that government policies are headed towards promoting increased cassava production in the attempt to reduce the currently large maize imports used for feed rations. Peat soils have been proposed as the areas for expanded cultivation, and some 10,000 ha have been suggested. A whole new group of farmers might be involved who are totally unfamiliar with growing cassava, which in itself may not be detrimental since they may be taught modern production technology from the start. Much of the costs of developing peat for cultivation, namely, felling, clearing, draining, and constructing access roads, will be beyond the capability and financial resources of the small farmer and will have to be paid by the government or large private agencies. At the same time, research should be actively investigating and formulating agronomic practices for cassava to ensure sustained productivity on peat.

Peat was at one time used mainly for the cultivation of pineapple, and some 18,700 ha had been developed for this purpose (MARDI, 1982). However, about 8000 ha of pineapple cultivation has been abandoned lately due to declining margins of profit, strong competition from other producing countries (such as Thailand), and overseas tariff restrictions on canned pineapple (MARDI, 1982). These abandoned but developed peat areas can therefore be converted to cassava cultivation as soon as the government accepts and implements the proposal. As only an additional 2000 ha of peat will need to be developed, it would be reasonable to expect about 2 years for cassava cultivation to reach its proposed target, and about 5 years for a yield level of 30-35 tons/ha to be attained.

At the same time, if the government were to concentrate part of its efforts on traditional cassava farmers on mineral soils, yields may fairly quickly be raised to the level of the present progressive farmers, (35-40 tons/ha), perhaps in a matter of 2-3 years.

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Improving the Productivity of Cassava in the Philippines

Algerico M. Mariscal

Introduction

Cassava (*Manihot esculenta* Crantz) is one of the few extensively grown crops in the Philippines that has attracted considerable attention from government policymakers, researchers, and private groups who recognize its potential for food, feed, and energy. The establishment of the Philippine Root Crop Research and Training Center (PRCRTC) at ViSCA (Visayas State College of Agriculture) in 1977 is an indication of the government's growing realization of the potential role of root crops in the Philippine economy.

A major concern of the cassava industry in the Philippines today is improving crop productivity. As of 1982, the national average yield of cassava was 8.86 tons/ha, which is much below the Asian average of 12.3 tons/ha. This information serves as a challenge to every agency or institution concerned with developing technologies that affect programs to improve cassava yields in the Philippines.

Area, Production, and Yield

A comparison of cassava statistics between 1977, when PRCRTC was formally created, to 1982, the year with the latest available data, is presented in Table 1. The area planted in cassava increased by 45% from 154,270 ha in 1977 to 224,350 ha in 1982. Total production increased by 101% and the average yield increased by 38%.

The increase in the national average yield in 1982 was affected by the high average yield for central Mindanao, 25 tons/ha, which represents a

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Table 1. **Cassava area, production, and yield by region, 1977 and 1982.**

Region	Area (ha)		% Change	Production (t)		% Change	Yield (t/ha)		% Change
	1977	1982		1977	1982		1977	1982	
Ilocos	2,130	2,420	14.08	16,314	17,489	7.20	7.66	7.23	- 5.61
Cagayan Valley	1,120	800	-28.57	3,307	3,856	16.60	2.95	4.82	63.39
Central Luzon	1,090	1,540	41.28	4,436	4,649	4.80	3.15	3.02	- 4.13
Southern Tagalog	8,540	8,120	- 4.92	46,149	43,854	4.97	5.40	5.40	0.0
Bicol Region	27,730	32,190	16.08	233,162	306,949	31.65	8.41	9.54	13.44
Western Visayas	10,680	11,070	3.55	42,248	49,982	8.31	3.96	4.52	14.14
Central Visayas	28,570	39,150	37.03	92,758	78,209	-15.68	3.25	2.00	-38.48
Eastern Visayas	29,780	31,020	4.16	91,223	147,981	62.22	3.06	4.77	55.88
Western Mindanao	20,410	34,990	71.43	349,889	411,906	17.72	17.14	11.77	-31.33
Northern Mindanao	13,840	26,040	88.15	55,154	145,368	163.57	3.99	5.58	14.79
Southern Mindanao	7,510	7,800	3.87	40,723	45,252	11.12	5.42	5.80	7.01
Central Mindanao	2,870	29,210	917.77	13,428	731,962	5,351.00	4.68	25.06	435.47
Total	154,270	224,350	45.43	987,791	1,987,457	101.20	6.40	8.86	38.44

Source: Bureau of Agricultural Economics, 1977 and 1982.

tremendous increase from the average of 4.7 tons/ha in 1977. This change can be attributed to the presence of large plantations in the area that supplies cassava to starch millers on the island. Most of these plantations adopt modern production technologies, and the area has the advantage of even rainfall distribution throughout the year and generally fertile soil.

The Visayas regions, which had the biggest area devoted to cassava in 1982, registered very low average yields, ranging from 2.0 to 4.77 tons/ha. This situation can be attributed to poor soil conditions, frequent typhoons, and very pronounced wet and dry seasons. In addition, cassava is planted in the marginal areas of these regions, i.e., rolling hills and rocky, infertile soils.

Principal Constraints to Productivity

Subsistence farming

In the Philippines, farms are classified as either commercial or subsistence types. The latter are the most dominant and characterize most farms devoted to cassava production. Commercial farms are usually large plantations managed by starch manufacturers and feed millers. Subsistence cassava farms are usually less that a hectare (about 0.38 ha) where cassava is grown as a cheap source of food or animal feed, or for cash whenever there is enough surplus for sale (Villanueva et al., 1980). Low yields are expected from subsistence farms because the growers use very few inputs and employ inappropriate management practices. Characteristics of subsistence and commercial farms are compared in Table 2.

Infertile areas devoted to cassava

Available land for cassava production is in marginal areas that do not favor growth of other crops. These areas are generally sloping and covered with alang-alang (*Imperata* spp.). Others are rocky and have problem soils. Such areas are heavily concentrated in central and eastern Visayas. The average yield under these conditions ranges from 2.0 to 4.5 tons/ha.

Poor production practices

A survey on cassava production in eastern Visayas (Colis, 1977) identified the following major causes of low yield: inadequate land preparation, low plant density, lack of selection of planting materials, inadequate cultivation and weed control, absence of fertilizer application and pest control, early harvesting, and small farm size. These situations also exist in other cassava-growing areas in the Philippines.

Table 2. **Comparison between a typical commercial farm and a subsistence farm in the Philippines.**

Descriptors	Commercial	Subsistence
Size	Several hectares	Less than a hectare
Topography	Flat to rolling	Flat to hilly
Soil	Poor to fertile	Poor to fair
Land preparation/ cultivation	Tractor, animal-drawn implements	Animal-drawn implements, manual
Variety used	High in HCN	Low in HCN
Planting time	Staggered	Once
Quality of stakes	Good	Poor to good
Fertilizer use	Often	Seldom
Pest control	Adequate	Inadequate
Harvesting time	Staggered, each area harvested once	Staggered, selection of big roots only
Harvesting method	Manual, mechanical	Manual
Age of plant at harvest	At least 10 months	As early as 4 months
Yield levels	Above 15 t/ha	Below 8 t/ha
User of product	Starch factory	Home
Cropping pattern	Monocrop, continuous	Rotation with other crops/fallowing
Main source of labor	Hired	Family/household

Source: National Workshop on Root Crop Research and Development Needs, 1982.

Furthermore, farmers who grow cassava on hillsides practice the slash-burn system of farming. Cultivation and weeding are not performed at all. Only major operations such as clearing, burning, planting, and harvesting using light, animal-drawn implements are employed.

Inappropriate research-generated technologies

The majority of available technologies related to cassava production have been developed by research centers in relatively fertile and easy-to-manage flatlands. Thus, technologies generated in most experimental sites may have little or no impact on marginal subsistence farms which constitute most of the country's cassava-growing areas.

Slow technology transfer

Available production technology for cassava in terms of improved varieties, fertilization, and cultural management is at least reasonably satisfactory in the open flatlands. (See Table 3 for an assessment of technology levels for various root crops.) This means that part of the problem of low yield is not due to the unavailability of production technology but to technology transfer or extension.

Unadopted technology

One survey (Jayme, 1982) revealed that the use of high-yielding varieties and fertilizer, control of weeds and insect pests, and crop rotation have very low adoption rates among farmers. Farmers want to plant high-yielding varieties but these are unavailable in their locality.

Jayme (1982) and Villanueva et al. (1980) pointed out that a recommended practice that does not entail cash expense on the part of the farmer usually is adopted. Farmers are very willing to adopt recommended technologies but lack of money prohibits them. Also, the low price of cassava and the lack of stable market outlets discourage farmers from adopting technologies that require cash. Costs of fertilizer, hired labor, insecticides, and other inputs have greatly increased but the price of root crops, especially cassava, has not risen proportionately. Villanueva et al. (1980) reported that the tenancy status of the farmers is another factor

Table 3. **Present level of available technology in different root crops.**

Discipline	Level of technology*				
	Cassava	Sweet potato	Taro	Yam	Others
Varietal improvement	4	3	2	2	1
Cultural management	4	4	2	2	1
Fertilization	3	3	2	1	1
Crop protection	3	2	2	1	1
Farming system	2	2	2	1	1
Postharvest handling	2	2	1	1	1
Processing	3	2	2	2	1
Utilization	3	2	2	2	1
Economics and marketing	2	1	1	1	2
Extension	1	1	1	1	1

* 1 - Unsatisfactory; 2 - Fairly satisfactory; 3 - Moderately satisfactory; 4 - Satisfactory; 5 - Very satisfactory.

Source: Minutes of the PCARRD Root Crop Commodity Team Meeting, March 11, 1982.

affecting technology adoption. Owner-operators and leaseholders adopt modern technologies more readily than share tenants (Jayme, 1982).

Additionally, the lack of other services such as roads, credit, and technical assistance hinder the adopting of improved production technologies.

Postharvest and processing problems

Cassava is a very perishable crop. Vascular streaking appears 24 hours after harvesting. This is the main reason why subsistence farmers stagger their harvesting over a long period of time. An estimated 10-30% of the losses in root crop production in eastern Visayas have been attributed to postharvest losses (E.S. Data, 1982). Buyers are reluctant to buy large quantities of cassava because the bulk poses a problem in transporting the produce from the farm to the user's base. It has been suggested that processing cassava into chips and drying them would encourage farmers to increase their production capacity. Dried chips are easier to transport and are much lighter than fresh roots. However, the lack of processing equipment and technical knowledge on the part of the farmer would then have to be addressed.

Research Programs and Action Projects

The main agencies conducting cassava research projects are PRCRTC/-ViSCA, the University of Philippines at Los Baños (UPLB), and the Bureau of Plant Industry (BPI)/ Ministry of Agriculture. They are under the coordination of the Philippines Council for Agriculture Resources Research and Development (PCARRD).

Development of improved cassava varieties

The objectives of the varietal improvement program are to develop varieties that are high-yielding and pest-resistant, that can adapt to a wide range of ecological conditions, that can tolerate extreme environmental stress, and that are highly acceptable for food, feed, and industrial uses. To attain these objectives, a scheme to evaluate germplasm collections and hybrids has been adopted by PRCRTC. Collection of local and exotic cultivars was started in1978 to obtain a population of diverse origins. From 1982 on, germplasm has been obtained from the Centro Internacional de Agricultura Tropical (CIAT) in Colombia to bolster the cassava collection in the Philippines.

Outstanding selections from advanced trials qualify for the Philippine Seedboard trials conducted in 6 to 13 locations within 2 years. Selected as cooperators for this national testing are research centers, experiment stations of the Ministry of Agriculture, and agricultural schools. These locations represent specific agro-climatic conditions in the Philippines.

Varieties exhibiting good performance are tried in farmers' fields to further verify and confirm their productive potentials. From these trials outstanding varieties are selected for multiplication and dissemination to root crop growers throughout the country.

Agronomic research

Research planners have modified research thrusts to give more attention to developing technologies that are specific to certain locations and situations, well-suited to farmers' resources and aspirations, and environmentally sound.

Research covers the areas of cultural management under hillside conditions, production technologies for areas with distinct wet and dry seasons, screening and evaluation of varieties under shade, agroforestry studies using root crops and legumes, and continuous production under marginal conditions.

Inasmuch as farmers do not readily adopt technologies requiring cash, researchers also are focusing on developing production technologies requiring only minimum production costs. One of these technologies is the use of high-yielding varieties.

The National Feed Root Crops Program

It is estimated that yellow corn (maize) importation in recent years has reached the level of 500,000 to 600,000 tons/year. Dollar reserves can be saved if the potential of root crops for animal feed processing is fully tapped. The feasibility of substituting cassava for part of the corn in animal feeds has prompted both the government and the private sector to massively increase production of cassava for feed and other industrial purposes. The government as well as private banks are offering financial assistance to cassava growers through loans.

The Ministry of Agriculture, ViSCA, PCARRD, UPLB, the National Food Authority, banking institutions, and economic development foundations created the National Feed Root Crops Program with the following objectives: (1) to fill the gap between production and supply of feed grains; (2) to increase the production of root crops not only for human food but also for animal feed; and (3) to generate farm employment and reduce feed importation. Although the program is not yet formally launched, the initial phase has already been started.

The initial year of the program is devoted to the establishment of a seed bank. Each region establishes a 2-ha seed bank as source of initial planting materials. Cassava varieties used are Golden Yellow, Kadabao, Java Brown, CMC 40, MCol 1684, Datu, Hawaiian 5, and Macan.

The packages of technology used are those developed by various research institutions. Training and related activities are provided by ViSCA, BPI, and UPLB. The funding agencies (Land Bank, Development Bank of the Philippines, Central Bank, and Philippines National Bank) extend loans to farmers in the amount needed for a specified farm area.

Pilot feed mill. In support of the National Feed Root Crops Program, ViSCA recently launched a pilot feed mill, which uses root crops to substitute for corn in feed formulations. Its ultimate goal is to augment the income of root crop farmers by creating a stable market for their produce.

The project has these specific objectives: (1) to demonstrate the feasibility of formulating quality feeds using locally available ingredients such as root crops and other raw materials; (2) to provide a ready market for the feed ingredients produced by farmers and fishermen (for the fish meal); and (3) to provide a steady supply of low-cost quality animal feeds to animal raisers in Leyte and neighboring provinces.

This project, which is funded by PCARRD, the National Science and Technology Authority (NSTA), and ViSCA, is implemented by the Ministry of Agriculture and ViSCA. It has two phases: Phase I - full operation of the ViSCA feed mill; and Phase II - expansion of the project throughout Leyte and then to other parts of the country.

Activities for the first year of project implementation include studying the feasibility of substituting root crops for corn in feed formulations, organizing and training root crop farmers from nearby villages, and negotiating with suppliers of other feed ingredients, such as fishermen for the fish meal and businessmen for other feedstuffs. Livestock scientists are responsible for quality control of the feeds and their ingredients.

In the expansion phase, more farmers will be organized and other feed millers tapped. The Ministry of Agriculture, particularly its Bureaus of Animal Industry and Agricultural Extension, are involved to assure continuity after the duration of the project. At that point, root crop producers are expected to have a strong linkage with feed millers.

Processing of cassava is a major problem of the farmers joining this project. Thus, PRCRTC agricultural engineers have been designing and developing village-level processing machines.

Training courses. Some strategies for speedy dissemination of information on cassava production are training courses and workshops. Two national level training courses for this purpose have been sponsored by PRCRTC at ViSCA. In attendance were extension workers from the 13 geopolitical regions of the country. Topics discussed covered all aspects of cassava production. It is also through training that distribution of promising root crop varieties for testing is facilitated.

Root crop farmers also are invited to a series of workshops on root crop production. In the workshops, they are encouraged to actually try new recommended technologies in their fields.

Technology packaging. In support of the national extension program, a project called Technology Packaging for Countryside Development was launched by PCARRD, the Ministry of Agriculture, and ViSCA in cooperation with other agencies.

This project aims to provide farmers with packages of commodity-based technologies that are specific to location and situation, economically feasible, socially acceptable, and environmentally sound. Outputs of this project are bulletins or guides containing all the recommended technologies on production, processing, utilization, and marketing of a crop.

Results of Research and Field Trials

Varietal improvement

After several years of evaluating cassava varieties, PRCRTC has recommended the three varieties listed in Table 4: Kadabao, Golden Yellow, and Colombia. Hybridization using local and CIAT accessions is ongoing at PRCRTC. CIAT F_1 hybrids exhibited excellent performance under Philippine conditions based on initial results of the varietal evaluation. Presently, the selected entries are subjected to single-row and plot trials.

Table 4. **Performance of cassava varieties recommended and released by PRCRTC.**

Variety	Maturity (month)	Yield (t/ha)* Fresh roots	Dry roots	Starch	Alcohol (liters/ha)
PR-C 13 (Kadabao)	10-12	42	14.4	4.9	7560
PR-C 24 (Golden Yellow)	8-10	43	16.9	8.4	7740
PR-C 62 (Colombia)	10-12	46	15.2	7.9	8280

* Average yield computed from results of a series of tests under favorable growing conditions.

Source: Philippine Root Crop Research and Training Center, 1980.

In the initial stage of screening, local hybrids registered yields ranging from 16 to 57 tons/ha under normal field conditions. In the general yield trials, yields obtained ranged from 12 to 51 tons/ha. A number of entries outyielded the check variety (Golden Yellow).

A series of farmers' field trials was conducted during the 1980-82 season using earlier CIAT clones and promising local cultivars. In both highly productive and marginal areas, the CIAT clone CM 323-52 outyielded the local cultivars (Table 5), suggesting that the former can be a potential breeding stock for the improvement of local cultivars.

Twelve cassava varieties (mostly of CIAT origin), six from UPLB and six from PRCRTC,were entered in the Philippine Seedboard trial. Initial yield results from five locations were varied. CIAT-derived material, especially M Col 1684, performed very well in most locations (Table 6).

Cultural management

Intercropping. Some studies have shown that the yield of monocultured cassava declines more over time than the yields of those intercropped with legumes. However, in a PCARRD intercropping study, monocultured cassava consistently gave higher yields than those intercropped with legumes (Table 7). While the productivity of cassava declined by 21% upon intercropping, the profitability of this system is higher than that of monoculture. Among the cassava-legume combinations, intercropping with bush beans gave the highest average profit (Table 8). Intercropping with legumes generates additional income while maintaining the productivity of the land.

Crop rotation. When traditional cassava varieties were rotated with legumes, the yield of cassava increased by 14-38% (Table 9). Intercropping

Table 5. **Yields of cassava varieties received from CIAT and local varieties in farmers' field.**

	Yield (t/ha)	
Entries	Fertile soil	Poor soil
M Col 1684	39.2	13.5
CM 323-52	41.6	32.8
CMC 40	26.0	16.9
Colombia	26.2	-
Golden Yellow (local check)	28.0	17.4
Kadabao (local check)	23.6	11.7
Average	30.8	18.5

Source: Philippine Root Crop Research and Training Center, 1984.

Table 6. **Results of the Philippine Seedboard regional trials for cassava.**

Entries	Yield (t/ha) 1982-83			Yield (t/ha) 1983-84		
	Leyte	La Granja	UPLB	USM	Leyte	Average
Bogor 397	29.2	25.8	54.3	43.5	43.6	39.3
CM 308-197*	11.6	20.3	30.8	42.5	20.3	25.1
CM 323-52*	37.3	-	-	51.1	26.2	38.2
CMC 40*	50.9	18.1	32.2	42.0	-	35.8
Datu I (check)	25.1	32.0	27.9	41.2	41.2	33.5
G 50-3	-	-	-	80.2	49.2	64.7
Golden Yellow	25.4	26.9	29.5	32.9	13.4	25.6
M Col 1684*	36.5	39.0	-	48.1	31.3	38.7
M Mex 59	27.2	-	25.2	-	23.2	25.2
MPTR 26	-	17.2	27.8	22.9	19.0	21.7
M Ven 218	27.4	21.0	29.5	41.1	22.8	28.4
Vassourinha	24.2	24.3	20.8	34.0	29.8	26.6
Java Brown	27.6	-	24.3	47.8	-	33.2
CV (%)	16.3	21.0	18.6	26.5	19.2	

* CIAT-derived material.

Source: Philippine Seedboard regional yield data, 1984.

Table 7. **Yield (t/ha) of cassava as affected by inoculated and uninoculated legume intercrops.**

	Treatments	Number of croppings					
		1	2	3	4	5	Mean
With inoculation	Mung bean	12.6	32.23	21.89	22.61	20.01	21.87
	Bush bean	14.2	31.73	28.40	20.68	25.93	24.19
	Soybean	13.0	30.50	27.79	21.04	21.16	22.69
	Mean	13.2	31.49	26.03	21.44	22.37	22.91
Without inoculation	Mung bean	13.3	30.10	20.66	22.72	13.56	20.07
	Bush bean	11.6	31.80	20.86	21.77	26.80	25.57
	Soybean	11.5	28.76	29.02	21.01	17.53	21.56
	Mean	12.1	30.22	23.51	21.83	19.29	21.40
Monoculture		14.3	39.37	35.60	28.40	22.30	27.99

Source: Escalada et al., 1983.

Table 8. **Economic analysis (per hectare per cropping season) of cassava-legume intercropping.**

Intercropping schemes	Gross income (pesos)	Cost of production (pesos)	Net income (pesos)
Cassava + inoculated mung bean	9892.20	2899.70	6992.50
Cassava + uninoculated mung bean	9208.60	2849.20	6359.40
Cassava + inoculated bush bean	13092.00	3144.70	9947.30
Cassava + uninoculated bush bean	12244.00	3094.70	9149.30
Cassava + inoculated soybean	11049.00	2876.70	8172.30
Cassava + uninoculated soybean	10513.00	2826.70	7686.30
Cassava monoculture	9524.00	2669.70	6854.30

Pricing: Cassava roots - p0.40/kg
Mung bean (shelled) - p6.00/kg
Bush bean (green pods) - p2.00/kg
Soybean (shelled) - p5.00/kg

US $1.00 = p14.00.

Source: Department of Agronomy and Soil Science, Visayas State College of Agriculture, 1982.

Table 9. **Yields of cassava rotated with different legumes.**

Rotation scheme	Yield (t/ha/cropping)	Difference over monoculture (t/ha)	Increase over monoculture (%)
Cassava - mung bean	20.53	2.53	14.06
Cassava - bush bean	22.84	4.84	26.88
Cassava - soybean	22.58	4.58	25.44
Cassava - peanut	24.92	6.92	38.44
Monoculture (without rotation)	18.00	-	-

Source: Department of Agronomy and Soil Science, Visayas State College of Agriculture, 1982.

with peanuts gave the highest yield and net returns. However, under this cropping system, the yield of cassava decreased in subsequent croppings, despite the incorporation of legume residues, although rotations were still more profitable than monoculture.

Fertilizer application. The general fertilizer recommendation for cassava in the Philippines is 60-60-60 kg/ha of N-P-K. However, lower rates are recommended in highly productive environments.

Hillside farming. Cassava showed varied responses to different tillage practices in hillside farming. Yields in the tilled plots were higher than in untilled plots (Table 10), although cassava still gave a relatively high yield in untilled plots owing to the high organic matter in newly opened areas.

Table 10. **Yields of cassava (t/ha) under continuous cropping on hillsides using different tillage practices.**

Tillage practice	1981	1982	Average
None	24.85	27.54	26.2
Minimum (within-row tillage)	26.98	28.99	28.0
Strip tillage			
25 cm wide	26.04	26.36	26.2
50 cm wide	28.71	28.38	28.5
75 cm wide	27.69	26.49	27.1
Tillage of entire plot	29.50	28.21	28.9

Source: Philippine Root Crop Research and Training Center, 1982.

Evaluating tillage practices has shown that plowing and harrowing only once is as good as doing them twice. The best post-planting practice is tilling 2 weeks after planting, hand weeding within rows, and hilling-up 4 weeks after planting.

Seedpiece production. Villamayor (1982b) found that cassava cuttings derived from plants under high population density performed similarly to those taken from plants under low population density. Table 11 shows that different diameters of stem cuttings do not influence the yield potential of cassava.

Plant protection. Cassava bacterial blight (CBB) caused by *Xanthomonas campestris* is commonly observed in the Philippines. However, this disease has not been reported to cause heavy damage. Cultural control including crop rotation, intercropping, clean planting materials, and use of resistant varieties are recommended to minimize this disease.

Spider mites (*Tetranychus telarius* L. and *Tetranychus kansawai* Kishida) have been observed to cause considerable defoliation of cassava during summer months (Bernardo and Esguerra, 1981). Integrated pest control management involving the use of resistant varieties and chemical control has been recommended to reduce or control mite population.

Hand weeding is the most practical method of weed control, especially when labor is cheap. Thorough land preparation to allow weeds to germinate is recommended. When labor is limiting, chemical control is more practical. A pre-emergence or pre-plant spray followed by paraquat 3 to 4 months after planting has been found to effectively control weeds.

Table 11. **Yield evaluation of cassava (Golden Yellow) from stem cuttings produced under different population densities harvested at 6.5 months, 1981.**

Source population (plants/ha)	Stem diameter (cm)	Germination (%)	Root yield (t/ha)	Harvest index
13,333	1.66	99	24.4	0.50
17,777	1.42	92	24.1	0.47
26,666	1.36	90	24.8	0.49
53,333	1.06	97	24.3	0.46

Source: Philippine Root Crop Research and Training Center, 1982.

Storage, processing, and use

PRCRTC has developed a practical village-level storage technique for cassava. It was observed that burying newly harvested roots in the soil for 3 months did not affect root quality, and pruning the cassava plants 2 to 3 weeks before harvest significantly reduced vascular discoloration and delayed the incidence of decay for a week (Data et al., 1983).

The Center has also designed low-cost implements for processing cassava into chips. The chips are then dried using solar dryers developed by PRCRTC. Cassava can also be preprocessed into dehydrated cubes for storage before being used as an ingredient in some snack items.

A technique to manufacture soy sauce from cassava and sweet potato flours has been developed by PRCRTC. The product, which is officially named Root Soy Sauce, is presently being marketed in a pilot phase. Other products are being developed from cassava and processing techniques are undergoing refinements.

Studies on cassava use in poultry feed showed that 85% cassava meal plus 15% soybean meal in the feed ration approximates the feed value of corn. Incorporation in the feed of up to 30% cassava (60% replacement of corn) has been generally suggested for broilers. Cassava can totally replace corn in pellet feeds. More recent studies have shown that cassava can replace corn to as high as 80-100% in rations for layers, and yellow cassava in the poultry ration increases the yellow pigmentation of the yolk.

Initial findings from ongoing research reveal that cassava can completely replace corn in the diet of growing-finishing pigs. However, for younger pigs, a maximum replacement of corn to the 70% level is recommended. Feed consumed in pellet form improved feed intake, weight gain, and feed conversion efficiency in the pigs. The carcass quality of pigs fed with cassava is as good as that of corn-fed pigs.

Potential Production

The current national average yield of cassava is only 8.86 tons/ha. However, with the introduction of high-yielding varieties and proper management practices, it is hoped that the yield can be increased to about 15 to 25 tons/ha. Such an increase would be very significant to the economy.

This projection, however, should be coupled with a stable market for the product. Any increase in crop productivity is meaningless, in fact a burden, to the farmer if a market for his produce is uncertain. Development-oriented agencies, both government and private, should design strategies to maximize use of products the farmers are willing to market.

With the attention given to cassava by the research community and national policymakers, it is hoped that productivity of the crop will increase dramatically in the next few years, and that the cassava industry will become a major income generator for the farmers and for the country.

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Improving the Productivity of Cassava in Thailand

Sophon Sinthuprama
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Production

In the past, the main cassava area was east of the central plain region. Today, the major cassava area is in the northeast region which accounts for 60% of the total area, followed by the central plain region occupying 37%, and the north region occupying 3%.

Edaphic and climatic conditions

In both major cassava-growing regions, the normal period of the rains (over 100 mm/month) is May to October. Both regions are predominantly dry for 6 consecutive months (November to April), receiving less than 100 mm rainfall per month (Table 1).

In Thailand cassava is grown on gray podzolic soils. The soils are highly leached with low base saturation (35-50%) and low amounts of N, available P, and K. They are light in structure and moderately to excessively well-drained. Available moisture storage ranges from 60-80 mm per meter of soil. The pH is 5.0-6.0 in the surface soil and decreases with depth. The pH of the subsoil ranges from 4.5-5.0 in the subsurface to as low as 3.8-4.0 at the lowest depth.

Cultivars

Virtually all the cassava area, 1.2 million hectares, is planted with a single genotype, Rayong 1. All evidence shows that it is a typical farmers' cultivar. It is basically high-yielding and its flexibility under sub-optimal conditions is striking. It is not an ideal cultivar for early harvest (needing 12 months or more) and so it is not suitable for relay or sequence cropping systems. Rayong 1 is one of the most important factors in successful cassava production in Thailand.

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Table 1. **Monthly annual rainfall and percentage of total cassava planted and harvested areas, 1975.**

Month	Rainfall (mm)	Planted (%)	Harvested (%)
January	5.2	4.15	7.01
February	18.6	8.22	11.81
March	42.1	11.25	14.41
April	77.4	14.99	18.91
May	180.3	18.53	7.82
June	175.5	14.61	6.56
July	178.5	5.96	4.96
August	200.5	3.81	4.23
September	290.1	2.03	1.86
October	110.0	2.90	4.62
November	17.9	7.46	13.55
December	2.4	6.08	4.26

Sources: Meteorological Department and Agricultural Economic Division.

Cropping practices

Production systems. Most cassava is grown continuously as monoculture without rotation or fallowing. Intercropping of cassava is practiced to a very limited extent, with corn (maize) in the upland and with young coconut or rubber in the lowlands.

Land preparation. On small farms, land is usually prepared by animal power at the beginning of the rainy season. On large farms, land preparation is done by tractor. Plowing is done as soon as possible after the harvest of the previous crop. A major problem in land preparation is the lack of tractors, which often results in delayed planting.

Stake preparation and storage. Planting material is obtained from plants 8-12 months old and is normally stored for less than 30 days, depending on the rain. Longer storage tends to affect the quality of the stakes, resulting in poor germination and initial growth. Generally stakes are not treated with chemicals.

Planting. Cassava is planted all year round. A survey in 1975 showed that 59% of the crop was planted in March to June, 15% in the heavy rains of July to October, and 26% in the dry season (Table 1). The reasons for planting cassava in the late rainy season and the dry season are to minimize weed problems, higher prices because of higher starch content, high demand from buyers, and probably to avoid competition with rice for labor.

Replacement of ungerminated stakes is usually done within 30 days after planting. Low germination, especially in dry season plantings, demands high labor cost for replanting.

Soil. Since cassava is rarely fertilized, one of the most serious field problems is declining soil fertility. One field trial on Sattahip soils revealed that the cassava yield of unfertilized plots had declined steadily from 30 tons/ha in 1955 to 17 tons/ha in 1971. The yield decline was similar on Huai Pong and Korat soils (Table 2). Incorporation of organic manure before planting, or application of chemical fertilizer 1 to 2 months after planting is occasionally practiced. Fertilizer costs are very high. Growing cassava on steep slopes tends to increase soil erosion, and in the long run, soil devastation caused by erosion may be the most serious problem.

Weeding. Cassava is susceptible to competition with weeds, especially at early growth stages. Failure of timely weeding can cause a total harvest loss. Weed control is traditionally done by animal and human labor. Labor for weeding accounts for about 40% of the total labor used, thus representing a major part of production cost.

Harvesting. Cassava is harvested all year round. The peak harvesting period is February to May, accounting for 53% of the total crop production. It is harvested less during the heavy rainy period of July to October due to low starch content, low price, and low demand from chip factories. Cassava yields progressively increase during the 6th to 18th month of growth. Harvest age varies from 7 to 14 months after planting, but most crops are harvested at 12 months.

Biological Yield Constraints

Cassava bacterial blight (CBB) caused by *Xanthomonas campestris* pv. *manihotis* is the only major disease of cassava that is widespread in the country. Rayong 1 is moderately susceptible to CBB; however, it is not well known how CBB affects cassava yield. Brown leaf spot caused by *Cercosporidium henningsii* and mites (*Tetranychus truncatus*) are commonly observed but their effects on yields are not well understood.

Cassava is presently threatened by only a small number of diseases and pests. However, this is no guarantee for the future because of the dynamic nature of biological yield constraints. The present situation of more than 1 million hectares planted with one single genotype is extremely vulnerable to any change in the disease and pest situation. Diversification of cassava genotype is important and great care should be taken to avoid accidental introduction of diseases and insects.

Table 2. **Yield of cassava (t/ha) from unfertilized plots in field experiments, 1955-1971.**

Year	Sattahip	Soil series Huai Pong	Korat
1955	30	-	-
1959	25	-	-
1963	23	27	-
1967	21	24	25
1971	17	20	21

Source: Soil Science Division.

Research Description and Objectives

The national average cassava yield is 14 tons/ha, which is low compared with experimental yields of more than 40 tons/ha in Thailand or 50 tons/ha or more at CIAT. There are clones with much higher dry matter content in the roots than Rayong 1, and so there is still much scope for yield improvement through breeding and cultural practices.

The number of cassava research personnel has gradually increased in the past and today, a total of 17 researchers are working full-time with cassava: 6 with varietal improvement, 4 in cultural practices, 5 in soil science, 1 in pathology, and 1 in entomology. There are others who work part-time on regional trials at different research stations around the country.

Varietal improvement

Germplasm introduction. Before 1960, some 20 cultivars were introduced (probably from Malaysia, Java, and Mauritius). From this stock, Rayong 1 was developed. More clones were introduced during the 1960s, from Java in 1963 and the Virgin Islands in 1965. In 1970 clones from CIAT were first introduced and introduction of other germplasm, such as seed populations from improved parent stock and hybrid clones from meristem cultures, has continued since that date.

Germplasm introduced from CIAT contributed to increased genetic variation. Many crosses were made yearly between Thai and CIAT clones, supplemented by a smaller number of crosses between Thai clones. Also, many hybrid seeds from CIAT have been directly incorporated into testing programs. From CIAT hybrid seeds introduced in 1975, two cultivars were developed: Rayong 3 from a CM 407 cross, and HP 6 from a CM 305 cross.

Rayong 1. Cassava breeding research began with the collection of local cultivars throughout the country and their systematic evaluation in 1956 at the Huai Pong Field Crop Experiment Station, Rayong Province. Not many genotypes were collected, and the leading cultivars from several locations subsequently were identified to be the same genotype. It was called local Rayong and used in comparison with introduced cultivars. It appeared that local Rayong had higher yields than all the introduced cultivars from Java, the Virgin Islands, and CIAT. This cultivar was later named Rayong 1 by the Department of Agriculture.

Breeding program. A breeding program based on open-pollinated seeds from Rayong 1 and introduced cultivars began in 1971. Not much was gained from the selections of open-pollinated seed. Controlled hybridization was started in 1975 by using limited germplasm from Java, the Virgin Islands, and CIAT. With the return of researchers trained at CIAT since 1977, the breeding program at Huai Pong Station began to form the core of the national program.

The major objectives of the cassava breeding program are:

- high yields, in terms of dry matter and starch
- early harvest
- diversification of germplasm, including resistance to major biological yield constraints

Breeding for high-yielding cultivars is focused on cultivars with high yields, high harvest indexes, and high root dry matter. High-yielding cultivars will contribute to higher productivity, hence lowering the cost of production and achieving more competitiveness with feed grains. Higher dry matter content will lead to higher values for roots and lower processing costs.

Breeding for early harvesting will increase the opportunities for better land use, cropping systems, and crop rotation to avoid soil erosion. Resistance to CBB and mites, as well as compatibility with various intercrops, are other targets of the breeding program.

Varietal testing. The Thai cassava research program includes every step of varietal improvement: germplasm collection, hybridization, F_1 seedling trial, single-row trial, preliminary yield trial, standard yield trial, regional trial, and on-farm trial.

From 15,000 to 20,000 F_1 seedlings are evaluated every year and about 10% of the plants are selected for single-row trial. From 10 to 20% of these are selected yearly for further trials. All the trials up to the preliminary yield trial are conducted at Huai Pong Station. Standard trials are planted in three major stations and regional trials are scattered throughout the major cassava-growing areas. While the majority of the experiment stations are located in areas of fertile soil, the soil fertility at Huai Pong Station is generally low so that it represents the majority of cassava farms.

Promising clones from regional yield trials, usually three to five, are tested in farm trials. Although the trials are conducted by using farmers' land and labor, the management input is borne by the researchers. The number of trials depends on the resources available.

The best clones are compared with the farmers' crop in farmers' fields using farmers' practices. Many large plots are required and extension workers participate in the evaluation. The best material is named and released by the Department of Agriculture.

Agronomic practices

The objective of research on cultural practices is to develop technology leading to high and stable production using the best available cultivars. The major recipients of the technology are small farmers, thus, the technology must be so designed that the mass of small farmers can afford it.

The principal components of study are land preparation, quality of planting material, planting time, planting methods, plant population, replanting, weed control, leaf production, stake multiplication, harvesting, and postharvest handling.

Soil fertilization and conservation research aim at increasing or conserving soil fertility to obtain as large an economic yield as possible and maintain it. Rotation experiments aim at controlling water erosion and returning the nutrients removed by the crop or leached out by drainage water back into the soils.

Cropping system research is designed to develop practices for soil nutrient conservation and soil erosion control. The research emphasizes intercropping cassava with legumes. Studies have been conducted to find the best legumes to grow in association with cassava with minimum reduction of cassava yield, minimum input to the system, and economically valid returns.

Weed control research is designed to find the best practices for controlling weeds in cassava production and to avoid labor competition during the time it is needed.

Research Findings

Varietal improvement

Rayong 1 is basically a farmers' cultivar. However, it was collected, selected, purified, named, and recommended by the Department of Agriculture. It is a high-yielding cultivar with a moderately high harvest index. Production of a high-quality stake and good sprouting under water-deficient conditions makes this cultivar highly versatile. Data from CIAT suggest that Rayong 1 is superior to many local Colombian cultivars under conditions similar to the Thai cassava-growing area.

Rayong 3 was selected from the CIAT seed population brought in 1975 and released by the Department of Agriculture in 1984. It has a higher starch content than Rayong 1, but fresh root yields are similar. Dry chip and starch yield of Rayong 3 can be higher than Rayong 1. Rayong 3 performs best on fertile soil and with intensive care.

HP 6 is another cultivar derived from CIAT material introduced in 1975. It is good for making fried chips and other table use.

Currently, the best selection sources are the crosses between Thai and CIAT clones. They are particularly good for early harvest. Some selected hybrid clones are outyielding Rayong 1 by 50% at 7 months. At 12 months, some new clones are yielding 20-40% higher than Rayong 1. Success of these clones ultimately depends on their flexibility in farmers' fields.

Agronomic practices

Land preparation. Preliminary studies indicated that land prepared with preemergence herbicide application but without plowing gave a similar cassava yield to the yield on traditionally prepared land, which includes one plowing by tractor plus furrowing by animal. The minimum tillage concept may be introduced to protect the soil from erosion and to reduce labor costs.

Stake storage and size. Cassava stalk storage studies showed that the survival rate of stakes taken from stalks stored up to 30 days in the field was higher than 80%. Storage under shade tends to be a better method than storage under the sun (Table 3).

Planting method. Yields were not significantly affected by stake lengths in the range of 10-30 cm, even though shorter stakes gave a lower survival percentage. Root yields were not different for cassava planted on ridges, flat ground, or flat ground followed by earthing up 30 days after planting. Horizontal planting gave lower yields than vertical, mainly due to lower survival rate in the former. Vertical or inclined planting were not different in yields. Depth of planting (5, 10, 15 cm) had no effect when plantings were either vertical or inclined.

Planting time. Studies on planting time and age of harvest carried out for 3 years from 1976 to 1978 indicated that root yield was the highest with June plantings and decreased with plantings after June (Table 4). Root yield increased with age of harvest from 8 to 18 months.

Fertilization. Fertilizer trials showed that cassava tended to respond most sharply to N, moderately to P, and less significantly to K. In one experiment, root dry matter yield responded positively to 90 kg/ha each of

Table 3. **Survival percentage of plants from stakes stored under different conditions and for various periods, 1976-78.**

Storage (days)	Storage conditions: Under shade (%)	Open (%)	Covered with leaves (%)
0	95.61	95.31	96.50
15	93.47	93.38	91.60
30	83.39	84.28	87.89
45	80.02	55.98	58.36
60	57.50	48.86	50.03
75	49.23	31.96	43.11
90	44.90	28.94	35.87
105	43.19	21.03	22.09

Source: Field Crop Research Institute.

Table 4. **Effect of planting time and harvest age on yield (t/ha), 1976-78.**

Planting date	Harvest age (months): 8	10	12	14	16	18	Mean
May	20.27	26.98	36.49	42.46	49.52	57.06	38.76
June	22.15	27.73	36.51	47.31	51.93	53.36	39.83
July	19.82	29.07	35.07	40.74	44.05	48.51	36.21
August	14.46	22.96	29.14	38.62	39.57	43.68	31.41
September	12.25	17.64	28.65	32.48	34.59	36.26	26.98
October	8.16	16.69	22.17	23.95	29.52	32.61	22.18
Mean	16.18	23.51	31.33	37.56	41.53	45.25	

LSD (0.05) for planting date x harvested age = 4.92 (t/ha)

Source: Field Crop Research Institute.

N, P_2O_5, and K_2O; beyond that level the response gradually decreased until at very high levels the response was markedly negative (Table 5). Broadcasting, banding under the stakes, or side placement at 20 or 50 cm were found to be equally good fertilizer placement methods.

The long-term effects of fertilization on three types of cassava soils have been studied since 1975. The influence of compost at the annual rate of 12.5 tons/ha plus incorporation of crop residue (stem and leaf) on root yield seem to be significant. It was concluded that higher root yield of cassava could be achieved by the yearly application of 50 kg/ha each of N, P_2O_5, and K_2O, and that further response could be obtained if compost or crop residue was incorporated before planting.

Rotation. Long-term rotation experiments in three research stations showed that in all rotation patterns of cassava/peanut and cassava/mung bean, cassava yields were higher than cassava without rotation in the 5th and 6th crop year. There was a slight increase in soil organic matter after 6 years of rotation.

Intercropping. Studies on land use efficiency and restoration of soil fertility through intercropping have been studied using peanut, mung bean, and soybean since 1970. The most promising intercropping systems appeared to be combinations of cassava/peanut and cassava/mung bean. Although cassava and legumes were shown to be competitive, up to 170% combined economic yield relative to cassava monoculture was demonstrated. This was also confirmed on farms with large plots.

Weed control. Weed control research showed that Diuron, at the rate of 1.5 kg/ha, causes no crop injury for either vertical or horizontal planting methods. This practice is as effective as three hand-weedings.

Table 5. **Effect of fertilization rate on yield.**

Rate of N - P_2O_5 - K_2O (kg/ha)	Fresh root (t/ha)	Dry root (t/ha)
0-0-0	21.36	7.59
93.7-93.7-93.7	34.49	10.48
187.5-187.5-187.5	38.88	10.44
375-375-375	40.61	10.28
750-750-750	32.60	7.17

Source: Soil Science Division.

Directions in Cassava Research

Varietal improvement programs have two major objectives:

1. Diversification of the germplasm base to include early maturity, drought tolerance, and resistance to diseases and pests.

2. Attainment of higher yields to gain better competitiveness.

Agronomic research will continue to define the most economically valid cultural practices. More emphasis will be placed on soil nutrient preservation and erosion control. Intercropping, crop rotation, improved soil preparation, and minimum tillage are the immediate research topics.

Most agronomic studies in the past have been conducted using Rayong 1. Thus, as soon as new promising clones emerge, cultural practices for possible new cultivars will have to be redefined. The agronomic studies have tended to be too sporadic to represent the vast area of Thai cassava production, and therefore, a more coordinated research network will have to be devised.

The program as a whole needs more economic studies to evaluate the socioeconomic relevance of research findings, which would lead to improvements in the welfare of the mass of cassava growers.

Potential Production

Practically, the only important market for Thai cassava is the European Economic Community (EEC), which absorbs nearly the entirety of Thai cassava exports (93% in 1980). The EEC has set a quota of 4.5 million tons for 1983-1984 with further possible reductions in the future. Within the quota, cassava products can enter the EEC market at the current preferential tariff of 6% and beyond the quota it will be subject to a 30% tariff and open competition with feed grains.

To comply with the Thai-EEC agreement, the cassava economic zone was established in February, 1983, by the Ministry of Agriculture and Cooperatives. This will lead to control of area, prices, and quality of cassava roots and root products, thus preserving the benefits to the farmers. The government is also searching for new markets other than the EEC. In addition the government and the private sector are trying to find alternative uses for cassava.

Production of cassava will have to be decreased if exports are limited by the current preferential arrangement with the EEC. Cassava growers in the economic zone will receive government support. The growers outside the zone will be encouraged to replace cassava with substitute crops. Studies are underway to find crops to replace cassava in these regions.

The future of cassava production depends on the markets, and the markets depend on production cost. If no improvement in production efficiency is expected, there is not much hope of improving cassava's competitiveness in international markets. Production will be at the mercy of the EEC policy. If the price of cassava products can be significantly reduced through improved production efficiency, there will be increased chances of creating new export markets.

Improved cultural practices have been shown to considerably increase yields when tested in farmers' fields. While timely planting, good selection of plant stakes, and opportune weeding are part of the technology, fertilization is in many situations the most effective component, but also the most costly. Yield increases by increased fertilizer application may not necessarily lead to a substantial cut in production cost. Hence, improving production efficiency through cultural practices is not very promising. Thai farmers prefer to adopt new cultivars in hope that higher yields can be attained without large additional costs.

Yield increases through new cultivars will not be realized in the immediate future. Rayong 3 offers higher starch content, but, it may not replace Rayong 1 over large areas because the total dry matter yield of Rayong 3 does not greatly exceed that of Rayong 1. However, there are a number of promising hybrid clones with high yield and early maturity being developed. It will take some time before any of these pass to the production fields. Whether we can obtain new clones whose yielding capacity is sufficiently high to significantly reduce the production cost depends on future work.

Higher-yielding cultivars may help farmers to withdraw cassava from erosion-threatened areas, and early cultivars can contribute to better land use through better cropping systems and crop rotation to avoid soil erosion.

CIAT Germplasm in Asian Cassava Research Programs

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Introduction

Cassava is one of the most efficient producers of carbohydrates in the tropics (de Vries et al., 1967; Martin, 1970; Nojima and Hirose, 1977; Kawano et al., 1978; Cock, 1982) and under marginal soil and rainfall conditions it is unsurpassed by other crops (Cock and Howeler, 1978). It is grown throughout the tropics by small farmers in areas with poorer soils using traditional methods of cultivation. Cassava is the fourth most important crop in terms of dietary energy produced and consumed within the tropics (Table 1). More recently it has been used increasingly for animal feed and industrial starch. The importance and potential of cassava, however, has been largely neglected when compared with other crops, as can be seen from the data in Table 2.

Cassava originated in Latin America and most of its evolution took place there. It was widely distributed throughout the lowland tropics of Latin America before the arrival of the Europeans in the 15th century, but did not exist outside the continent. However, in the post-Columbian era, the crop spread rapidly, first to Africa and later to Asia.

Germplasm variation of a crop species is richest in the center of origin and diversification of the species. Evolution of disease and pest species that thrive on a crop parallels the evolution of the crop species, thus, the number of biological yield constraints is highest in the center of crop origin and diversification (Jennings and Cock, 1977).

True to the theory, nearly the entire germplasm variation of cassava exists in Latin America; the African and Asian germplasm consists of a

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Table 1. **Calories from major staples used for direct human consumption within the tropics.**

	Calorie consumption Billions of calories per day		Tropics % of world
	Tropics	World	
Rice	924	2043	45
Sugar	311	926	33
Maize	307	600	51
Cassava	172	178	97
Sorghum	147	208	71
Millet	128	204	63
Wheat* less than	100	1877	5
Potato	54	434	12
Banana	32	44	73
Plantain	30	30	100
Sweet potato	30	208	14

* Wheat figures are distorted by the fact that major production zones in Brazil, Mexico, and India are outside the tropics and have been adjusted to account for this.

Source: FAO Food balance sheets, 1975-1977

Table 2. **Research expenditure as a percentage of commodity value for various crops in Asia (excluding China and Japan), 1959 and 1974.**

Crop	% of product value expended on research	
	1959	1974
Cotton	0.43	0.58
Rubber	0.40	0.57
Sugarcane	0.10	0.24
Wheat	0.08	0.23
Maize	0.06	0.12
Rice	0.05	0.12
Sorghum and millets	0.04	0.11
Pulses	0.02	0.06
Roots and tubers	0.01	0.03

Source: R.E. Evenson (1978). The organization of research to improve crops and animals in low income countries. In *Distortions of agricultural incentives,* edited by T.W. Schultz, Indiana Univ Press. 233-245.

part of the Latin American germplasm and its local recombinants. A broad spectrum of diseases and pests is found in Latin America, while the number of diseases and insects is less in Africa and especially in Asia. African mosaic disease seems to be the only major disease of cassava that does not exist in Latin America.

This background makes Colombia, South America, a logical location for an international center of cassava research. A cassava program was established in the early 1970s at the Centro Internacional de Agricultura Tropical (CIAT) in Cali, Colombia. The importance of African mosaic disease and the overwhelming importance of cassava to the African diet led to the establishment in the late 1960s of the Cassava Program of the International Institute for Tropical Agriculture (IITA) at Ibadan, Nigeria, with the regional responsibility in Africa.

The CIAT Cassava Program seeks to develop improved technologies in support of increased production efficiency and utilization of cassava. New production technology is based on improved germplasm with increased yield potential and tolerance to diseases, insect pests, and adverse soil and environmental conditions. Additional constraints are minimized through the development of low-input management practices. Training and communication to make the developed technology more readily available are important parts of the program.

Characteristics of Available Technology

The CIAT germplasm collection, which now comprises more than 3,000 traditional cultivars, is the major vehicle with which the technology is transferred to the national programs.

The goal of varietal improvement is to provide cassava genotypes that give high, stable, and economically valid yields using cultural practices that are within the reach of farmers for major cassava-growing areas. During the past 10 years, significant improvement has been made in the yield capacity of advanced materials both under favorable and stress conditions (CIAT, 1982 and 1983).

Yield stability across geographical areas (wide adaptability) may not be important to individual farmers; however, this is an important measure of the validity of technology developed by international or national programs for other areas. A hybrid clone, CM 507-37, which is now frequently used in hybridization, is a good example, showing a yield superiority over local cultivars in widely different locations in Colombia with average temperatures of 24-28°C (Figure 1). Many selected clones have shown a similar tendency, suggesting that genotypes carefully selected through a network of regional trials can be adapted to different geographic areas within the same macro edapho-climatic zone.

Lack of yield stability over years has often been a problem with new high-yielding genotypes in several crops. Interactions of crop genotypes with disease and insect populations and adverse environmental conditions

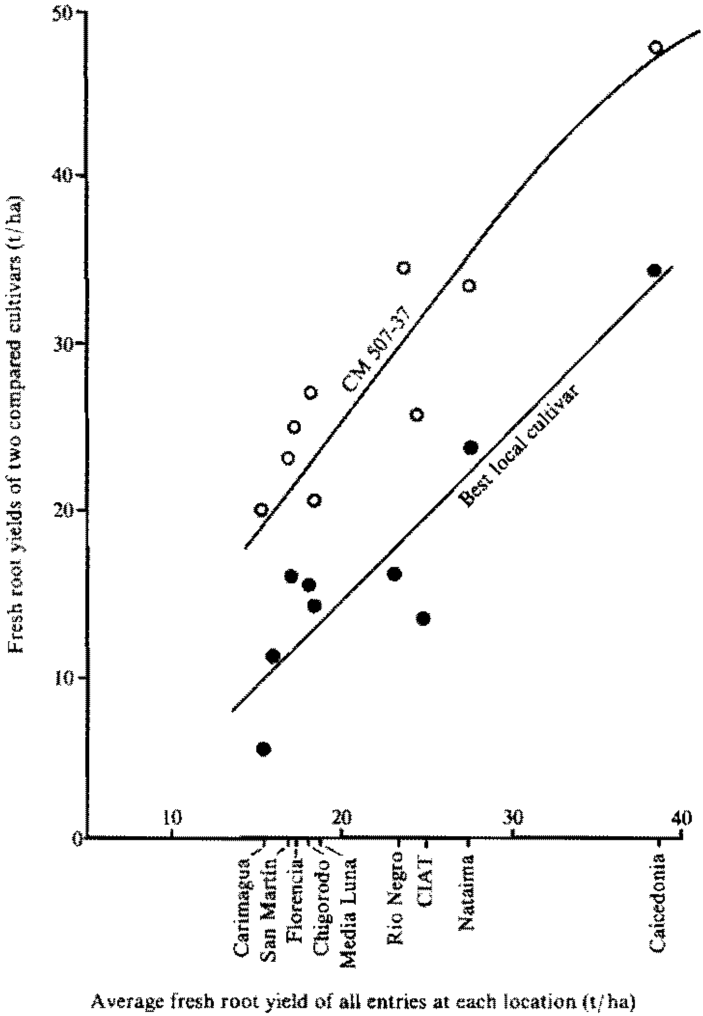

Figure 1. *Productivity of CM-507-37 and best local cultivar at various trial sites.*

such as irregular rainfall pattern are the main reasons for this type of instability. Using the most difficult cassava-growing environment in Colombia (Carimagua in the Llanos Orientales), where the number and intensity of biological problems are highest— the soil fertility is extremely low, and the dry season pressure is high— as one of the basic sites for germplasm selection, has helped to accumulate genes for resistances. The recent CIAT populations contain tolerance to these adverse factors in high frequency while they still maintain large phenotypic variability for other plant characters (Kawano et al., 1983; *Umemura* and Kawano, *1983).*

It has often been observed that genotypes selected under high-input conditions do not perform well under low-input conditions. Similarly, genotypes of many crops selected at well managed experiment stations often do not perform well in farmer's fields (Kawano and Jennings, 1983). By selecting under low-input conditions, and perhaps also owing to the characteristics of cassava germplasm *per se*, these phenomena do not appear to be occurring with the CIAT cassava selections. Selected hybrid clones showed yield superiority over traditional cultivars on farms with varying soil fertilities (Figure 2).

These data do not automatically indicate that CIAT materials perform as well in national programs. They should be understood as an indication of what national selection programs may achieve after incorporating CIAT materials into their breeding systems.

Germplasm Exchange

Introduction of germplasm always involves a combination of potential benefit and potential risk. Benefit may result from increased productivity of a crop. This must be weighed against the risks of accidentally introducing pests or pathogens. Neither the benefits nor the risks are easily assessed.

Three types of germplasm materials, i.e., germplasm accessions, hybrid clones, and hybrid seeds are available from CIAT in the form of (1) stakes, (2) meristem cultures, and (3) true seed. Advantages and disadvantages of each method are summarized as follows: stakes are the easiest to handle but the risk is highest; meristem cultures are less risky and offer reproduction of identical genotypes but are not suitable for transferring a large number of genotypes, and their handling requires certain skill and facilities at the receiving end; seed is the least risky and offers easy handling of a large number of genotypes although the identical genotype cannot be obtained (Kawano and Hershey, 1982). Lozano and Jayasinghe (1982) have described pathological problems disseminated by sexual and asexual propagated materials.

CIAT has been actively distributing germplasm materials for testing and use by national programs. Emphasis in recent years has shifted from sending clonal materials to sending seeds from selected parents. Sending stakes internationally has been totally eliminated by CIAT. As national cassava breeding programs are strengthened, seed will continue to increase in importance as a means of exchanging genetic material. Crosses will continue to be more precisely tailored to the needs of national programs by incorporating feedback information.

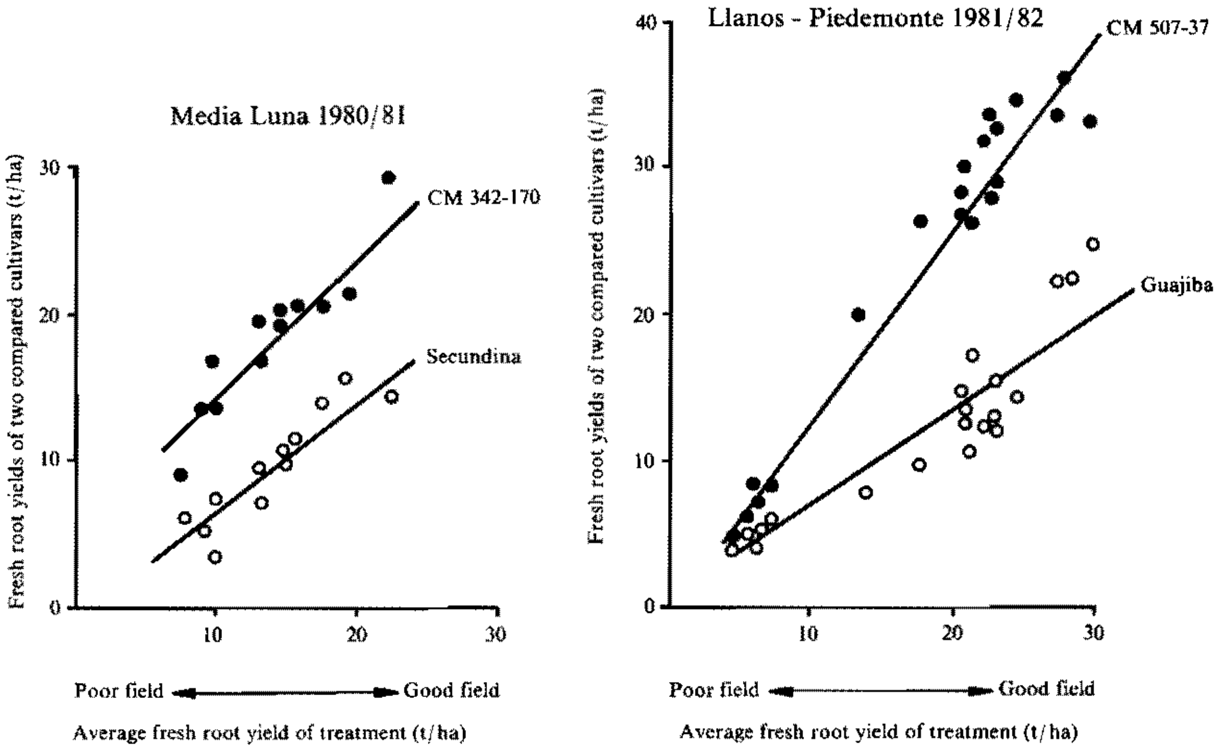

Figure 2. *Results of on-farm trials at two locations in Colombia.*

Source: Cassava economics section, CIAT.

CIAT intends to remain a primary resource for genetic diversity in cassava with the national programs taking an increasing role in local selection and incorporation of improved characteristics into local cultivars.

Regional Program for Asia

The potential for increasing the efficiency of cassava production through research in Asian countries is great, not only because much cassava is already produced in Asia, but also because national research institutions are generally strong and cassava is a vital portion of the national or local agricultural economy in many parts of Asia.

The functions of the CIAT Cassava Asian Regional Program are to:

- Distribute and use CIAT germplasm in Asian national programs through direct participation,
- identify suitable germplasm to be provided by CIAT for Asian programs,
- help develop agronomic practices suitable for Asia with special emphasis on erosion control,
- coordinate efforts between CIAT and national programs with special reference to training and conferences.

As of now, approximately 82,500 hybrid seeds from some 1,600 crosses have been distributed to eight national programs in Asia (Table 3). These are being evaluated at various stages of varietal improvement programs (Table 4). Evaluations of segregating populations and selected clones from these populations enable CIAT to provide hybrid populations more adjusted to the specific requirements of each national program.

Cassava has a reputation of being a soil-devastating crop. Due to cassava's ability to produce reasonable yields on poor soils, it sometimes appears that after cassava the soil cannot be utilized by other crops. Actually, the mineral nutrition requirement per unit yield of cassava is lower than many other crops (Cock and Howeler, 1978), thus, the reputation of cassava as a soil-exhausting crop is debatable. However, partly due to the long period required for canopy establishment, cassava is liable to cause soil erosion; thus, cultural practices for minimizing soil erosion are much needed.

Close coordination with CIAT headquarters in research, training, and communication will enable the national programs to make better use of available technology. Thus, this is also an important part of CIAT's activity.

Table 3. **Number of CIAT cassava F_1 hybrid seeds distributed to Asian program.**

Country	1975	1976	1977	1978	1979	1980	1981	1982	1983	Total
Thailand	900		6170	7720		3050	1400	7450	7900	34590
Indonesia	900		700						4600	6200
Philippines	900		950				5100	4700	5500	17150
China								2300	6100	8400
Malaysia	900		1500		2050	2050	1250	4050	9750	9750
India	900		850					1050	1050	2800
Vietnam									1900	1900
Taiwan	500							1200		1700
Total	5000		10170	7720		5100	7750	19700	27050	82490

Table 4. **Evaluation of CIAT cassava materials in Asian national programs, 1983/1984 (expressed in number of genotypes).**

	Thailand*	Indonesia	Philippines	Malaysia	China
F_1 seedling	14400	3300	4500	3000	2500
Single-row trials	1950		850	330	30
Preliminary trial	164	48	150	66	
Advanced trial	32	23		25	
Regional trial	16	2	6	15	
On-farm trial	5		4		
Multiplication	1		2		
Varietal release	1				

* Most of the good Thai materials are Thai x CIAT type crosses.

Breeding Objectives

In Thailand, nearly 99% of the cassava area is planted with a traditional cultivar, Rayong 1. Preparation of diversified cultivars is recommended for counteracting possible outbreaks of diseases and pests in the future. Early cultivars combined with a short season crop would enhance the total productivity of land. Development of substantially higher-yielding cultivars would decrease the production cost, thus opening new markets for cassava exports outside the EEC without depending on preferential tariff treatment. Higher production efficiency would also enable the reduction of cassava plantings in areas threatened by soil erosion without decreasing the total production.

In Indonesia, cassava is planted over a wide range of environmental conditions and utilized in a variety of ways. In Java, where land is extremely limited and intensively utilized, early cultivars are urgently needed. Since cassava's main advantage lies in its ability to offer inexpensive carbohydrates, higher production efficiency using low-input cultural practices is a highly important breeding target in the long run. Diversification of cultivars is important not only for disease and pest problems but also for adaptation to different environmental conditions and different uses.

In the Philippines, cassava together with sweet potato has been providing inexpensive carbohydrates for the rural poor. Under these circumstances, earliness may be the most important breeding objective. If cassava is to fulfill the new role of substituting for imported feed grains in livestock rations, high yield should be the most important selection target.

In Malaysia, cassava has been a relatively minor crop providing raw material for starch production. Only development of substantially higher-yielding cultivars can change the present status of cassava.

High yield selection from advanced CIAT gene pools would be an intriguing work target, particularly since the real potential of cassava germplasm has not yet been fully exploited. In all these countries, strong demand also exists for cultivars with higher root dry matter or starch content.

Breeding objectives differ from country to country; nevertheless, common important objectives are:

- Substantial yield increases to acquire higher competitiveness with other sources of carbohydrates,
- early maturity to give additional alternatives to the production systems,
- higher root dry matter or starch content,
- diversification of cultivars to gain resistance to diseases and pests.

Present Status of CIAT Germplasm in Asia

Experimental results in Thailand indicate that Rayong 1 is a highly productive, versatile cultivar. Recent data from CIAT showed that Rayong I was superior to most of the germplasm accessions under similar environments in Colombia (Hershey, personal communication). Without doubt, the superior agronomic characteristics of Rayong I were the core of successful cassava production in Thailand. Since Rayong 1 is basically a high-yielding cultivar, it is not easy to outyield it with hybrid selections. Crossings within local germplasm do not seem to have produced anything significantly better than Rayong 1.

Yield improvements on the order of 100% or more over local cultivars, which have been repeatedly demonstrated in Latin America and Africa, may not occur. Nevertheless, some hybrid clones selected from local x CIAT crosses have shown yield superiority over Rayong 1 (Figure 3). Later selections seem to be even more promising (Table 5). Their real utility depends on their flexibility and performance in farmers' fields. For earliness, for which Rayong 1 is not particularly strong, many local x CIAT selections are showing highly promising results (Figure 4).

It has only been recently that CIAT hybrid populations from well defined cross parents were introduced. Crossing Rayong 1 with the best available CIAT genotypes is yet to come. Whether hybrid selections can be made that will give substantially higher yields than Rayong 1 in average farmers' fields depends on future selection. A combination of physiological yield potential with the toughness of Rayong 1 would be ideal.

Since many CIAT cross parents have been screened for a long list of adverse yield factors under high stress environments, CIAT materials can probably provide immediate sources of germplasm diversification. The majority of Thai x CIAT or CIAT x CIAT crosses show better resistance to cassava bacterial blight (CBB) than Rayong 1. CBB is the most widespread disease of cassava in Thailand and can cause significant yield damage. Aside from resistance factors, selection of specialty cultivars such as the newly released Rayong 3 with high starch content or Rayong 2 for table use may prove a wise way of broadening the germplasm base in farmers' fields. Both Rayong 2 and 3 were selected at Huai Pong Station, Rayong, Thailand, from 1974 CIAT crosses.

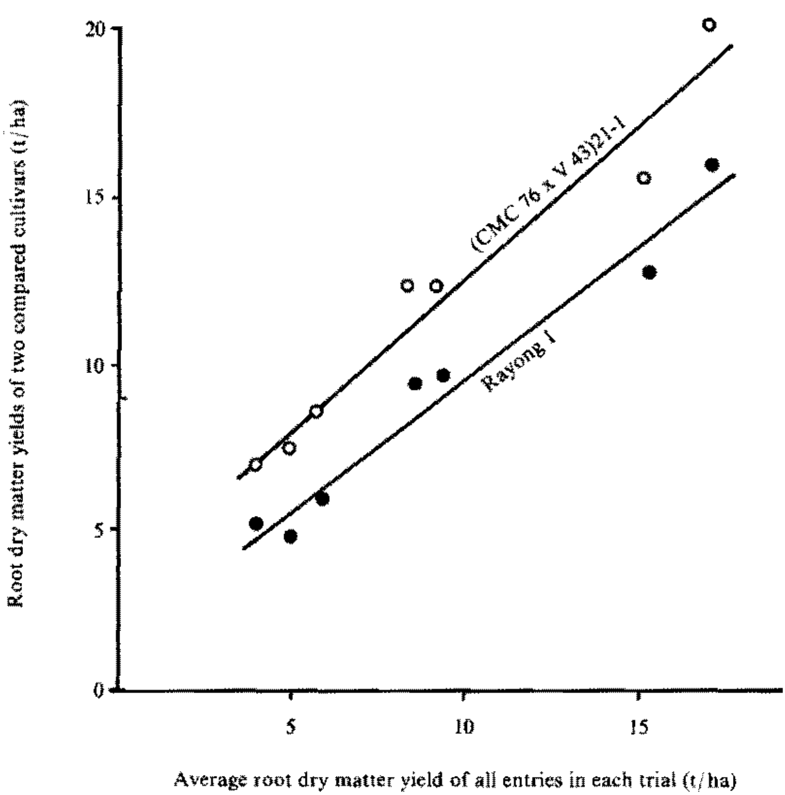

Figure 3. *Productivity of Rayong 1 and promising selection under different environmental conditions.*

Table 5. **Yields of some promising clones in different environments in Thailand.**

Clone[a]	Parents	Root dry yield (t/ha) at: Low-yielding environment (Huai Pong)	Intermediate-yielding environment (Banmai Samrong)	High-yielding environment (Khon Kaen)	Average
OMR 23-29-15	CM 407-14	9.2	11.6	15.1	12.0
CMR 23-128-141	CM 407-9 x CM 309-211	6.6	8.9	13.8	9.8
CMR 23-149-128	CM 407-24 x M Col 1684	7.6	8.6	11.5	9.2
CMR 23-17-251	Kaset x M Col 1684	8.7	5.7	10.6	8.3
Rayong (local)		5.5	6.7	10.1	7.4

a) Crossed in 1980 and selected from 1980-1983 at the Huai Pong Station.

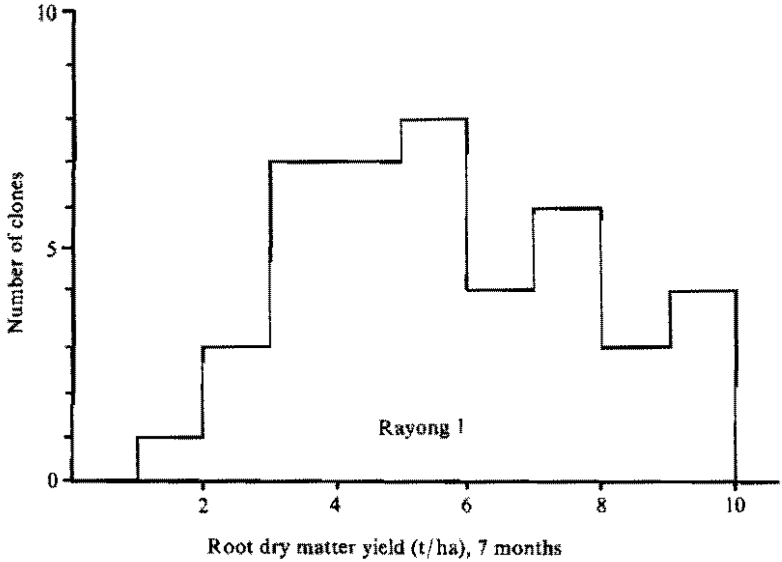

Figure 4. *Results of preliminary yield trial for early harvest, December, 1983.*

Source: Huai Pong Field Crop Research Center, Department of Agriculture, Thailand.

In Malaysia, the leading cultivar Black Twig is basically a high-yielding cultivar capable of yielding up to 50 tons/ha under favorable conditions. Several selections from the early CIAT introductions seem to possess higher-yielding capacity than Black Twig (Table 6); nevertheless, this modest yield superiority may not be sufficient to cause change in production fields. Evaluation and selection of more recent CIAT introductions will indicate whether advanced germplasm introduced from Latin America can offer a yield improvement significant enough to open new horizons for cassava production in Malaysia.

In the Philippines, CM 323-52 and M Col 1684 showed yield superiority over local cultivars (Table 7). These are selections from twelve clones introduced as stakes in the early days of the CIAT cassava program. While the yield superiority of these clones seems to be sound, they are unlikely to be released due to low dry matter content (CM 323-52) and high cyanide content (M Col 1684) in the roots. These data suggest that CIAT germplasm can immediately broaden the scope of varietal selection. However, the chance of obtaining a recommendable cultivar adapted to all the local requirements using only a small number of introduced clones is small. Later selection programs based on massive introductions of CIAT seed populations seem to be highly promising and may lead to the

Table 6. **Results of a cassava regional yield trial at Sitiawan, Perak, Malaysia, 1982/1983.**

Clone	Site of hybridization	Site of selection	Starch yield (t/ha)	Fresh yield (t/ha)	Harvest index
CM 378-17	CIAT	MARDI	8.97	31.6	0.62
CM 621-24	CIAT	MARDI	8.95	34.1	0.56
CM 942-28	CIAT	MARDI	8.78	34.1	0.60
CM 860-25	CIAT	MARDI	8.55	30.2	0.53
CM 845-9	CIAT	MARDI	8.03	28.2	0.53
B. Bengkok 247 (local cross)			7.84	28.4	0.53
CM 845-13	CIAT	MARDI	7.78	27.6	0.48
M Mex 1-20	CIAT	MARDI	7.58	26.3	0.45
Black Twig (local cultivar)			7.51	28.0	0.58
M Mex 1-22	CIAT	MARDI	7.37	26.3	0.49
C5 (local cultivar)			6.87	27.1	0.47
CM 845-8	CIAT	MARDI	6.75	25.9	0.52
B. Bengkok 245 (local cross)			6.43	23.4	0.49
CM 429-9	CIAT	MARDI	4.89	20.3	0.47
CM 845-23	CIAT	MARDI	4.92	18.4	0.40
		Average	7.41	27.3	0.51
		LSD (0.05)	1.45	4.8	0.12

Source: MARDI, Malaysia.

Table 7. **Results of a cassava on-farm yield trial at Dulay, Leyte, Philippines, 1982/1983.**

Clone	Site of hybridization	Site of selection	Fresh yield (t/ha)
CM 323-52	CIAT	CIAT	41.6
M Col 1684 (CIAT accession)		CIAT	39.2
Golden Yellow (local cultivar)			28.0
Colombia			26.2
CMC 40	Brazil	CIAT	26.0
Kadabao (local cultivar)			23.6
		Average	30.8

Source: PRCRTC, ViSCA.

identification of more desirable clones for varietal release. Crossing local cultivars with elite CIAT clones is also a logical alternative.

Indonesia has the longest history of institutional cassava breeding work in Asia. One result from these efforts is the cultivar Adira I, which is a selection from crosses made in 1963 between Indonesian cultivars and released in 1978. It is moderately high in yield and starch content, and moderately resistant to CBB. More recent selections from the Indonesian germplasm appear to be even more promising (Table 8). These clearly indicate that a continuous, well orchestrated program, even though modest in scale, can result in significant progress.

A small seed population (750 F_1 seeds from 15 crosses) in 1977 was the only seed introduction from CIAT to Indonesia until recently. Some selections from this population appear to be promising (Figure 5). Recently, large introductions of advanced seed populations from CIAT have been made, and evaluation and selection of these populations is under way.

Judging from experience gained in these four countries, CIAT germplasm can immediately broaden genetic diversity by offering disease and pest resistance as well as quality characteristics such as high dry matter content. CIAT germplasm seems to be a particularly good source for early maturity. Additional work in coming years on the recent introductions of advanced CIAT germplasm and local crosses with elite CIAT clones will determine whether new cultivars with a substantial yield advantage over currently available cultivars can be obtained.

Distribution of CIAT germplasm to China and Vietnam began only recently. The climatic conditions under which cassava is grown in these two countries are expected to be different and CIAT germplasm has not

Table 8. **Results of a cassava regional yield trial at Moguwoharjo, Jogyakarta, Indonesia, 1982/1983.**

Clone	Site of hybridization	Site of selection	Fresh yield (t/ha)	Harvest index
M-31	CRIFC, Bogor	CRIFC, Bogor	47.4	0.60
W 236-28	CRIFC, Bogor	CRIFC, Bogor	46.2	0.64
M-30	CRIFC, Bogor	CRIFC, Bogor	46.0	0.69
W 236-31	CRIFC, Bogor	CRIFC, Bogor	45.9	0.60
H-7	CRIFC, Bogor	CRIFC, Bogor	39.0	0.58
G. 168	CRIFC, Bogor	CRIFC, Bogor	38.7	0.58
WL 54	CRIFC, Bogor	CRIFC, Bogor	34.6	0.54
Adira I (Recom. cultivar)	CRIFC, Bogor	CRIFC, Bogor	31.1	0.62
CMC 84 (CIAT accession)		CIAT	30.6	0.50
W 1548	CRIFC, Bogor	CRIFC, Bogor	29.6	0.49
I-130	CRIFC, Bogor	CRIFC, Bogor	26.4	0.47
Mentega (local cultivar)			24.1	0.47
		Average	36.6	0.57

Source: Central Research Institute for Food Crops, Bogor, Indonesia.

been as thoroughly tested for conditions there as for the rest of cassava-growing areas in Asia. Thorough, on-site evaluation of CIAT germplasm to identify well adapted cross parents and incorporation of these parents into hybrid populations will improve the selection programs in these countries.

One of the most important yield constraints to the Indian cassava production is African mosaic disease. Since Latin American germplasm has not been exposed to this disease, most of the CIAT germplasm does not possess sufficient resistance to it. Thus, transfer of CIAT germplasm to the Indian cassava program has not been very active. Yet, the favorable agronomic characteristics of CIAT germplasm may be useful once they are crossed with locally proven resistant genotypes.

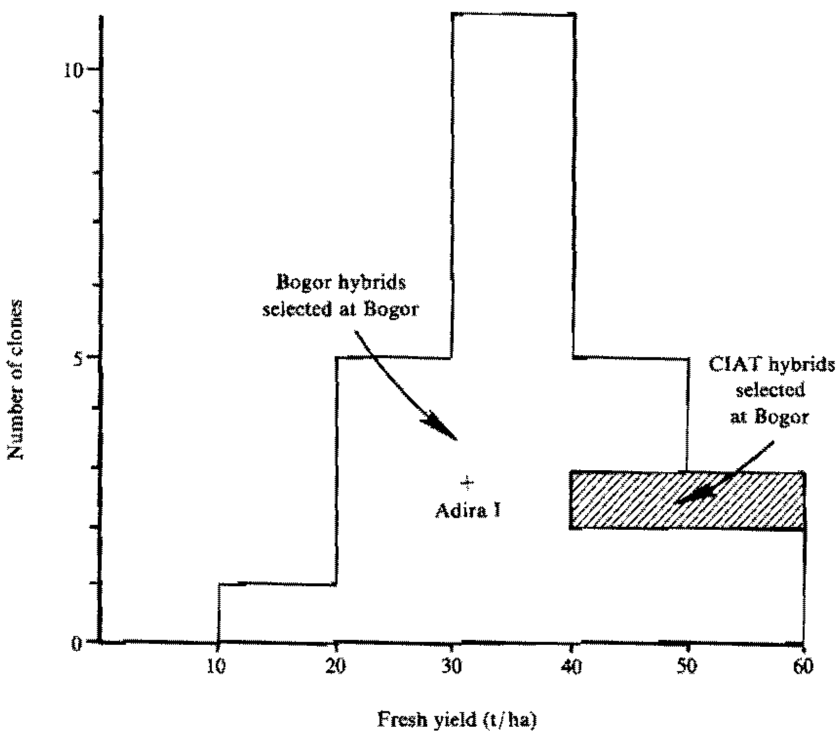

Figure 5. *Results of cassava yield trial at Muara Station, Bogor, Indonesia, 1982/83.*

Source: Central Research Institute for Food Crops, Bogor, Indonesia.

Need of On-Site Selection

Edapho-climatic conditions of cassava-growing areas vary from one area to another within a country even though they are classified under the same macro-edapho-climatic zone. Quality requirements also vary depending upon utilization and locations. Any new material for varietal selection has to be thoroughly screened for local adaptation and requirements.

Local germplasm is a result of generations of farmers' selections, which can be seen in the results of germination trials with CIAT and local clones under scarce rainfall at Huai Pong Station (Table 9). Planted with irrigation, all CIAT-crossed clones, locally-crossed clones, and Rayong 1 germinated reasonably well. However, planted without irrigation, the germination of CIAT clones was extremely poor compared with that of local clones. The germination of Rayong 1 was virtually the same with and without irrigation. Although the average germination of CIAT clones was low, some CIAT clones germinated nearly 100% without irrigation. Erratic rainfall is a common phenomenon with Thai cassava production, and the CIAT cassava breeding program has not yet screened for germination under such conditions.

Local germplasm may be an excellent source of adaptation to traditional cultural environments and requirements of the locality. Yet a quantitative jump, either in yield or resistance factors, is not expected as long as the breeding program uses only local germplasm; it by nature possesses limited genetic variability. Thus, incorporating Latin American germplasm into Asian breeding populations is the most appropriate way to improve cassava production.

Table 9. **Comparison of germination rate between CIAT and Thai crosses, Huai Pong Station, 1983.**

Planting	Clone	Site of hybridization	Number of clones	Average germination (%)
Irrigated	CM	CIAT	165	68.4
Irrigated	CMR and OMR	Huai Pong	1323	75.8
Irrigated	Rayong 1 (local cultivar)		1	89.2
Non-irrigated	CM	CIAT	249	42.7
Non-irrigated	CMR and OMR	Huai Pong	135	60.4
Non-irrigated	Rayong 1 (local cultivar)		1	86.6

Source: Field Crop Research Institute, Thailand.

Latin American germplasm on the whole offers much wider genetic variation but it contains genes for local adaptation in much lower frequencies than the local germplasm. Consequently, obtaining a recommendable cultivar selected from a small number of clones introduced from CIAT is unlikely. CIAT now intends to pass elite parental clones through meristem cultures to be used for hybridization in the Asian breeding programs rather than as candidates for immediate varietal release. Thus, local selection from large numbers of introduced CIAT seed populations, selection from local x CIAT crosses, or the combination of both become the most logical alternatives.

Traditionally, experiment stations in Asia have been built primarily for rice experiments. Most of the experimental sites tend to be on fertile soils with favorable water control. As a consequence, many varietal trials are conducted under conditions which bear little resemblance to farmers' fields. These are the bases for "high input technology syndrome " or " experiment station effect" (Kawano and Jennings, 1983). Cassava has been no exception to this general tendency. Extra care should be taken to establish selection plots under environments similar to those of average cassava growers.

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Rapporteur's Summary of Discussions

Douglas R. Laing

Participants raised a number of key issues in the general discussion, namely, (a) the progress to be expected in crop improvement activities in Asia, especially in terms of yield improvement, (b) likely effects of increased productivity on the cost of production of cassava, (c) erosion in monoculture cassava cropping systems and the role intercropping could play in reducing soil loss, (d) the dangers of planting large production areas in a single genotype, (e) the related matter of specific versus general adaptation of cultivars, (f) cassava production in tree plantations, (g) the need for pre-release evaluation of cassava cultivars and testing production methods in farmers' fields and (i) the relative economic importance of secondary diseases such as *Cercospora* and the need for further research.

In general the conclusions of the discussion session were in line with the information provided by each speaker. One issue in which there were no clear conclusions was the degree of beneficial effects to be expected from intercropping or rotational systems involving cassava and other crops, particularly legumes such as pigeon pea, mung bean, cowpea, soybean, and groundnut. Data from the Philippines suggested that there were considerable benefits, especially in slowing down the rate of yield decline often observed in monoculture systems. Other data from Thailand, which was not discussed in detail at the workshop, apparently raises some doubts on the agronomic and economic benefits to be expected from intercropping. Participants were in strong agreement, however, that more research on stable cropping systems involving cassava was of vital importance in Asia.

A further issue in which no clear concensus could be reached was in relation to the potential value of cassava intercropping in plantation tree crops, such as rubber. Little data existed on the eventual yield effects on the rubber when the trees were in the juvenile stage, as well as the effects on cassava from reduced solar radiation under the developed tree canopies.

Research to select cultivars with adaptation to shade conditions was recommended by the participants.

The participants agreed that *Cercospora* was indeed prevalent throughout most of the cassava production zones in Asia but there was no clear consensus as to the degree of attention which should be given to the disease in future collaborative network activities.

A number of more country-specific issues were discussed including (a) the problems related to cassava mosaic virus in India and the threat this poses to the rest of the countries in the region; (b) the apparently higher levels of fertilizer application being researched in the Philippines and the likely economic advantages of this level of application to the cassava farmer; (c) the yield levels being quoted in variety trials in Indonesia in relation to the very low yields being reported in commercial production throughout the various production zones of the country; and (d) the possible influence of winter temperature regimes on cassava production at subtropical latitudes in China.

A general theme running through the discussion was the need for more strongly stated governmental policies in relation to cassava research and development priorities. It is clear that most countries, except possibly the Philippines, have not yet clearly defined the future role for cassava in their economies. The participants recognized this was in part due to the overwhelming importance of rice in Asian economies. On the other hand, the need for improvement of crops such as cassava, which are adapted to more stressful conditions of poor soils and low and fluctuating rainfall regimes, was clearly recognized by all. This was further emphasized by the clear recognition that most land areas in Asia which are available for development are usually in less favored areas of both soil and climate. Cassava should be seen as a crop with significant development potential in Asia.

IV. Cassava Research and Development Needs

Cassava-Based Farming Systems in Tropical Asia: Research Issues and Development Needs

Frederick C. Roche

Introduction

Cassava production in Asia can be expanded either through growth in areas planted to the crop or increases in yields on land already planted to cassava. Significant growth in areas planted was confined largely to Thailand during the 1970-80 period (Table 1). Cassava hectarage was stagnant or declined slightly in the other major producing countries for which the data are reasonably reliable. The available information suggests that cassava areas will continue to stagnate or decline in the region as a whole during the coming years as long as there are no major changes in government policies which affect this crop's farm-level profitability (i.e., the Common Agricultural Policy and cassava import limits in Europe; domestic feed grain, sweetener, and energy policies within Asia).

Growth of cassava areas in Thailand is likely to taper off as more stringent enforcement begins of both the European quotas and Thai laws protecting forest reserves where much of the new plantings occurred during the 1970s (Falcon et al., 1984). In the densely-settled areas of Java and the Indian states of Kerala and Tamil Nadu, the expansion o irrigation and tree crops reduced cassava areas and should continue to dc so in the future. Considerable unopened land could potentially be plantec to cassava in the Philippines, Malaysia, and the islands of Indonesia othe than Java, but this would often require major public investments i infrastructure. The expansion of cassava plantations, as occurred in part of Indonesia during the 1970s, seems unlikely in the future because of th uncertain prospects for cassava prices. Even during the recent years c rising demand induced by European policy, cassava prices were nc

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Table 1. **Cassava production in the principal producing regions of non-communist Asia, 1980.**

	Area (000 ha)	Trend[a] (1970-1980)	Yield (t/ha)	Trend (1970-1980)	Production (000 t)	Trend (1970-1980)
India	335	+/-	17.4	0	5,817	+/-
Kerala	274	+/-	14.8	-	4,058	-
Tamil Nadu	52	0	29.5	++	1,540	++
Indonesia	1,412	0	9.7	+	13,726	+
Java	997	-	9.7	+	9,607	+
Off Java	415	+	9.7	+	4,119	+
Malaysia[b]	13		20.3		254	
Philippines[c]	204	++	11.2	++	2,277	++
Thailand	1,319	++	13.1	0/-	17,204	++
Northeast	709	++	13.3	0/-	9,445	++

a) + indicates a general increasing trend during the decade, while - indicates the opposite. +/- indicates an increasing trend followed by a decline, while ++ indicates a very rapid growth throughout.

b) Cassava areas and yields varied widely without any perceptable trend.

c) Lynam considers these oficial government figures to be very unreliable and estimates total Philippine production to have been only 450,000 tons in 1983.

Source: Lynam, 1983.

sufficient to encourage much substitution of cassava for other crops under Asian small-holder conditions.

In sum, growth in cassava output will depend upon the development and farm-level adoption of technologies which increase productivity. Because the total demand curve for cassava is probably inelastic within the range of prices likely in view of present policies, the principal research goal must be to reduce production costs. There is considerable evidence that appropriate technologies exist, consisting principally of locally adapted varieties, careful selection and, perhaps, fungicidal treatment of stakes, proper weeding, and maintenance of soil fertility. However, with the partial exception of weeding and fertilizer use, these practices have not yet been exploited in most of Asia. Consistent, reliable trends toward higher cassava yields were reported during the last decade only in Indonesia and Tamil Nadu, where cultivation practices are relatively labor-intensive and chemical fertilizers are, directly and indirectly, applied to cassava. In contrast, reported average yields are declining in Thailand, in part because soil fertility has been degraded under continuous cassava cultivation without fertilizer amendments (Sinthuprama, 1979).

A simple, yet analytically useful means of assessing the potential for increased cassava yields lies in the distinction between current farm yields, economically optimal yields, and the maximum farm yields that could be obtained with present technologies without regard to input costs. Current farm yields are doubtless well below the technical ceiling in most of Asia, with the difference being largest in Indonesia. The gap between current and economically optimal yields is less clear, however, and varies among countries as a result of input prices, market opportunities, and farmer knowledge. In Indonesia, for example, significant economic incentive exists for increasing cassava productivity: present average yields could be doubled profitably in many areas with available technology (Roche, 1983). In contrast, average yields are reportedly already very high in the main producing areas of India, but declining relative prices of rice, the principal staple of local diets, may limit the growth of market demand for substitute staples such as cassava and, thus, reduce the incentives for even higher yields through intensification of present cultivation practices (Lynam, 1983). Both input and output markets are likely to have adverse incentive effects in Thailand where cassava prices are determined largely by European demand and fertilizer is a very expensive input (Sinthuprama, 1979).

The following pages discuss technical and economic constraints to greater cassava productivity in Asia. The discussion will focus most heavily on Indonesia, but contrasting examples from other Asian countries will be offered when possible. The first section deals more fully with improved cassava cultivation practices for raising farm yields. The second section describes the program requirements and necessary economic incentives for the adoption of improved cultural practices, and discusses some secondary effects of greater cassava productivity: soil erosion and water pollution from starch production. The final section concludes by summarizing the principal issues for future agro-economic research on cassava in Asia.

Improved Cassava Cultivation Practices

The agro-climatic conditions of cassava production vary considerably in Asia. Cassava is almost exclusively a rainfed crop and is planted in areas with widely varying levels and patterns of seasonal rainfall. Although most cassava is grown at altitudes below 1,000 meters, topographical conditions range from level lowlands to steep and often unterraced hillsides. Soils vary correspondingly from deep and fertile to thin and highly degraded. Because of cassava's agronomic characteristics, however, it is most commonly grown in environments representing the less favorable extremes of these spectrums. It is tolerant of drought and poor soils, and is less prone than the other major food crops to severe losses to pests and diseases. Although productivity is typically low, cassava yields reliably and, as a result, the crop adds stability to farming systems in marginal upland areas.

The socioeconomic characteristics of cassava-producing areas also vary widely. Population densities and labor availability are low in northeast Thailand and on the Indonesian islands off Java. Population pressure is much higher on Java and in India, with the result that cassava is often intercropped intensively with staple and cash crops. In the better endowed producing areas of Indonesia, farm incomes are relatively high and cassava is grown principally for market, but the crop is a basic subsistence staple in poorer regions where its importance in terms of area is greatest.

The nature and intensity of cassava cropping systems are diverse, but it is generally true that labor is the major variable production input. Labor intensity varies as a function of population density, land productivity, and market opportunities for outputs and for the farmer's own labor. Reported labor use in cassava production ranges from 60-75 days per hectare in areas of Thailand, Malaysia, and the Philippines, to 440-550 days per hectare on densely settled Java (Lynam, 1983; Roche, 1983). Animal and mechanical power are used in land preparation and tillage operations in some regions, while manual labor predominates in others. The generally low use of non-labor inputs, particularly fertilizer, is related to cassava's agronomic characteristics, but is more fundamentally determined by economic constraints: relative prices, market information, and farm cash incomes.

The variability of production environments will complicate efforts to develop and promote improved cultivation practices for cassava. Research and extension recommendations must be location-specific, particularly in regard to varieties and the intensity of labor and non-labor input use. It appears that general recommendations can be made for only a few specific practices, most notably the preparation of planting material and weeding.

As a first step in the design of a regionally coordinated program for cassava, a very useful research task would be the development of an operational typology of Asia's cassava production environments based on agro-climatic and socioeconomic criteria. Such a typology should assess the significance of these environments in terms of area, population, present and potential productivity, and specific constraints. The simple classification of Java's producing areas in Table 2 is a first step in this direction, but would require considerable amendment to be of practical value to agricultural scientists. A goal for the typology should be that the variables are easily quantifiable using secondary data or rapid field measurement techniques.

Cassava varieties

Research at CIAT and other cassava centers has demonstrated the benefits of locally adapted varieties as one component of a package of improved practices for cassava (see, for example, Toro, 1979). The development and release of superior varieties will be a major goal of future cassava research in Asia and will require an active commitment to the crop on the part of national agricultural agencies. The case of Indonesia is perhaps typical. Although yield trials of local and introduced varieties have been conducted by agronomists in many areas and for many years, no serious efforts have been made by the extension service to demonstrate and release appropriate varieties at the farm level.

The agronomic characteristics desired of superior varieties will depend upon the agro-climate, farming systems, and end uses of cassava in a given producing area. Although cassava is relatively tolerant of acid soils and drought, appropriate varieties must be selected in accordance with local conditions of pH and seasonal rainfall. In regions where intercropping is practiced, as in much of Indonesia, the cassava variety must be appropriate for the planting and growth patterns of the companion intercrops across space and time. How well new cassava varieties fit into current intercropping systems will be a major determinant of their acceptability to farmers who may view cassava as secondary in importance to the intercrops, despite the fact that cassava often contributes the largest single share to the total value of output. In general, the varieties most desirable will be non-branching types which establish canopy cover

Table 2. **Characteristics of Java's main cassava-producing regions, 1977-79 averages.**

	Region				
	I	II	III	IV	V
Principal location	West Java	Central Java	South-central Java	East Java	Madura
Cassava production (millions of tons)	1.80	1.64	1.78	0.58	0.84
% of total Java production	19.0	17.3	18.7	6.1	8.8
% of total staple crop area in cassava[a]	14.7	17.6	34.5	13.9	23.6
Yields[b] (t/ha)	10-12 (6-20)	9-11 (5-12)	7-9 (2-10)	10-11 (10-40)	7-9 (4-8)
No. of consecutive wet months (rain $\geq$ 200 mm)	6+	3-9	3-6	3-10	3-4
No. of dry months (rain $\leq$ 100 mm)	2-4	2-6	2-6	2-6	5-6
Level of soil erosion	High	High	Severe	Moderate/severe	Moderate
Principal cassava intercrops	Upland rice/ legumes	Maize	Upland rice/ maize	Maize/legumes	Maize

Continues.

Table 2. **Continued.**

	Region				
	I	II	III	IV	V
Principal location	West Java	Central Java	South-central Java	East Java	Madura
Principal cassava end use	Starch	Gaplek/starch	Staple food	Gaplek/staple food	Staple food/ gaplek
Direct human consumption of cassava					
Quantities	Low	Low/moderate	High	Moderate/high	High
Form	Fresh	Fresh/gaplek	Gaplek	Gaplek	Fresh/gaplek
Relative farmer income levels	Medium	Low/medium	Low	Low/high	Low

a) Cassava areas as a percentage of the total areas in major food crops. These crops include irrigated and rainfed rice, maize, soybeans, peanuts, and sweet potatoes in addition to cassava.

b) Numbers in parentheses refer to the range of yields reported by farmers in these regions during field trips in 1979/80. Numbers above parentheses are the ranges of average yields reported by the Central Bureau of Statistics for the year 1977-1979.

Sources: 1. Data on cassava production and yields are from the Central Bureau of Statistics, *Production of food crops on Java and Madura*, for the years 1977 to 1979.

2. Data on rainfall are taken from L.H. Oldeman, *An Agro-climatic map of Java and Madura*, Contribution No. 17, Central Research Institute for Agriculture, 1975.

3. Observations on erosion and income levels, and the principal intercrops with, and end uses of, cassava are based upon field interviews with farmers during 1979/80.

4. Quantities and principal forms of cassava consumption are from the Central Bureau of Statistics, *SUSENAS* (the national socio-economic survey of Indonesia), 1978

slowly over the course of 3 or 4 months, but the specific requirements will vary depending upon the growth habits of the primary intercrop: grain, legume, or vegetable. When cassava is interplanted among tree crops, shade tolerance will also be a relevant consideration in varietal research. Finally, high starch content is a desirable quality of cassava varieties in all production systems, but root color, moisture percentage, and HCN content are additional concerns when the crop is to be directly consumed in fresh form.

Preparation of cassava planting material

In Indonesia, as is probably true throughout most of Asia, cassava stalks are stored under adverse temperature and humidity conditions for periods of 2 to 4 months between harvest and replanting. Java's farmers report that significant percentages of cuttings often fail to germinate and must be replaced several weeks into the growing season. CIAT strongly recommends the careful storage, handling, and selection of planting material in order to ensure high sprouting rates and vigorous early growth (Lozano et. al., 1977). An inexpensive fungicidal treatment has also been recommended prior to planting, but recent research has called this practice into question because of a potentially negative effect on mycorrhizal fungi, which live symbiotically with plant roots and facilitate cassava's uptake of phosphorus (Howeler, 1980). Because CIAT's recommendations can significantly increase yields for a very low cost per hectare, research and extension for these practices in Asia should certainly be given a high priority.

Cassava pests and diseases

Cassava's reputation for pest and disease resistance may be warranted in Indonesia, but little reliable information exists and the matter deserves systematic study. On Java, the incidence of red spider mites (*Tetranychus urticae*) and cassava ash disease (*Oidium manihotis*) is often high during the dry season, but the resulting damage is apparently minor: rarely do farmers report losses exceeding 20% of expected yields. Cassava bacterial blight (*Xanthomonas manihotis*) is reputed to be a serious concern in isolated areas of north Java and, within the past few years, on some cassava estates in the province of Lampung, Sumatera, but is probably of minor importance overall in Indonesia. Various types of cassava root rot problems caused by soil fungi are common on heavily textured, poorly drained soils, but overall losses are again reportedly small. This sketchy information is based largely on farmer interviews and should be augmented by more systematic research by plant protection specialists. The assessment of the economic importance of cassava pests and diseases in Asia would be an important objective of the production systems typology proposed above.

Weeding

Proper weeding of cassava is known to be important for high productivity. Only the more vigorous cassava varieties can compete successfully against weeds during the first 3 to 4 months of the crop's growth (Leihner, 1980). In labor-abundant agricultural economies such as Indonesia and India, current manual weeding practices may already be adequate. On Java and Lampung, for example, labor use for weeding ranges between 70-150 days per hectare in typical cassava cropping systems (Roche, 1983). However, in the considerably less intensive cassava systems of Thailand, Malaysia, and the Philippines, insufficient manual weeding may be contributing to reduced yields. In these systems total labor use is reported to range between 60-75 days per hectare (Lynam, 1983). To the extent that labor availability and high wage rate are limiting factors, alternative cultural and chemical practices can substitute for manual weeding. Leihner (1980) reports success with a variety of weed control techniques involving various combinations of capital and labor inputs in Colombia (Table 3). Mulching, which also adds organic matter and conserves soil moisture, could be a particularly attractive possibility in Asian farm settings where there exist readily available supplies of raw material (rice, maize, and sugarcane residue). Because proper weed control can have a major impact on cassava yields, research and extension for these techniques could be highly profitable for Asian farmers.

Cassava fertilizer requirements

Cassava can produce large amounts of dry matter per unit of land and, as a result, the crop will extract considerable soil nutrients during the course of its growth. Yields of continuously cultivated cassava tend to decline when these nutrients are not replaced, even though cassava will continue to produce relatively well on highly infertile soils in comparison to alternative crops. There is considerable agronomic evidence of cassava's general fertilizer responsiveness in Asia, although there has been variance both within and among countries in the effect of specific nutrients. Howeler (1981) cites research conducted in India, Thailand, Malaysia, and Indonesia, and concludes that nitrogen and potassium are the principal limiting nutrients in Asia. Cassava's response to phosphorus has usually been minor.

This general pattern has also been observed in agronomic trials on Java where per hectare fertilizer recommendations range between 70-135 kg N, 30-45 kg P_2O_5, and 50-100 kg K (Indonesia, various years). Within these levels of application, farmers can expect to obtain between 10-35 kg of cassava for each kg of fertilizer used on average. Prices of urea and triple superphosphate (TSP) are heavily subsidized in Indonesia and at present

Table 3. **Benefits and costs of alternative weed control techniques for cassava, Colombia, 1979.**

Weed control technique	Cassava yield (t/ha)	Legume yield (kg/ha)	Labor use (days/ha)	Capital cost ($US/ha)
No weed control	12.9	—	0	0
Pre-emergent herbicide[a]	23.4	—	1	47.70
Mulching (sugarcane residue)[b]	27.6	—	6	7.70
Legume intercrop (annual)[c]	26.8	1,945	25	150.00
Legume intercrop (perennial forage)[d]	26.9	600	29	60.00
Manual weeding[e]	33.2	—	48	0

a) Linuron and fluorodifen at 1 kg and 7 liters per hectare, respectively.

b) Sugarcane bagasse at a rate of 17 t/ha. Transportation cost to field not included.

c) Black beans intercropped at a seeding rate of 120 kg/ha, plus two initial hand weedings.

d) *Desmodium heterophyllum* intersown at a seeding rate of 4 kg/ha, plus two initial hand weedings.

e) Four hand weedings performed at 22, 40, 60, and 115 days after cassava planting.

Source: Leihner, 1980.

cassava prices, farmers in Java's more marginal areas could expect the incremental value-to-cost ratios from fertilizer to range between 4-6:1 (FAO, 1979; Effendi, 1980).

Despite the apparent profitability of fertilizer and its ready availability in markets on Java, official statistics and extensive field observations suggest that little is generally applied directly to cassava (Roche, 1983). Low average fertilizer use on cassava has also been reported in Thailand, Malaysia, and Kerala (Weber et. al., 1979). A detailed understanding of the economics of cassava fertilization in Asia would seem to be a key research priority. Fertilizer prices may be too high to justify the use of this input in Thailand. Despite the subsidies in Indonesia, fertilizer is nonetheless an expensive input for Java's small farmers, who have traditionally allocated limited inputs to preferred staple crops and may often be unaware of cassava's fertilizer responsiveness.

Sufficient evidence of the potential profitability of fertilizer use exists in Indonesia to warrant a serious program of on-farm research, extension, and demonstration trials in the major cassava-producing areas. Farm-level fertilizer trials would serve two important purposes. They would result in locally appropriate recommendations for dosages of specific nutrients and would be a vehicle for showing farmers what they could be achieving.

The specific concerns of on-farm research and extension will vary in Asia depending upon relative fertilizer and cassava prices, local climate and soil conditions, and present cassava cultivation practices. In Indonesia, special attention should be given to the overall nutrient requirements of intercropping systems which include cassava, upland rice, and maize. Particular attention should be given to cassava's potassium needs because forms of this nutrient are expensive and scarce in markets. Although cassava's response to potassium has not been consistent in Indonesian agronomic trials, it has often been large and highly significant where observed. The practice of cassava leaf removal prior to root harvest is widespread, resulting in lower root yields of many varieties and forestalling the natural recycling of nitrogen that would occur if foliage were left to decompose in the soil. The economic benefits and costs of this practice should be investigated. Methods of fertilizer application can probably be improved in upland areas where fertilizer broadcast on steep hillsides can be lost with soil runoff.

Cassava intercropping systems

Although most of Asia's cassava is planted in pure stands, cassava intercropping predominates in several regions and is particularly suited to small, labor-intensive farms. Individual crop yields may be lower in intercropped stands, but overall land productivity is generally much greater and the stability of total carbohydrate output (food calories) may be higher as well.* Cassava intercropping requires more labor input than pure stands, with positive implications for employment and income distribution in rural Asia. For these reasons, research on intercropping systems will often be more relevant than research on cassava alone.

Cassava intercropping systems vary widely in Asia. Staple cereals and legumes are typical intercrops throughout Indonesia, while systems involving cassava and tree crops are said to be more common in India and Malaysia (Weber et al., 1979). A systematic agro-economic assessment of the more common systems would constitute a useful starting point for a regionally coordinated program of cassava intercropping research. A primary goal of future research should be to build upon current systems by developing improved cropping practices that are appropriate for the specific conditions existing at the farmer's level. New cropping systems which diverge too greatly from current practices, or which require too much of a scarce input, are likely to be unacceptable to farmers. Cassava intercropping research in Indonesia illustrates this point.

In the western islands of Indonesia, where rainfall is relatively abundant, the basic rainfed intercropping systems consist of maize, upland rice, and cassava (Figure 1). The rice and cassava are planted at near pure stand density (25 cm x 25 cm and 1 m^2, respectively) while maize is planted in wide rows. Minor legume crops may be interplanted along field edges and can contribute significantly to total output value. Moderate quantities of fertilizer, and occasionally, pesticides are used on the cereals, but little or none are directly applied to the cassava.

During 5 crops years between 1973-78, agronomic research on this cropping system was conducted on acid, infertile soils in transmigration areas of Sumatera. The results demonstrated that productivity and profitability can be increased substantially with locally adapted combinations of selected crop varieties (including new late-season legumes), greater fertilizer and pesticide use, mulches, and plant spacing arrangements which reduce competition for sunlight. The new agronomic practices were consistently superior during all 5 years of the experiments and also reduced the variability of output and net profitability (Table 4). Absolute variance

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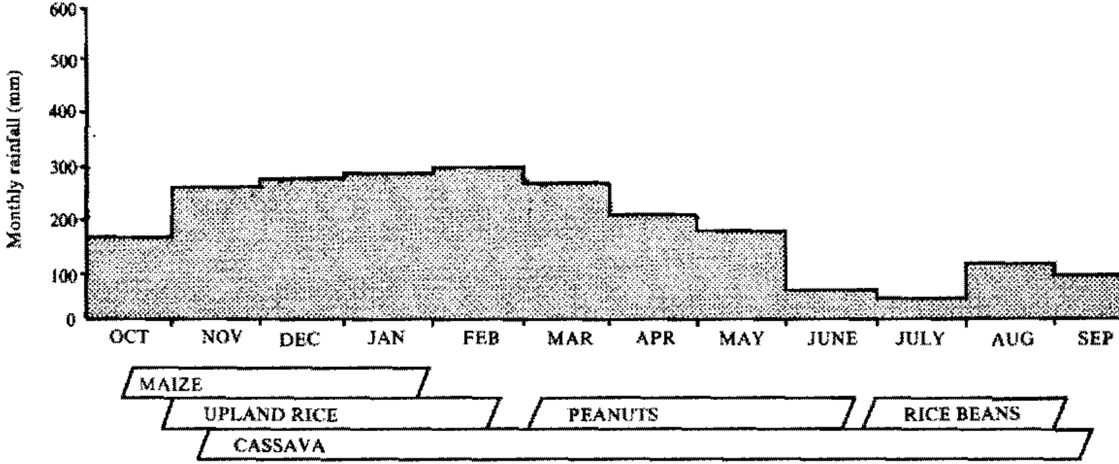
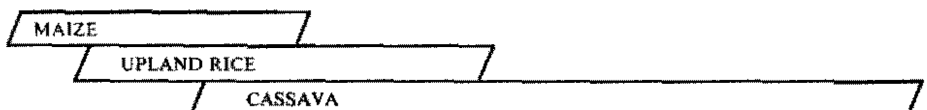
* The degree and causes of greater stability are not yet understood clearly and deserve further study. Intercropped species may provide physical barriers to pests and disease vectors, and may, in certain spatial arrangements, create micro-environments in which temperature and humidity conditions are unfavorable to disease infection. See Moreno (1979). Alternatively, yields of interplanted crops may simply tend to co-vary negatively, i.e., poor growth of one crop in one year is counterbalanced by more vigorous growth of others.



CRIA's basic intercropping pattern with improved crop varieties and cultural practices.



Current farmer intercropping pattern with traditional varieties in CRIA's test site in Lampung province, Sumatera.

Figure 1. *Current and improved cassava intercropping patterns in the Sumateran transmigration areas.*

Source: Inu Ismael et al., *Cropping systems research in transmigration areas, South Sumatera, 1978*, CRIA, Bogor, 1979.

Table 4. **Mean and variance measures for three treatment levels in CRIA intercropping research, Central Lampung, Sumatera, crop years 1973/74-1977/78 (per hectare units).**

	Maize	Upland rice	Peanut	Rice bean	Cassava	Value of maize, rice and cassava (000 Rp)[a]
Level 1 - control						
Mean yield (t)	.212	.595	.286	.050	6.860	331.5
SD	.153	.275	.121	.043	4.473	180.0
CV(%)	72.1	46.3	42.4	86.0	65.2	54.3
Level 2 - fertilizer + lime						
Mean yield (t)	1.828	2.024	.525	.321	19.580	1,159.0
SD	.279	.653	.172	.258	3.113	180.8
CV(%)	15.3	32.3	32.9	80.3	15.9	15.6
Level 3 - fertilizer, lime, + mulch						
Mean yield (t)	2.031	2.280	.601	.388	23.740[b]	1,352.4[b]
SD	.428	.695	.115	.305	7.858	263.7
CV(%)	21.1	30.5	19.2	78.7	33.1[b]	19.5[b]

Continues.

Table 4. **Continued.**

	Maize	Upland rice	Peanut	Rice bean	Cassava	Value of maize, rice and cassava (000 Rp)[a]
Sample size (all levels)						
No. of years	5	5	4	3	5	5

a) Commodities valued at prices prevailing during 1983/84.

b) Mean and variance increased by 1 year of very high cassava yield (36.8 t/ha) The mean cassava yield for the remaining 4 years at level 3 treatment was 20.5 t/ha (CV = 16.4%). At this latter yield, the average value of the maize, rice, and cassava becomes Rp 1,253.1 thousand/ha (CV = 15.0%).

* Level 1: No fertilizer, lime, or mulches applied.

Level 2: Treatment consisted of lime broadcast at 200 kg/ha and.

	N	P_2O_5	K_2O
		(kg/ha)	
Maize	48	15	15
Rice	72	24	24
Cassava	20	20	20
Peanut	14	25	36
Rice bean	14	25	36
Total year	168	109	131

Level 3: Treatment consisted of above fertilizer and lime applications plus use of crop residues as mulches, requiring approximately 30 labor days per hectare.

All Levels: Same crop varieties used, intercropped in rows; all received pesticide.

Source: Derived from Jerry L. McIntosh and Suryatna Effendi, Soil fertility implications of cropping patterns and practices for cassava, in Edward Weber et al., eds., *Intercropping with cassava*, International Development Research Centre, Ottawa, 1979.

of output increased with average yields, but coefficients of variation declined significantly for most crops as a result of the use of fertilizer, lime, and mulches. The increase in variance was very small for the early maize, upland rice, and cassava, suggesting stability in overall output of the major staples of the system.

Despite these apparent benefits, an evaluation in 1980 indicated that the new recommended practices had not been adopted by any of the farmers living near the experimental sites (personal communication, Richard Bernsten, Winrock International). The single exception was one large farmer who planted the improved systems on 0.5 ha of his 10-ha holding as a cooperative demonstration exercise with the local extension service. It is likely that the improved system was simply too labor- and capital-intensive to be feasible under the conditions of transmigration areas, where markets for labor, credit, and other inputs are poorly developed. The complexities of the improved system also put a heavy burden on the extension service.

These practices would be much more appropriate in the labor-intensive uplands of Java, but differences in soils and rainfall would probably prevent the direct transfer of the Sumateran research results. Even on Java, competing demands for farm labor —for example, in irrigated rice fields— would occasionally conflict with the seasonal labor requirements of the Sumateran system. In sum, an understanding of resource availability and farmer decision-making is an essential first step in the development of locally adapted cassava cropping systems.

Policy Issues and Program Requirements

Cassava productivity increases will require both locally-adapted, cost-reducing technology and the economic incentives for its farm-level adoption. The latter will depend primarily upon cassava prices, although the cost of inputs, particularly fertilizer, will also be important. The commitment to develop and extend new technology will depend on the perceptions of policymakers as to the potential role for cassava in meeting food policy objectives: increased incomes of poor farmers, adequate nutrition for poor consumers, food security, and efficient economic growth (Falcon et al., 1984). Environmental concerns will also be relevant in the case of cassava.

In many Asian countries during the 1960s and 1970s, a considerable degree of centralization was possible in national programs of research and extension for the new irrigated wheat and rice technologies. The limited research resources of the national programs were concentrated in a few sites in the successful efforts to adapt the fertilizer-responsive varieties developed initially at the international centers. In Indonesia, a single extension and credit package, Bimas paddy, was organized and adopted throughout most of the country's irrigated rice areas. It is unlikely that such centralization will be possible in the 1980s, as policy attention is focused increasingly on non-rice crops and the development of Indonesia's agro-climatically varied rainfed areas.

Program requirements

The elements of a package of improved practices could be highly profitable for Asia's cassava farmers. However, the variability of Asia's uplands and the particular agro-climatic constraints of many cassava-producing areas will require that adaptive research be much more site-specific than was the case for irrigated wheat and rice. Because well-trained research staff are limited, the responsibility for identifying and testing the primary components of improved cassava systems —varieties, fertilizers, and intercrops— must fall upon local extension workers to a greater extent than in the past. In Indonesia, these workers have been trained primarily in production methods for rice and additional short-term training may be necessary in the complexities of rainfed cropping systems.

Input distribution systems are likely to constitute serious constraints in efforts to deliver new technologies to farmers. The introduction of new cassava varieties will be slow unless rapid propagation methods are utilized, but the application of these techniques has not yet been undertaken in Indonesia. Fertilizer distribution channels for urea and TSP are well-developed on Java, but fertilizer is less readily available on the other islands and potassium is difficult to obtain throughout the country. Delivery capacity would also be a severe constraint to the adoption of improved intercropping systems based on improved varieties because Indonesia's breeder seed production programs are presently very small for crops other than rice.

Marketing infrastructure must also be developed in both the isolated uplands of Java and, more generally, on the Indonesian islands off Java. Feeder roads will reduce marketing costs and enhance the farm-level profitability of all upland crops, but would have a particularly large impact on cassava because of this crop's low value-to-weight ratio and perishability (see Unnevehr, 1982, for a detailed discussion of cassava marketing in Indonesia). Private or public investment in small-to-medium scale cassava-processing facilities would be one way of increasing farmer returns in isolated areas and would also generate employment during cassava harvest periods.

Farm credit may be an additional program requirement in many upland areas, especially for cassava systems with new fertilizer recommendations and for intercropping systems. Upland farmers tend to be more subsistence-oriented than their lowland counterparts and their ability to purchase cash inputs is often limited. Because repayment rates have been disappointing in Indonesia's credit programs for rice, it may seem difficult to justify credit for secondary, less-preferred staples like cassava which are grown under more inherently risky rainfed conditions. However, cassava tends to yield reliably and larger shares of production are marketed by farmers than is typical for other staple crops. High and relatively stable cash receipts would constitute a sound basis for credit programs for cassava as compared to other rainfed crops. It might be possible to tie the extension of new technology and farm credit to final sales of cassava to local processors, whether public or private. Various types of farmer-processor linkages are now being attempted in Indonesia, but the results have not yet been investigated.

Although there could be a role for the private sector in the extension of new cassava technology, the tasks of initial research and development must be a government responsibility. The necessary adaptive research has yet to begin in earnest in Indonesia, where agronomic work on cassava is a secondary activity at the country's major agricultural research institutions. The above discussion has relied on Indonesian examples, but it is probable that many of these program considerations will arise elsewhere in Asia. Given the predominant importance of rice in Asian food economies, the commitment to develop cassava and, more generally, rainfed cropping systems could result in serious trade-offs in the allocation of limited research resources among rice and other crops.

Cassava's role in food and farm policy

In view of the complexities involved in developing and promoting new technologies for cassava cropping systems, policymakers must be convinced that the social benefits outweigh the investment costs. The balance between benefits and costs will be influenced by the expected supply, demand, and prices of cassava and cassava substitutes in domestic and world markets. The potential benefits of improved farm practices in relatively poor agricultural areas might also be weighted heavily by policymakers.

Cassava prices in Asian producing countries will generally be determined at the intersection of the domestic supply curve and the total demand curve representing domestic and international markets. In Indonesia, the international supply curve of cassava starch becomes a determinant of prices in years of low domestic food supplies, but this occurs infrequently, according to Falcon, et al., 1984. Given present trade policies in the major cassava-importing countries, the international demand for cassava chips, pellets, and starch is predicted to grow slowly or stagnate during the coming years (Nelson, 1982; Lynam, 1983). As a result, most Asian producers would be forced to rely upon the domestic market to absorb the production increases possible with new technology. However, the profitability of alternative domestic uses of cassava will continue to be affected by the strength of the price linkage between Asian producers and world markets for cassava products.

Cassava's role as a cheap calorie source for poor consumers would be enhanced if supply increases lead to lower prices. However, evidence from Indonesia, India (Kerala), and the Philippines indicates that the direct demand for cassava declines as consumer income rises (Lynam, 1983). The demand for food and non-food products made from cassava starch is likely to increase with income, but per capita consumption of these products is relatively low. Hence, the total direct demand for cassava will grow more as a function of population than of consumer income, although domestic price policies for other staple foods, particularly rice and wheat flour, will influence the overall level of cassava demand at any point in time.

The two principal sources of new cassava demand are the livestock feed and sweetener industries. Consumer demand for meat products and sweeteners tends to be highly income-elastic and is expected to grow rapidly in Asia during the coming decade. In the sweetener industry, cassava would compete with maize and sugarcane in supply (crop areas for production of raw materials) and in demand. Cassava would compete principally with maize in compound feed mixtures, but the profitability of dried cassava in rations will also depend upon the prices of protein supplements such as soybean and leaf meals.

Domestically-produced cassava could substitute for maize in the Malaysian, Philippine, and Indonesian feed industries (Lynam, 1983). In Malaysia and the Philippines, such a substitution could result in significant foreign exchange savings (Table 5). The efficiency of this substitution depends upon world cassava and maize prices, and the relative domestic resource costs of producing feed ingredients. Improved cassava technology would doubtless reduce production costs per ton of output: conservative estimates from Java suggest that selected varieties and increased fertilizer use could lower production costs by as much as 35% in pure stand cassava systems (Roche, 1983). At the same time, new downy mildew-resistant hybrid maize technologies could have an equally dramatic impact on maize production costs in Asia (Dorosh, 1984). Demonstration trials and extension programs for hybrid maize have

Table 5. **Trade balances for maize and sugar in Asian cassava-producing countries, 1980/81 (000 t).**

	Maize[a]	% Imports[b]	Sugar	% Imports[b]
India	0	—	-170	1.7
Indonesia	-19	0.5	-650	25.0
Malaysia	-415	90.0	-490	81.8
Philippines	-251	7.8	+1,015	—
Thailand	+2,362	–	+1,900	—

a) - refers to net imports; + refers to net exports.

b) Imports as a percentage of total net domestic consumption plus final stocks.

Sources: maize - FAO (1983); sugar - Schnittker Associates (1983).

begun in the Philippines and Indonesia, but the data necessary for a detailed evaluation are not yet available.

The potential for cassava is more problematic in the sweetener industry. At current and projected world prices of cassava and raw sugar, this end use of cassava could be justified only if very high priority is placed on domestic food security objectives. Malaysia and Indonesia depend upon imports for large percentages of domestic sugar requirements and international sugar prices have historically been quite volatile. Cassava or corn-based sweeteners would be a means of reducing import dependence. In Indonesia, this substitution would permit productive irrigated land to be taken out of cane production and used instead for rice, a more valuable crop for which import dependence is also high. However, the necessary industrial technology is capital-intensive and costly as compared to that for refining cane sugar. Foı cassava, large subsidies would be necessary to make fructose production profitable at the present time. Such a subsidy is provided implicitly in Indonesia in the form of trade barriers which result in high domestic prices of refined sugar. Several medium-scale cassava fructose plants are currently operating or under construction. These plants will be moderately profitable at the levels of present domestic prices, but their competitive edge would disappear entirely if sugar trade restrictions were eliminated (Roche, 1984). As with cassava's potential role in the feed industry, however, this outcome could be modified if cassava production costs and prices were lowered sufficiently.

In some of the better endowed, rainfed areas of Indonesia, cassava, maize, and sugarcane are substitutes in farm production. A variety of government policies, both domestic and external, affect the relative profitability of these crops in different ways. Farmers at times respond rapidly to changing policy incentives by making significant substitutions in areas planted. Programs to develop and extend new technologies will further affect relative profitability.

Sensible policy decisions should be guided by a detailed understanding of the private and social profitability of current and improved production systems for cassava, maize, and sugarcane on similar land types in Indonesia. Initial studies indicate that the farm-level profitability of cassava exceeds that of maize under the cultivation practices currently recommended by local extension services (Suryana, 1980; Roche, 1983). However, comparative studies of sugarcane have not yet been undertaken and there is also a need for systematic comparisons of hybrid maize with cassava grown under the full set of improved practices outlined in the first section of this paper.

The possibilities for crop substitutions are fewer in Indonesia's poorer agricultural areas where cassava tends to have a major role in farming systems. On efficiency grounds, one would normally argue for concentrating cassava research and extension efforts in regions of high potential productivity and assigning lower priority to marginal production environments. The development of improved technologies would be more difficult in areas agro-climatically constrained by poor soils and rainfall, but the relative impact on farmer incomes could be substantial. Although absolute yield potential may be low, the real costs of cassava production are likely to be low as well because alternative opportunities for land and labor are limited. Hence, the trade-off between equity and efficiency may be minor in efforts to increase cassava productivity. The principal choice is likely to be between development costs and the regional distribution of the benefits of improved cassava technology.

The above examples have again been drawn from Indonesia, but the general issues are relevant in varying degrees throughout Asia. Cassava's multiple end uses require that prospects for the crop be assessed within the full matrix of policies affecting the supply and ultimate demand for Asia's basic staples. The potential substitution interlinkages in demand will be stronger than those in supply because cassava is a minor commodity in Asia's most productive agricultural areas.

Cassava, soil erosion, and water pollution

Cassava has the undeserved reputation of being a soil-depleting crop. Cassava does extract large quantities of soil nutrients and soil fertility will naturally decline if these nutrients are not replaced, but cassava's nutrient removal is not excessive as compared to other staple crops (Jones, 1959). However, because cassava tolerates poor soils, it tends to be a major crop in steep and highly eroded areas where little else can be grown as profitably. Under such conditions, cassava can accelerate erosion because of limited canopy cover during its early growth and soil movement during harvest. Although a number of ameliorative innovations should be investigated, they would not constitute a complete solution to a dilemma brought about fundamentally by the pressure of people on land in Asia.

Bench terracing would be highly desirable on steep hillsides, but the labor costs would be perceived as excessive by most farmers, particularly in areas such as northern Thailand where much cassava is planted illegally on state forest lands. The effective enforcement of land use prohibitions would be administratively difficult and might result in unacceptable social tensions in forest areas. The planting of cassava on contour ridges is an intermediate step that should be encouraged where possible. Mulching would be a complementary practice that could also raise cassava yields. The use of fertilizer, particularly nitrogen, would promote faster canopy closure early in the crop's growth when erosion potential is greatest. However, farmers in Asia's marginal uplands are generally the least able to purchase fertilizer. Cassava intercropping systems provide denser ground cover than pure stands, but would be technically difficult to develop on unterraced hillsides where topsoil loss is most severe.

Soil runoff is not the only problem associated with cassava production. Effluents from cassava starch processing constitute an additional form of water pollution that can have serious environmental effects. In Indonesia, cassava wastes have damaged rice crops, caused intestinal illnesses in humans and livestock, and made water supplies impotable in areas downstream from starch factories in southern Sumatera (Jakarta Post, 1984). Field observations suggest that similar problems could be common in the starch production centers of west and east Java. Environmental damage will grow in magnitude as starch production expands, but there are at present no explicit regulations to control this form of industrial pollution. An assessment of the costs and benefits of alternative remedial measures should be considered as part of a regional program for cassava development.

Conclusion

Substantial agronomic evidence supports the view that a combination of selected varieties and several straightforward cultivation practices can profitably increase cassava productivity. Considerable field testing will be required to locally adapt these practices in Asia's varied cassava-producing areas. The principal constraints to increasing cassava production are likely to be economic rather than technical and will operate more on the side of cassava demand than supply. In Asia's better rainfed regions, policies affecting relative production costs and returns should be assessed to ascertain the potential supply impact of new technologies that could cause significant substitutions in area between cassava and other crops. Cassava's agronomic characteristics assure the crop's important role in Asia's poorest agricultural areas, where much cassava will be grown even when its relative price is low. Although potential cassava yield increases may be relatively small in these areas, their effect on incomes and welfare could be quite large.

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Postharvest Research Priorities for Cassava in Asia

Diane M. Barrett

Introduction

One of cassava's principal advantages over other carbohydrate crops is its ability to be used in varied product forms. Although the comparative food value of cassava to other carbohydrate crops is low, when one compares costs of production and calorie yield per hectare, per man-days, or per capital investment, cassava dominates other starchy staples. The reduced risk to disease, drought, and climatic uncertainties also favors cassava.

Cassava utilization patterns in Asia vary substantially from country to country. In Thailand, cassava is produced almost entirely for starch and pellet exports. Cassava is not consumed directly for a food source in Thailand, however, domestic consumption of cassava starch has been increasing rapidly in the past decade. Cassava use in Indonesia, the second largest Asian producer, differs throughout the country. On Java, where 62% of Indonesia's population resides, cassava is used primarily as a food, whereas in South Sumatra cassava goes to animal feed production and export. Cassava produced in the Philippines is used predominantly for domestic food and starch production. In Malaysia, the majority of cassava produced is used domestically as starch. Finally, India's utilization is for both human consumption (in Kerala) and starch production (in Tamil Nadu).

The ability of cassava to grow under diverse agricultural conditions and the variety of its end uses has resulted in a wide range of utilization patterns among countries. However, there is a general similarity in postharvest research needs for specific end products. Therefore, this paper discusses research needs on a product basis rather than a country basis.

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Harvesting and Processing Problems

Difficulties in the postharvest cassava system pose some of the principal restraints to the future potential of cassava markets. The postharvest quality of cassava must always be considered in terms of pre-harvest practices, which have a significant effect; however, for the purpose of this paper, discussion focuses on difficulties encountered during and after harvest.

Some researchers have suggested that postharvest losses of cassava may amount to 20-25%. However, most technologists working with cassava in developing countries would estimate that losses are much higher. The major losses are incurred during drying and storage, which are seldom carried out with adequate care. Difficulties in each postharvest step and with each major cassava product are discussed briefly.

Harvesting

Optimal harvest times for specific varieties are seldom known and roots are often harvested either too young (starch not properly developed, therefore content low) or too old (starch content reduced, lignification begun). Harvesting is generally done by hand and great damage is often incurred due to lack of care in lifting roots from the ground. Damage during harvesting provides sites for the initiation of physiological deterioration (Booth, 1978). In addition, manual harvesting is time-consuming and tedious. Mechanical harvesting methods have been evaluated at CIAT; however, capital equipment costs may restrict their use to large, plantation-scale operations. Also, the introduction of machines would have a deleterious effect on employment opportunities. Losses could be reduced if farmers are made aware of improved harvesting methods and if simple, improved manual tools are introduced.

Transporting fresh roots

Fresh cassava roots deteriorate within a few days after harvest due to both physiological processes and mold attack (Booth, 1978). In light of this rapid deterioration and the fact that cassava roots are very bulky and occupy a lot of space, transportation is difficult and, depending on distances, expensive. Unless a cassava-producing area is located near a fresh root processing factory or the market price of fresh cassava is high, it is usually more economical for farmers to pre-process or dry roots prior to storage or sale.

Peeling and cleaning

Proper peeling and cleaning operations are important to the production of a high-quality product. Often cassava roots are not well peeled and cleaned prior to subsequent processing, and the resulting product is high in fiber, silica, and other residues. However, some pelletizing factories in Indonesia specify that farmers leave a certain amount of peel on their roots in order to increase product weight, since, as Manurung (1974) has stated, it does not seem necessary to peel roots for animal feed purposes. Another factor to consider is that most bitter cassava varieties, which are the predominant varieties for industrial purposes, have the greatest hydrogen cyanide (HCN) concentration in the peel. Starch processors must also take care in their peeling and cleaning operations in that improper practices will prohibit the production of the whiter, more desirable starch. Farmers rarely clean their roots prior to drying, with the result that the amount of dirt incorporated is high. Installation of root cleaners in commercial plants would be an added capital expense but would upgrade product quality tremendously.

Size reduction

The purpose of size reduction (cutting, chipping, and slicing) is to make the bulky roots more manageable and to hasten drying. The increased surface area of cut roots allows moisture diffusion to occur faster. Roots which are not reduced in size often suffer from mold attack and are more likely to pick up foreign matter. On the other hand, size reduction requires additional labor and some farmers argue that whole dried roots are easier to pack and carry. Dried slices or chips may break more easily and result in higher losses during drying and transportation. In addition, many times there is no economic incentive for farmers to produce smaller, better-dried, and therefore higher-quality cassava chips.

Sun drying

The vast majority of cassava is dried in the sun, while a small percentage, that produced on a commercial scale, is artificially dried. Sun drying rates depend on root size, drying surface, aeration, and turning frequency. Manurung (1974) reported that the overall heat efficiency of sun drying is only 11-14%, due to incomplete absorption and re-radiation, heat transfer by convection to the atmosphere, and heat transfer by conduction through the drying floor (if used) to the ground.

At the commercial level, improved methods of root drying, such as the use of blackened surfaces, raised and/or inclined trays, and frequent turning, may be implemented without restriction. At the farm scale, however, the farmer is usually limited as to space for drying and money for investments such as concrete and materials for trays. Perhaps the biggest deterrent to upgrading drying methods at the farm level is the farmer's lack of awareness that a better method exists and lack of the technical knowledge to implement improved methods. The development of cooperatives at the farm and processing levels would serve to coordinate the multitude of small units currently processing cassava and would assist in technology improvement. Another factor playing a part in poor drying techniques is the lack of acceptable, workable grades and standards for quality control and the difficulty of implementation and supervision.

Artificial drying

Although the costs of equipment, fuel, and maintenance used in artificial drying are high, other advantages outweigh these disadvantages in large-scale cassava root processing operations. These advantages include reduction of space and labor, lack of dependence on weather conditions, and better control of product quality. Research is still required to monitor time-temperature relationships and their effects on gelatinization, caramelization, and case hardening of cassava during drying. Artificial drying beginning with fresh roots may not be economical due to their high moisture content, and an initial sun drying step may be required. It should be possible to coordinate this with activities at the farm level.

Storage

The storage of fresh cassava roots is hampered by the speed with which physiological deterioration and mold attack take place. Various short-term storage methods, including reburial, storing under water, coating with mud or wax, refrigeration, and the use of clamps (earthen and straw-covered structures covering piles of heaped roots) and moist packaging to stimulate root curing have been investigated. In general, these methods require additional inputs of manpower and materials and have not been received with enthusiasm. Recent studies (CIAT, 1984) have concluded that storage in economical plastic bags would insure product quality for 10-14 days.

Dried cassava products are much more stable and storage deterioration appears to result from exogenous factors, such as insect and mold attack, rather than endogenous ones (Coursey et al., 1982). In Malaysia and Thailand, dried cassava chips are only stored for a few days before being sent to farms, feed producers, or pelletizers. In Indonesia, however, storage of uncut roots in the farmer's home or processor's warehouse may be extended and often results in high levels of mold and insect infestation. Farm-level storage methods need to be improved and processor-level storage times reduced in order to upgrade dried root quality.

Research Needs for Specific Products

Food

Typical steps in food production. Both the cassava roots and leaves may be used for human consumption. The average composition of roots and leaves appears in Tables 1 and 2. A great diversity of techniques has been developed for the production of food products from cassava, and these techniques differ from country to country. Some techniques are merely general methods of preparation which may be applied to any starchy food, while others would appear to have specific objectives such as HCN reduction or increased storability.

In Asia, food products are created from both fresh and dried cassava. Fresh cassava may be consumed raw or following cooking (boiling, stewing, steaming, frying, roasting, baking) in the form of whole tubers, tuber pieces, chips, or grated cassava. It may also be consumed following fermentation (Figure 1). Dried cassava is used as a food product as well, particularly as *gaplek* in Indonesia. Typical dried cassava processing steps appear in Figure 2. Cassava leaves are usually processed simply (Figure 3) and consumed as a vegetable.

Consumer preference. Cassava is generally thought to be an inferior food. Phillips (1974) and Dixon (1982) found that cassava consumption generally decreased as income increased. One exception to this general trend was found in the demand for fresh roots, which continued to increase to a certain level. Cassava consumption differs in rural and urban areas. In Indonesia, for example, urban demand is low and is geared almost entirely towards fresh cassava as a snack or vegetable, whereas rural demand is higher and is fairly evenly divided between fresh and dried cassava, which function as a staple food (Dixon, 1982). If domestic consumption of cassava and cassava products is to increase, it will be necessary to upgrade the prestige value of cassava and to change the conception of it as a poor man's food.

Nutritional composition. In order to objectively analyze the question of cassava's so-called inferiority, one is required to look at nutritional composition and energy value as related to alternative staples. Cassava is basically a starchy food (Table 1) and its main value is as a source of carbohydrates. Although the comparative food value of cassava to other starchy crops is low, in terms of cost of production and yield of calories per hectare, cassava comes out ahead (Table 3). On a dried root basis, calories per 100 g of edible material are similar to those of rice and maize. Cassava is rich in vitamin C and calcium but poor in protein and other vitamins and minerals. The protein content of cassava is not only low but it is of poor

Table 1. **Nutritional composition of fresh cassava roots.**

Item	Composition of cassava roots per 1,000 g edible portion[a]			
	1	2	3	4
Food energy (megajoules)	5.481	6.109	5.481	6.025
Water (g)	600	625	647	620
Carbohydrates (g)	320	347	327	350
Protein (g)	7	12	11	7
Fat (g)	trace	3	3	0
Calcium (mg)	250	330	330	250
Phosphorus (mg)	-	-	530	500
Iron (mg)	10	7	8	5
Vitamin A (I.U.)	0	trace	trace	-
Thiamine, B1 (mg)	0.2	0.6	0.7	0.2
Riboflavin, B2 (mg)	1	0.3	0.3	0.7
Niacin (mg)	-	6	6	6
Vitamin C (mg)	300	360	400	300

a) Samples taken from different analytical sources.
Source Jones, 1959.

Table 2. **Nutritional composition of fresh cassava leaves.**

	Composition of leaves per 100 g edible portion[a]				
	1	2	3	4	5
Food energy (megajoules)	0.18	0.26	0.23	-	-
Water (g)	85	80.5	74	-	-
Carbohydrates (g)	6	9.6	5	-	-
Protein (g)	4	6.8	7.5	-	-
Fat (g)	0.4	1.3	0.7	-	-
Calcium (mg)	210	206	100	206	-
Iron (mg)	3	2.6	3.0	3.5	-
Vitamin A (I.U.)	13,000	10,000	9,000	-	-
Thiamine, B1 (mg)	0.15	0.16	0.30	0.15	0.27
Riboflavin, B2 (mg)	0.25	0.30	0.43	0.30	0.42
Niacin (mg)	0.85	1.8	1.5	2.0	3.53
Vitamin C (mg)	100	265	60	311	320

a) Samples taken from different analytical sources.
Source. Jones, 1959.

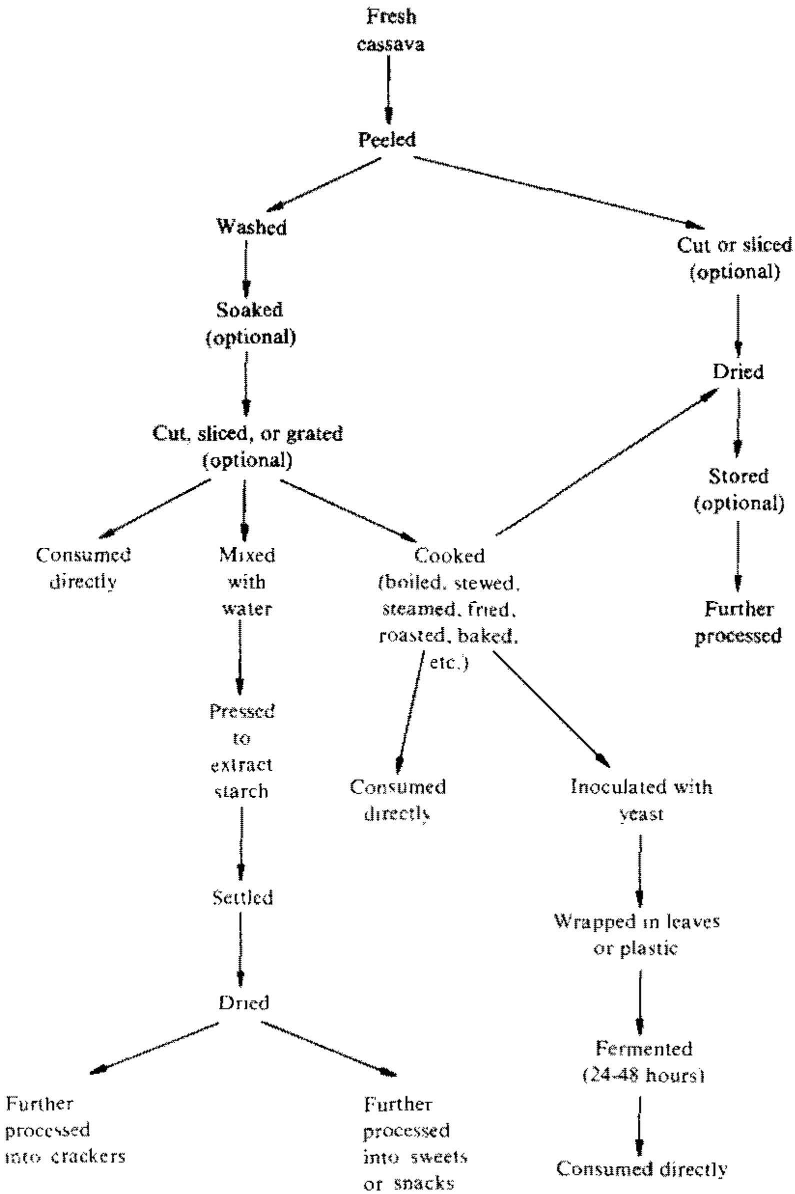

Figure 1. *Typical steps for production of food products from fresh cassava*

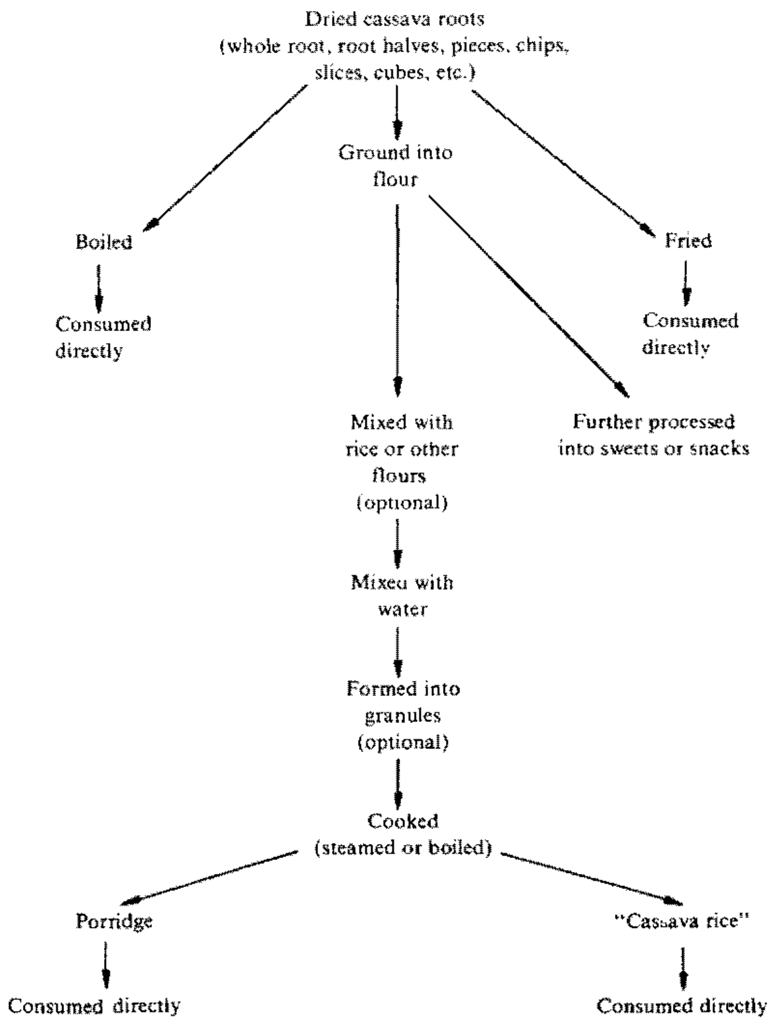

Figure 2. *Typical steps for production of food products from dried cassava.*

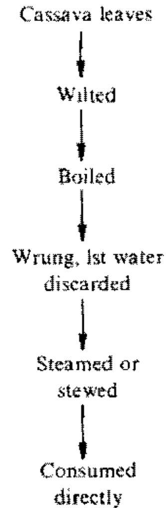

Figure 3. *Typical steps for production of food from cassava leaves.*
Source: Dixon, 1982.

Table 3. **Calorie productivity of various staple food crops.**

Food crops	Calorie productivity (calories/ha/day)
Cassava	250 x 10^3
Rice	176 x 10^3
Wheat	110 x 10^3
Corn	200 x 10^3
Sorghum	114 x 10^3

Source: Hendershott et al., 1972.

quality. A major proportion exists as simple nitrogenous compounds. Digestibility of cassava protein is similar to that of rice, with approximately 48% biological value. Cassava protein is low in the essential amino acids lysine, methionine, and tryptophane.

It has been reported that traditional processing techniques generally have a detrimental effect on the nutritional value of cassava, reducing the protein, vitamin, and mineral content even further. At the present time, therefore, cassava must be viewed principally as a source of carbohydrates.

Meanwhile, research on genetic improvement of cassava is taking place in various locations. CIAT has selected a new variety, Llanera, with 7% protein (dry basis) and the International Institute of Tropical Agriculture (IITA) is investigating yellow-fleshed varieties with high carotene. Potential methods of upgrading the protein content of cassava besides breeding involve fermentation and microbial synthesis of protein. (See last section of this paper.)

Hydrogen cyanide presence. An aspect of cassava composition that causes concern is the presence of HCN. Hydrogen cyanide content of cassava depends on many factors, the most important of which is genetic constitution. An analysis of the HCN content of cassava leaves, bark, and roots of two clones having relatively low HCN concentration (about 50 µg HCN/g fresh weight) and two clones having relatively high HCN concentration (about 200 µg HCN/g fresh weight) is shown in Table 4. Hydrogen cyanide is one of the most powerful poisons known: 50-60 mg HCN is a lethal dose for an adult male weighing 50 kg (Nestel et al., 1977). Cassava contains two cyanogenic glucosides, linamarin and lotaustralin, which are hydrolized in the presence of the endogenous enzyme linamarase to liberate hydrogen cyanide. Therefore, in order to bring linamarase in contact with cyanogenic glucosides, tissue cells must be ruptured and HCN eliminated by volatilization or solution in water.

Traditional methods of cassava processing appear to reduce HCN levels considerably; however, little published information exists on this subject. In addition, past analytical methods for HCN detection were questionable and results varied a great deal. A new, more sensitive method for HCN has been developed recently and it is hoped that use of this method will clarify past discrepancies. Future research needs include analysis of traditional detoxification methods and resultant products, agronomic practices influencing HCN concentration, and genetic manipulation to produce a cassava variety low in HCN content.

Desirable varietal characteristics. Cassava varieties for human consumption should possess the following characteristics: high starch and improved protein contents, low HCN content, high degree of consumer acceptance (appearance, texture, odor, and taste), ease in preparation, a variety of utilization properties, and extended keeping quality after harvest.

Starch

Typical steps in starch production. Starch production techniques differ slightly depending on location and size of operation. A flow chart for steps involved in large-scale starch production appears in Figure 4, while the steps for small-scale production are illustrated in Figure 5.

Table 4. **Distribution of glucoside in plants of four clones (μg HCN/g fresh weight).**

Part of plant	Clones				Average
	Tabouca	A 13	Ta 25	461	
Leaf blades					
Very young, in expansion	330	330	490	790	490
Just full grown	420	340	570	1040	590
Older	250	210	320	730	380
Leaf stalks					
Very young, in expansion	400	750	770	940	720
Just full grown	210	350	350	460	340
Older	120	110	170	180	150
Stem bark					
Near oldest leaves	270	350	550	1330	630
At $\frac{2}{3}$ of leafless part	90	230	330	580	310
At $\frac{1}{3}$ of leafless part	190	420	430	650	420
Lowest part	550	680	900	970	780
Bark of cutting	190	370	810	390	440
Bark of tuberous roots	400	540	890	730	640
Inner part of tuberous roots	36	55	210	240	140

Source: Nestel and Graham, 1977.

Supply of raw materials. Lack of a consistent and dependable supply of raw materials, i.e., cassava roots and water, is often the biggest limitation in starch production. Edwards (1974) calculated the raw material needs for various-sized factories (Table 5). Many times not enough thought is given to factory location or feasible factory size prior to construction and the starch processor finds, too late, that the factory is not able to run at optimal capacity.

Starch quality. The quality of starch produced is often low due to lack of knowledge and/or technical supervision. For example, water for washing

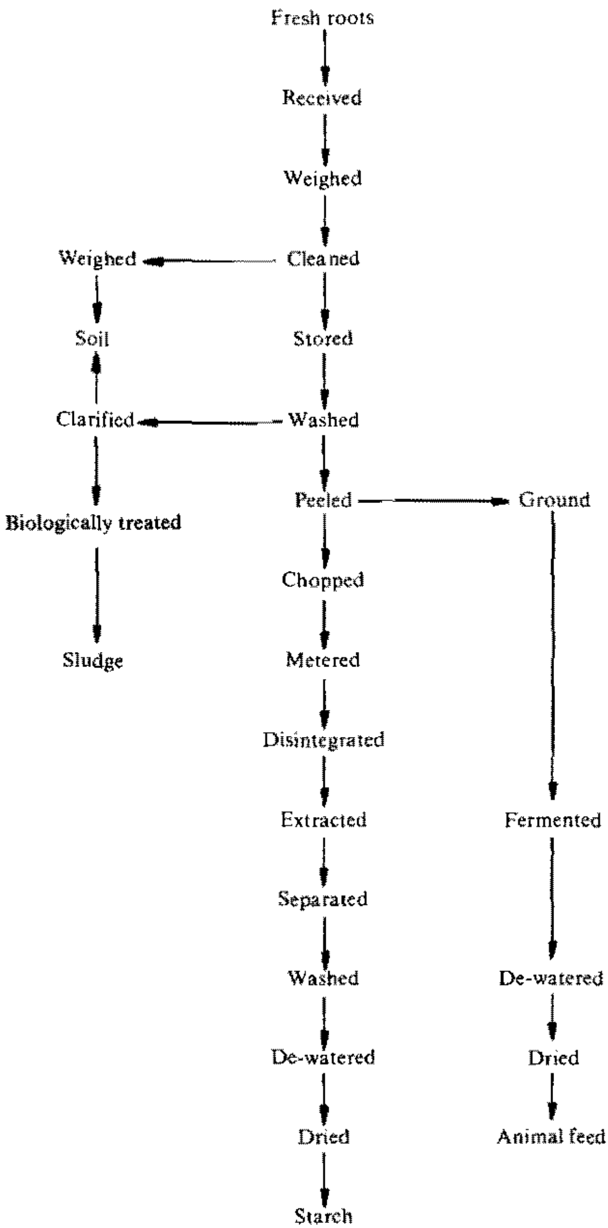

Figure 4. *Large-scale cassava starch processing.*
Source: Dahlberg, 1978.

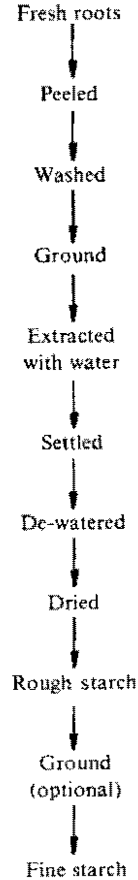

Figure 5. *Small-scale cassava starch processing.*

roots may be either unfiltered river water or well water; for starch extraction either filtered river water or well water may be used. Failure to use clean water will result in the incorporation of impurities in the starch. In addition, cyanide is known to react with iron and other metals which may be found in water, and produce dark compounds. Insufficient drying of starch will encourage the growth of mold. Standards for cassava starch have been developed in various countries (Table 6) in order to insure quality. However, these standards differ drastically. It should be emphasized that in order to eliminate microbial growth, the maximum moisture content allowable in cassava starch is 14%.

Sanitation. The need for sanitary practices is often not sufficiently stressed. It is common for piles of cassava peelings to sit in peeling rooms,

Table 5. **Cassava root and water requirements for starch production.**

	Operating capacity (based on one working shift per day)		
	535 tons starch per year	1075 tons starch per year	3225 tons starch per year
Cassava roots (t)	2,320	4,660	14,000
Water[a] (liters)	18,600,000	37,280,000	112,000,000

a) 8,000 liters clean water per ton of roots; not included: 5,000-15,000 m^3 of additional crude water (drawn from river).

Source: Edwards, 1974.

attracting insects and rodents. Often cleaning equipment and pressing cloths are not cleaned frequently, and pieces of root become lodged in them and spoil there. Finally, the fibrous pulp and acidic water produced as waste products are not always properly treated, but rather dumped directly into the nearest river. In general, sanitary practices require greater care than is currently practiced.

Desirable varietal characteristics. Cassava varieties destined for starch production should possess the following characteristics: high starch content, good quality starch, high root yield, roots of simple and uniform shape, thin skin, good storage potential, palatability in foods, and white color.

Animal feed

Typical steps in animal feed production. Cassava products used in animal feed include cassava meal (residue of roots and chips after starch processing), cassava chips, and cassava pellets. The typical steps used in chip and pellet processing are outlined in Figure 6. Native and brand pellets, the two types of cassava pellets produced in Thailand, differ in processing steps and subsequent pellet quality. Brand pellet producers precondition feed ingredients through the addition of heat and water, use greater heat and pressure in pellet formation, and cool the pellets following extrusion. These steps are not usually performed by producers of native pellets (Thanh, 1974).

Supply of raw materials. As is the case with starch, the supply of cassava roots for animal feed production is not consistent or reliable. Processors find it too expensive to stockpile cassava feed, and unforeseen changes in feed components also result in economic loss. Edwards (1974) estimated cassava root needs for various-sized animal feed factories as outlined in Table 7

Table 6. **Cassava starch standards in selected countries.**

Component	Indonesia			India		Brazil	Malaysia		U.S.A.		U.K.
	I	II	III	Edible	Textiles		Edible	Textiles	Paper	Food	
Starch (% max) (dry basis)	-	-	-	98.0	98.0	80	-	-	-	-	-
Moisture (% max)	17	17	17	12.5	15.0	14	12.5	12.5	13.5	14.0	8-12
Ash (% max)	0.6	0.6	0.6	0.5	0.4	1.0	0.4	0.5	0.2	0.3	-
Fiber (% max)	-	-	-	0.3	0.6	-	0.2	0.8	-	-	-
pH	-	-	-	4.5-7.0	> 4.8	-	3.8	3.8	6.5-7.0	5.0-7.0	-
Acidity $\left(\frac{\text{ml .1 N NaOH}}{\text{100 g}}\right)$	<4	<4	< 4	-	-	-	-	-	-	-	-
Viscosity	3-4	2.5-3	> 2.5	-	-	-	-	-	-	-	-
HCN	-	-	-	-	-	-	-	-	-	-	-
Whiteness ($BaSO_4$ = 100%)	≥ 94.5	≥ 92.0	< 92.0	-	-	-	-	-	-	-	-

Source: Ingram, 1975.

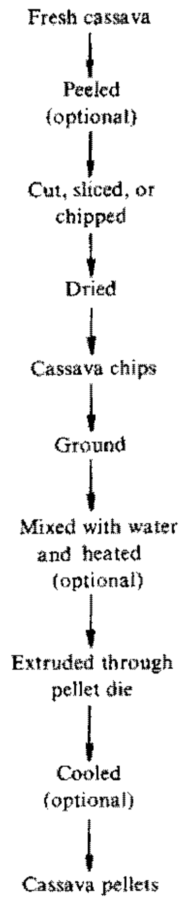

Figure 6. *Cassava chip and pellet processing.*

Table 7. **Cassava root and water requirements for animal feed production.**

	Operating capacity (based on one working shift per day)			
	700 tons dried chips per year	4900 tons dried chips per year	4900 tons pellets per year	9800 tons pellets per year
Cassava roots (t)	2,000	14,000	14,000	28,000
Water[a] (liters)	5,000,000	35,000,000	35,156,000	70,312,000

a) Washing and peeling: 2500 liters per ton of roots.
Pelleting: 156,000 liters for steam raising per shift of 2.5 tons per hour.

Source: Edwards, 1974.

Processing technology. Basic studies on the pelletizing characteristics of cassava, including materials flow characteristics, gelatinization degree necessary, and minimum pressure required are sorely lacking (Manurung, 1974). In addition, practical studies of the optimum conditions for conventional sun drying of sliced or chipped roots, comparative economics of the use of screens and hammer mills, and preconditioning and cooling advantages must be performed. Investigations are presently being conducted, but final recommendations are by no means available.

Product quality. The quality of cassava products used for animal feed is, in general, low due to two main factors:

1. Poor protein, mineral, and vitamin content of cassava.
2. Lack of quality control in processing and storage.

The intrinsic quality of cassava as a whole might be improved through genetic manipulation or microbial synthesis of protein. The present method of overcoming this problem is to supplement the feed with proteins, minerals, and vitamins.

The lack of quality control, which is fairly universal in cassava animal feed production, has been the cause for criticism by European customers. Typical complaints are that minimum starch content (62%) is not achieved; maximum sand and foreign matter contents (7% raw cellulose and 3% sand) are exceeded; maximum moisture content (14%) is exceeded; bacteria and mold content are too high; and pellets are of a poor, friable consistency (Thanh, 1974). Standards for cassava flour, chips, and pellets are presented in Tables 8, 9, and 10, respectively. In addition to the use of these standard analyses, simple methods for determination of abrasion and shatter resistance of pellets should be developed (Manurung, 1974).

Storage. Storage losses incurred in Malaysia and Thailand are not as high as those in Indonesia due to the short storage time. Coursey et al. (1982) cite reported weight losses due to insect attack of up to 16% in 2 months' storage in Malaysia. The most destructive insects in this study were found to be *Rhysopertha dominica, Lasioderma serricorne* F., and *Araecerus fasciculatus* de Geer. The enforcement of strict quality standards would force farmers and processors to take more care in their treatment of cassava animal feed products. In addition, the use of fumigants or insecticides, where economical, would arrest infestation.

Desirable varietal characteristics. The characteristics of cassava destined for animal feed might include the following: high root yield, ease of harvesting, maximum foliage without sacrificing root yield, high starch and improved protein content, low HCN content, roots of uniform size and shape, thin skin, and good storage potential.

Table 8. **Dried cassava flour standards in selected countries.**

Component	Indonesia			Brazil		India	Paraguay	Malagasy		
	I	II	III	I	II			I	II	III
Starch (% min)	70	68	65	71.0	70.0	82.0	70-82	-	-	-
Moisture (% max)	14	14	15	13.0	14.0	13.0	12.5	-	-	-
Fiber (% max)	4	5	6	-	-	2.1	-	-	-	-
Filth and ash (% max)	4.0	5.5	7.0	-	-	-	-	-	-	-
Ash (% max)	-	-	-	2.0	2.0	1.8	1.6	-	-	-
Filth (% max)	-	-	-	0.5	1.0	-	-	-	trace	trace
Pulp (ml)	-	-	-	40.0	45.0	-	-	-	-	-
Acid insoluble ash (% max)	-	-	-	-	-	0.10	-	-	-	-
pH	-	-	-	-	-	4.5-7.0	3.5	-	-	-
Cold water solubles (% max)	-	-	-	-	-	11.0	-	-	-	-

Source: Ingram, 1975.

Table 9. **Dried cassava chip standards in selected countries.**

Component	Indonesia			Brazil		Thailand	India	Tanzania
	I	II	III	I	II			
Starch (% min)	70	68	65	75.0	70.0	70.0	-	75
Moisture (% max)	14	14	14	13.0	14.0	14.0	13.0	-
Fiber (% max)	4	5	6	-	-	5.0	2.1	2 - 3
Ash and filth (% max)	4	5.5	7	-	-	-	-	-
Acidity (ml .1 N NaOH / 100 g)	-	-	-	2.0	2.5	-	-	-
Ash (% max)	-	-	-	2.0	3.0	-	1.8	1.0
Filth (% max)	-	-	-	1.0	2.0	3.0	-	-
Acid insoluble ash (% max)	-	-	-	-	-	-	0.10	-
Cold water solubles (% max)	-	-	-	-	-	-	11.0	-
pH	-	-	-	-	-	4.5-7.0	-	

Source : Ingram, 1975.

Table 10. **Cassava pellet standards in selected countries.**

Countries	Indonesia			India		Thailand	EEC
	I	II	III	Chips	Flour		
Starch (% min)	70	68	65	82	82	700	70-75
Moisture (% max)	14	14	15	10	10	14.0	13-14
Fiber (% max)	4	5	6	2.5	2.5	5.0	5
Filth and ash (% max)	40	5.5	7.0	-	-	-	-
Ash (% max)	-	-	-	2.5	2.5	3.0	-
Filth (% max)	-	-	-	-	-	-	3
Raw cellulose (% max)	-	-	-	-	-	-	-
Acid insoluble ash (% max)	-	-	-	1.0	1.0	-	-
HCN (% max)	-	-	-	00.3	00.3	-	-
Alcoholic acidity as H_2SO_4 in 90% alcohol (% max)	-	-	-	0.15	-	-	-

Sources: Ingram, 1975. Philips, 1974.

Hydrolized starch products

The production of hydrolyzed cassava starch products, i.e., ethyl alcohol, single cell protein, and high-fructose syrup, may provide the newest market potential for cassava. Each product is discussed briefly below.

Ethyl alcohol. Interest in the production of ethyl alcohol from cassava has initiated research activities in Brazil, France, and other countries. Ethanol is being promoted as a replacement for imported fuel. The French Ministry of Industry and Research recently authorized oil companies to include a variable proportion of substitute fuel derived from sugar-producing plants and tubers and seeds that synthesize starch. The method for producing ethyl alcohol from cassava is outlined in Figure 7.

Mixtures of gasoline with up to 15% cassava alcohol does not incur difficulties, but higher concentrations result in higher fuel consumption, more tendency to corrode, and decreased performance. A more in-depth look at the above effects and economic feasibility needs to be taken before operations begin on a larger scale.

Single cell protein. The feasibility of using cassava as a substrate in the production of single cell protein (SCP) has been verified by research at the Universities of Guelph and Malaya, and the International Center for

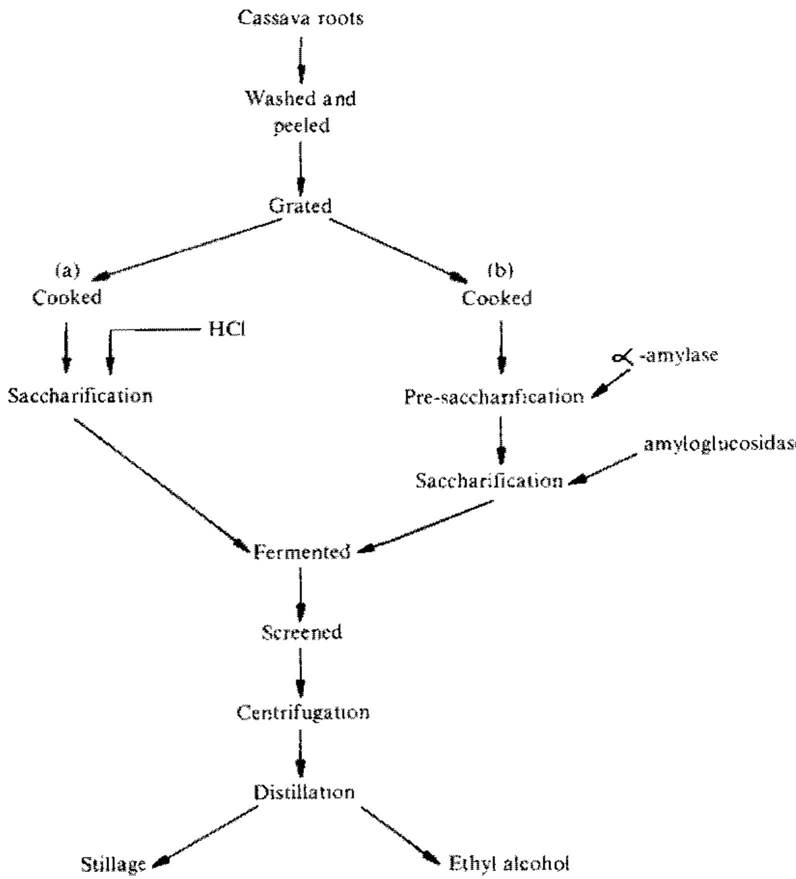

Figure 7. *Flow chart of cassava alcohol production: (a) acid hydrolysis and (b) enzymic hydrolysis.*
Source: de Menezes, 1978.

Tropical Agriculture (CIAT). A flow diagram of typical processing steps appears in Figure 8. A method for small-scale (3000-liter capacity) production of a nearly balanced pig feed is now possible under nonseptic tropical conditions (Phillips, 1977). The SCP resulting from this process is not fit for human consumption; therefore, research activities will be geared to the animal feed market.

High-fructose syrup. Another emerging market for cassava use is in high-fructose syrup (HFS). Increases in global consumption of sugar and wide variation in sugar prices in recent years have led to the search for

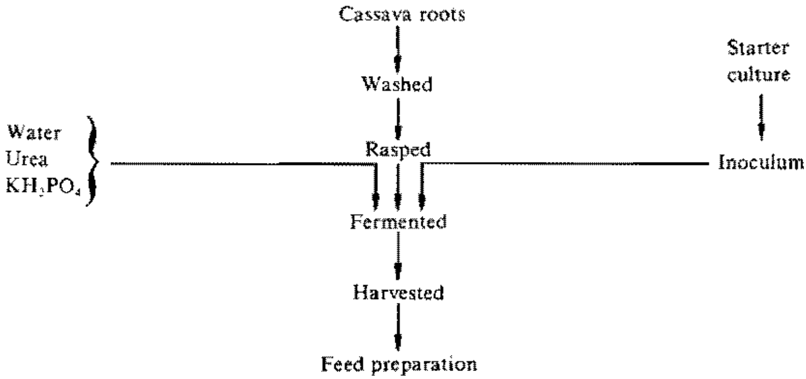

Figure 8. *Flow diagram of cassava single-cell protein fermentation.*
Source: Santos and Gomez, 1977.

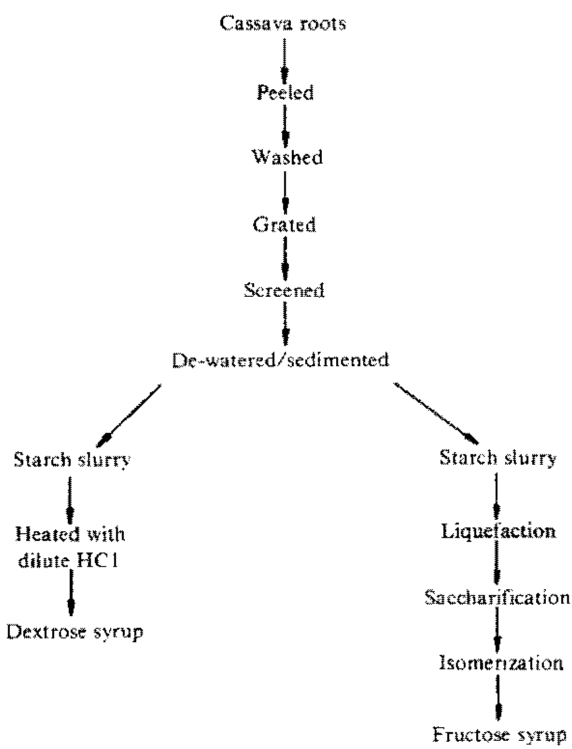

Figure 9. *High-fructose syrup production.*

alternative sweeteners. Fructose is 1.5 times as sweet as sucrose and therefore would be a feasible alternative. It is now possible, using the basic processing steps outlined in Figure 9, to produce a high-fructose syrup containing 42% fructose, 50-52% glucose, and 6-8% higher saccharides from various starchy food crops. With the additional manipulation of column chromatography separation, fructose content may reach as high as 90-95%. The future potential for HFS production from cassava will rely, to a great extent, on world sugar prices and the comparative price of cassava.

Conclusions

Cassava utilization patterns differ in each Asian country. Starch would appear to be the major potential market in Indonesia and India. In Thailand, the Philippines, and Malaysia, future development policies will be geared towards the animal feed market, with Thailand exporting to non-EEC countries and the Philippines and Malaysia using the feed internally.

Postharvest losses of cassava are estimated at a minimum of 20-25%, with major losses occurring during the drying and storage stages. Lack of knowledge of proper postharvest practices and lack of economic incentive to improve existing practices combine to create a situation where cassava products are of poor quality.

Food consumption is restricted by the perception of cassava as an inferior food and its low protein, mineral, and vitamin contents.

Starch production is hampered by the lack of a consistent, dependable supply of fresh roots and water. Little care is taken in sanitary practices and resultant starch quality is often poor.

The production of animal feed is also limited by raw material supply. Improvements in present processing methods and greater overall quality control must be achieved before product quality is upgraded. Storage losses due to insects are high but may be avoided through the use of fumigants or insecticides.

Hydrolyzed starch products, such as ethyl alcohol, single cell protein, and high-fructose syrup have emerged as areas of great potential for cassava utilization.

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Extending New Cassava Technology - the Lab-to-Land Program in Southern India

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S. Ramanathan

Genesis of Lab-to-Land Program

The socioeconomic development of the Indian rural population started with the initiation of community development programs in 1952. During the 1960s, intensive production-oriented projects like the Intensive Agricultural District Program (IADP), the Intensive Agricultural Area Program (IAAP), the High Yielding Varieties Program (HYVP), the National Demonstration Program, and the Multiple Cropping Program were initiated. These were followed by commodity-oriented development projects for increasing the production of crops like tobacco, sugarcane, cotton, oil seeds, fruit, and other food crops in the early 1970s. All these programs made good progress, but evaluation studies indicated that their benefits often did not percolate down to the vast majority of the poorer sections in rural India.

Realizing the importance of development with social justice, programs to target specific groups like the Small and Marginal Farmers Development Agency, the Tribal Development Program, and the integrated Rural Development Program (IRDP) were launched. In spite of these changing strategies of rural development in India, it was noted that a majority of the viable technologies generated at the research institutes and agricultural universities were yet to reach the intended clientele, leaving a wide gap between technology generation and technology utilization. As a major step towards bridging this gap, the Indian Council of Agricultural Research (ICAR) developed the Lab-to-Land Program commemorating its Golden Jubilee Celebrations during 1979. This program helps transfer proven technologies to the farmers' fields and enables research scientists to gain practical experience of the problems associated with the technology transfer process.

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In southern India, comprising the states of Kernataka, Kerala, and Tamil Nadu and the union territories of Pondicherry and Lakshadweep, the Lab-to-Land Program was undertaken by 13 technology transfer centers. They include three agricultural universities, six ICAR central research institutes, and four voluntary organizations located in southern India. These agencies together adopted 8120 small and marginal farmers and agricultural laborers for their overall development (Table 1), out of 50,000 families throughout the entire country who benefited under the first phase of the program.

Under the second phase, the number of farm families was increased to 75,000 in the nation, thereby increasing the beneficiaries of the southern zone from 8120 to 12,000. A wide range of technologies relating to crops like paddy, cassava, cotton, pulses, and vegetables, besides improved fish culture and processing techniques, were transferred to the adopted farm families. These technologies were well received by the beneficiaries, as they were effective in improving their economic condition.

Table 1. **Farm families adopted under Lab-to-Land Program in southern India.**

Implementing agency	No. of adopted families	
	Phase I (1979-82)	Phase II (1982-84)
Agricultural universities	5920	8100
ICAR institutions	1674	2600
Voluntary organizations	526	1300
Total	8120	12000

CTCRI Program

CTCRI (Central Tuber Crops Research Institute), specializing in the research and development of tropical root crops in India, was identified as one of the technology transfer centers for implementing the Lab-to-Land Program. The aim of this program was to popularize two new cassava hybrids, Sree Vishakom (H-1687) and Sree Sahya (H-2304), using groundnut as an intercrop in between cassava rows to get an early additional income from cassava plots. The program was constituted of two phases; 200 farmers having small and marginal holdings in Kerala and Tamil Nadu were assigned to each phase. Details of the program are given in Table 2.

Marginal farmers operating less than 1 ha of land constituted 78% of the selected farmers during the first phase of the program and 91.5% during the second phase. The remaining farmers operated small holdings between

Table 2. **Details of CTCRI Lab-to-Land Program.**

	Phase I	Phase II
No. of states covered	2	2
No. of villages adopted	4	4
No. of farm families benefited	200	200
No. of marginal farmers	158	183
Area brought under hybrid cassava (ha)	19.82	23.20
Area brought under groundnut intercrop (ha)	15.77	23.20

1 to 2 ha. Since an understanding of the present farming conditions is necessary in planning for future development, the program started with a benchmark survey of the adopted families to take stock of the resource availability and utilization pattern at the farm level.

Profile of cassava farmers

Age. About 29% of the farmers were from the young age group under 35 years old, while 61% were from the middle age group (36-60) and 10% were from the old age group (above 60).

Education. About 15% of the farmers were illiterate. Among those that were literate, 40% had primary school education, 26% had high school education, and 16% had middle school education. Only 3% had education above the high school level.

Family size and type. The majority of the farmers (60%) belonged to large families (more than five members). Around 87% were nuclear families.

Occupation. Nearly 50% of the farmers were agricultural laborers who derived a major portion of their income through agriculture, while 39% of the farm families were entirely dependent on agriculture for their livelihood. About 12% of the families derived additional income apart from agriculture from small business and cottage industries.

Media exposure for farm messages. It was observed that only a very few farmers obtained farm messages from media like newspapers and radio.

Farm size. The average size of the farm holding was 0.25 ha. The major part of the holding (70%) was non-irrigated. About three-fourths of the farmers possessed land holdings of up to 0.4 ha only.

Program implementation

With the farm family as the basic unit of development, a cluster approach was adopted in selecting and implementing the technology transfer program to achieve the desired socioeconomic impact and spread of new cassava technologies in the social system of the adopted villages. Individual family farm plans were developed, keeping in mind the capability and resource potential of farm families. These plans were implemented with the active cooperation of the allied development and credit institutions functioning at the village level. On-farm demonstrations, the only effective method in proving the worth of the technology and giving working experience to the farmer, were the major techniques employed in technology transfer, combined with other suitable methods and media.

CTCRI organized an exposure training program in improved cassava cultivation as the first step in introducing the new cassava technologies to the adopted farm families. This was followed by demonstrations laid out in the farmers' fields with hybrid cassava and groundnut intercropping. The inputs, supplied free of cost, acted as external motivating factors in the adoption of technologies. An interdisciplinary team of scientists gave the necessary guidance and supervision to farmers in conducting the demonstrations through weekly farm and home visits. This efficient system of technology transfer also enabled the technology generators to understand the operational constraints in the adoption of technology. The field days, exhibitions, press coverage, and radio programs undertaken on appropriate occasions gave wide coverage to the program. Besides the transfer of new cassava technology, overall training of farm families was undertaken by integrating agriculture with animal husbandry and cottage industries.

Socioeconomic impacts

The impact of any program is judged by the extent of achievement of its goals. The impact of extension-oriented programs can be viewed from three angles: 1) economic benefit accrued through the technologies transferred, 2) effect of the program on behavioral changes of adopted farmers and, 3) spread of the technology in the social system.

Economic benefits. The new cassava hybrids in the demonstration trials have recorded impressively high yields, thus proving their high-yielding potential under farm conditions. The yield and income statistics of the new cassava technology are given in Table 3. The hybrids Sree Vishakom and Sree Sahya yielded an average of 27 tons/ha while the local varieties gave only 12 tons/ha. Thus, a 125% increase in yield was achieved through the introduction of the new hybrids. After meeting all costs, the adopted

Table 3. **Economic impact of new cassava technologies under Lab-to-Land Program.**

	Phase I[a] (1979-82)	Phase II[b] (1982-84)
Mean yield of hybrid cassava (t/ha)	27.30	27.00
Mean yield of groundnut intercrop (kg/ha)	625	290
Net income from cassava (Rs/ha)	5,125	5,000
Net income fron groundnut (Rs/ha)	1,400	1,000
Total income (Rs/ha)	6,525	6,000

a) Average of 3 years.
b) 1 year.

US $1.00 = Rs 10.00.

farmers obtained an average net income of about Rs 5,000 (US $500) per hectare from the introduced cassava varieties.

Similarly, the groundnuts raised as an intercrop with cassava enabled the farmers to get an additional income of about Rs 1000-1500 (US-$100-150) per hectare. This income was of great help to the small-scale cassava farmers as it was obtained only 3 to 3 1/2 months after planting. Apart from the early additional income, the intercropping technology effectively utilized the manpower available within the farm families. It is estimated that by the adoption of new cassava technologies, an additional employment of about 125 labor days per hectare was generated.

Behavioral changes. Major components attributable to behavioral changes in farmers as a result of technology introduction are change in knowledge and adoption levels.

Knowledge about improved technologies is a prerequisite and a catalytic variable for practical adoption at the farm level. The Lab-to-Land Program is primarily an extension effort to increase farmers' knowledge of technologies. Change in knowledge level brought about by the program would be a measure of its success. In order to evaluate change in knowledge, a survey was undertaken before and after the program. The overall and specific level of knowledge before and after the program is given in Table 4. From the data presented, it can be seen that prior to the program, the majority of the farmers (87%) possessed low knowledge on specific practices like seeds and sowing, manures and manuring, after care, and groundnut intercropping. One year after the program there was significantly increased knowledge of agricultural practices except in the case of fertilizer application, where only slight improvement was noticed. This could have resulted from difficulties in recalling numerical recom-

Table 4. **Knowledge level before and after Lab-to-Land Program.**

Practices	Knowledge level before program (% of farmers)			Knowledge level one year after program (% of farmers)		
	Low	Medium	High	Low	Medium	High
Seed and sowing	70	20	10	3	7	90
Manures and manuring	100	-	-	56	24	20
After care	96	4	-	10	30	60
Groundnut intercropping	100	-	-	16	30	64
Overall knowledge	87	13	-	13	73	14

mendations coupled with lack of interest in fertilizer application due to its cost factor.

Adoption of the technologies is governed by, besides many other factors, the soundness of the technology and mental preparedness of the farmers. Overall adoption behavior of farmers was observed before and after the program (Table 5). The data indicate that the majority of the farmers were in the low adoption category before the program,and that after exposure to the program, many farmers adopted improved technologies.

An attempt was also made to analyze the adoption of specific practices to better understand the acceptance procedure. Table 6 shows that in the pre-program period, the majority of the farmers continued with the traditional practices, except for practices concerning stake length. The reasons for the lack of adoption of high-yielding varieties, fertilizer application, spacing, and other practices were lack of seed materials, capital, and knowledge. After one year remarkable acceptance was observed in some of the practices, such as high-yielding varieties, stakes per hill, stake length, planting method, spacing, and retention of shoots. Reasons for only partial adoption of practices were lack of capital (for fertilizer application), no reduction in yield (for mosaic control), and pest menace (for groundnut intercropping).

Table 5. **Overall adoption level before and after Lab-to-Land Program.**

Adoption level	Before program (% of farmers)	One year after program (% of farmers)
Low	87	7
Medium	13	46
High	-	47

Table 6. **Adoption-specific practices before and after Lab-to-Land Program.**

Practices	Before program			One year after program		
	Recommended practice (% of farmers)		Traditional practice (% of farmers)	Recommended practice (% of farmers)		Traditional practice (% of farmers)
	Full adoption	Partial adoption		Full adoption	Partial adoption	
High-yielding varieties	-	13	87	27	47	26
Stakes per hill	30	10	60	93	7	-
Stake length	60	-	40	100	-	-
Planting method	17	-	83	90	-	10
Spacing	13	10	77	43	27	30
Fertilizer application	-	17	83	-	46	54
Mosaic control	-	-	100	23	13	64
Retention of two shoots	33	-	67	70	6	24
Groundnut intercropping	-	-	-	27	20	53

Technology spread. Spread of technology is a vital part of any extension program as it socializes the benefits to other members of the community. The technology spread was measured in terms of extent of introduced varieties in the farms of beneficiaries as well as non-beneficiaries. It was found that the introduced hybrids had spread to nearly 34% of the area of adopted farmers and nearly 12% of the area of non-adopted farmers just one year after introduction.

Conclusion

The remarkable change in the knowledge level and adoption behavior of farmers and the satisfactory spread of technology to non-adopted farmers confirms the significant impact of the Lab-to-Land Program, not only on the program beneficiaries but also on the cassava farming community of the adopted villages.

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Planning Cassava Development: The Philippine National Research and Development Program for Cassava

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Introduction

Agriculture dominates the Philippine economic life. Together with fisheries and forestry, it provides the main source of livelihood for 70% of the Filipino populace and employs more than 50% of the labor force. It produces about half of the Philippines total export revenues and contributes about 26% to the gross domestic product. These figures explain why research and development efforts in the Philippines are heavily focused on agriculture.

Root crops, particularly cassava, are steadily gaining a foothold in Philippine agriculture. Within the last 10 years, the area devoted to cassava increased by 265% while yield increased by 82%. In 1982, it outranked sweet potatoes in terms of area planted. Today in the Philippines, cassava is used primarily as food, for starch manufacture, and to a lesser extent, for livestock feed. With the growing interest in the use of cassava in animal feed rations, it is expected that cassava's prominence in Philippine agriculture will continue.

Structure of Research and Development Planning

In the Philippines, planning and coordination of research and development (R&D) programs for agriculture and natural resources is a primary function of the Philippine Council for Agriculture and Resources Research and Development (PCARRD). Established in 1972, PCARRD has been charged with the task of providing a systematic approach to the planning, coordinating, and directing of the country's agricultural and natural resources R&D programs and gearing it to national development.

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PCARRD coordinates and integrates the research activities of the different bureaus and commodity institutes, and also ensures the full participation of colleges and universities involved with agricultural and natural resources research and development.

The organizational structure of PCARRD enables it to link with national agencies and specific sectors involved in agriculture and natural resources, keeping it attuned to both national and regional needs. The structure is made up of a secretariat with seven technical departments. Root crops research, which includes cassava, is monitored by the Crops Research Department. The implementation of programs and projects is carried out by the National Research Systems, which is composed of research centers and stations located strategically all over the country.

Working closely with the research departments on an on-call basis are the multidisciplinary national commodity research teams. These teams plan, review, and update the various commodity research programs. The National Root Crops Commodity Research Team for 1984, for instance, is composed of ten members representing different disciplines and agencies.

A national research program for cassava was first formulated during a National Research Workshop convened by PCARRD in September, 1973. Researchers, scientists, extensionists, representatives from the private sector, and policymakers worked together to establish benchmark information, research status, and problem areas. Short- and long-term objectives and research priority areas were identified based primarily on relevance to the national development goals and research needs.

Since then, the national commodity research teams meet at least twice a year to review and update the research priorities of different commodities, taking into consideration new opportunities and trends. The commodity research programs now stand as the guidelines for all research and development activities in the various areas of agriculture and natural resources.

At present there are 36 commodity groupings sharing the national research budget allotted for agriculture and natural resources. The national research system accorded cassava research, together with sweet potato and white potato research, a high priority (Priority I) among the hierarchy of commodities, signifying the importance of the crop to the Philippine agriculture.

Cassava and National Development Goals

The cassava R&D program supports the national goals of attaining sustainable economic growth, equitable distribution of the products of development, and total human development. Specifically, it is envisaged that the cassava R&D program will lend support to the following program thrusts: food and nutrition, import substitution, energy, income generation and distribution, and overall countryside development as cited in the PCARRD Corporate Plan (1983).

In the area of food and nutrition, there will be a shift in research focus from rice to other carbohydrate sources, particularly towards crops with potential for greater adaptation to stress conditions. Cassava is considered a good candidate for this because of its ability to give modest yields in areas not suitable for other crops, its high calorie production per unit area of land or per labor input, the relatively stable yields, and the long potential harvest period.

Cassava is also expected to play a major role in import substitution, replacing imported yellow maize as a main ingredient of animal feed rations. To achieve this, production, processing, marketing, and utilization of cassava chips as a feed ingredient will be improved.

With the worldwide oil crisis in 1973-1974, it is imperative that other sources of energy be tapped. Again, cassava as a source of alcohol is in the front line among the crop commodities to be tapped for this purpose. Crop research will explore ways to develop more efficient methods for producing alcohol from cassava and select and breed crops for high alcohol yield.

The cassava R&D program has been formulated with the end view of contributing to the generation and equitable distribution of income. Hence, research on village-level processing of cassava into chips and other food products is given prime consideration in the R&D program so that rural women and out-of-school youth, otherwise unemployed or under-employed, can be engaged in productive activities. All of these endeavors, if successfully implemented, will inevitably lead to countryside development.

Priorities for Cassava

The overall strategy for the development of cassava in the Philippines is to popularize its production through both the development of effective processing methods and techniques, thus expanding its uses, and also through the development of marketing channels and outlets. This is supported by a strong breeding program and a system of cultural management techniques. While the ultimate objective of transforming the subsistence type of cassava production to a market-oriented one is still being worked out, attention is presently being given to the immediate needs of the subsistence farmers for a low-input type of technology.

Within this strategy, the priority research areas for cassava for 1983-1987 have been identified as follows (PCARRD, 1983c):

Priority rank I

1. Development of appropriate technology for production of chips
2. Processing and utilization of products and by-products for food and feed
3. Design and development of tools and equipment for chipping, drying, and packaging
4. Development of high-yielding cultivars/varieties under a wide range of conditions
5. Improvement of postharvest and storage techniques suitable at the farm level

Priority rank II

1. Development of appropriate technology for production under marginal conditions
2. Integrated cassava-based farming systems
3. Development of integrated pest management strategies for major pests
4. Biological control of major insect pests and diseases
5. Development of fertilizer recommendations for particular soil types

Priority rank III

1. Development of strategies for effective transfer of technology
2. Studies on socioeconomics and marketing

The priority ranking of research areas as indicated above guides the researchers and policymakers as to which areas of concern should be accorded immediate attention and support. Under the PCARRD scheme, research projects falling under priority rank I are given preferences in terms of funding.

Present Research Activities and Future Plans

Processing and utilization

To widen the market possibilities for cassava, processing and utilization are given emphasis. Research is directed towards development of processing techniques to improve the quality of the product and expansion of uses of cassava. Ongoing studies in this area include utilization of dehydrated cassava in main dishes and as snack items, design and development of a root crop dicing machine for home-based industry, and use of cassava leaves as a potential feed for broilers. A pilot project using root crops (sweet potato and cassava) for animal feed formulation is underway in eastern Visayas. There is also ongoing research on technology transfer for countryside development based on alcohol production.

The proposed studies which are expected to be implemented next year concern fortification of root crop flour with legume flour, microbial protein enrichment, and evaluation of protein-rich feeds from root crops. There will be a sustained research and development effort to transform cassava into highly-valued products.

Postharvest technology

Rapid postharvest deterioration has always been a problem with cassava. With the development of soil storage techniques which can extend the storage of fresh roots for up to 5 months, the postharvest handling and storage of fresh roots seem to be well covered at the moment. However, there are areas where knowledge is still inadequate; hence, some studies are still being conducted. Investigations include the effect of pre-harvest factors such as fertilization, planting location, pruning, and irrigation on the quality and storage life of cassava.

In the area of postharvest handling and storage, efforts are being shifted to the control of postharvest pests of cassava and cassava products. Problems on packaging and storing cassava products will be high on the research agenda in the coming years.

Crop improvement

Breeding for high-yielding cultivars/varieties with resistance to major insect pests and diseases and wide adaptability is a continuing concern in the development of the cassava industry. Recognizing that the success of a plant breeding program depends on the amount of genetic variability available to carry out selection, the collection, establishment, maintenance, and evaluation of germplasm are given high priority in the cassava national R&D program. Emphasis is now given to collection and screening of cassava varieties with low hydrocyanic acid (HCN), high starch content, and tolerance to shade. Varietal evaluation is also underway for tolerance to drought and soils with high acidity. Breeding for pest resistance will focus on resistance to red spider mites and cassava bacterial blight.

Outstanding varieties may be identified in the evaluation of germplasm, but hybridization of selected cassava cultivars will still be necessary. To complete the crop improvement scheme, preliminary testing and advanced regional trials are vigorously pursued. Recently, a National Cooperative Testing (NCT) project has been formed to evaluate the adaptability of promising entries in specific locations. Twelve testing stations, representing the different agro-climatic types, have been identified (Figure 1). A root crops technical working group was formed to determine which materials to accept for regional testing.

Cassava-based farming systems

The level of productivity of cassava farmers in the Philippines is very low and, therefore, income is correspondingly low. Moreover, in subsistence farms, farmers apply very little inputs. Usually, cassava is regarded as an insurance crop or a supplementary crop, with rice and maize as the primary crops. It is not surprising, therefore, that cassava yields are low since farmers naturally give priority to their main crops. To generate technology for a cassava-based farming system, ongoing research is being conducted on a continuous production scheme for cassava with minimum tillage. Other studies are being proposed on intercropping cassava with melons and vegetables, and several studies on intercropping cassava with legumes have been conducted. Results will be verified in farmers fields and the most acceptable combinations will be identified.

Integrating cassava production with livestock raising through the establishment of village-level feed processing mills is being tested in a number of villages in Leyte. If found technically feasible and socially acceptable, this scheme will be tried in other cassava-producing regions.

Pest management

Although cassava has long been considered as a plant which is resistant to pests, it is now established that heavy losses and even complete crop failure are attributable to diseases and insect pests. Under Philippine conditions, problems with cassava pests have not reached serious proportions. However, with the increase in area planted to cassava and the adoption of varieties with narrow genetic variability, serious crop protection problems may well arise.

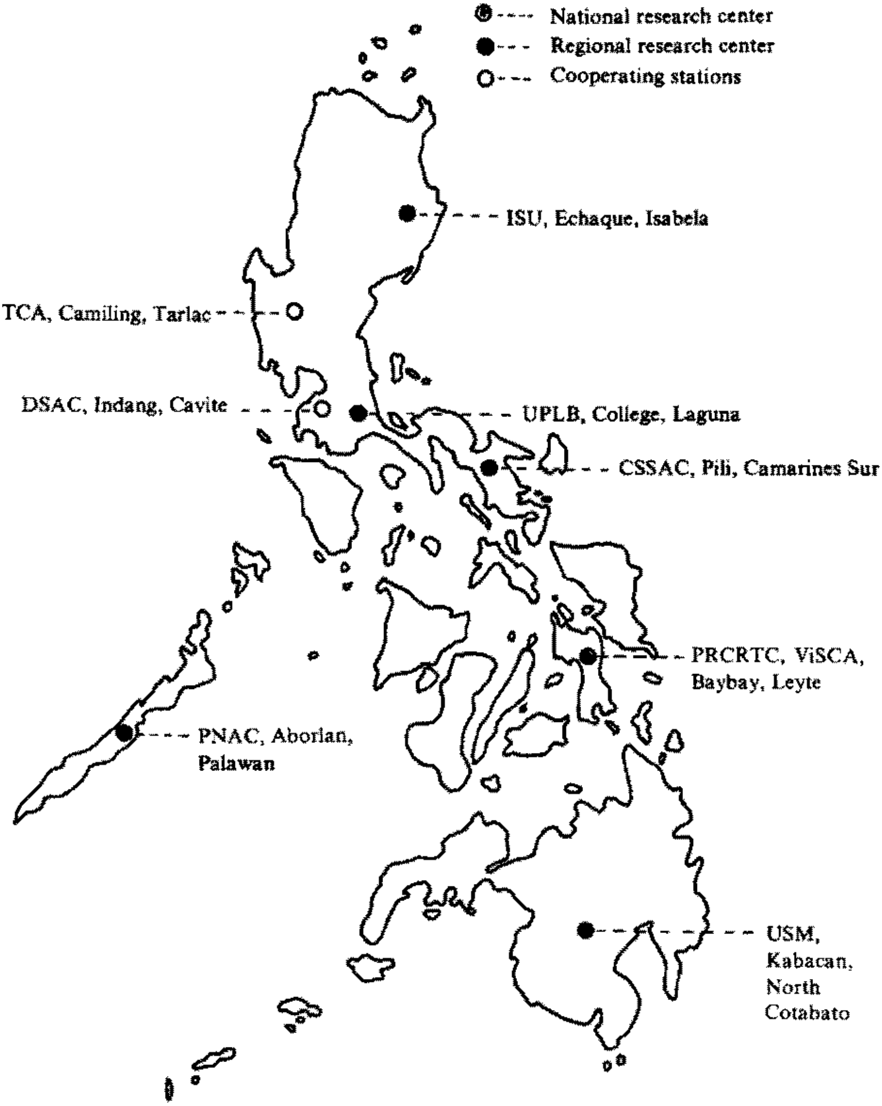

Figure 1. *National network of research centers and stations for cassava.*

Research on pests and pest management of cassava is currently being undertaken. Among the studies in progress are estimation of yield losses due to major insect pests (particularly spider mites), effect of cassava bacterial blight on yields, and survey, identification, and biology of natural enemies of spider mites. An integrated pest management approach will be stressed in future research projects. Other basic studies supporting the integrated pest management scheme, such as the biology and ecology of pests and their natural enemies, will be given attention.

Cultural management

An integration of agronomic findings into a complete system of practices where costs and returns and other socioeconomic factors are considered is being studied. In fertilizer and nutrition studies, use of indigenous materials is accented. Ongoing studies on the effect of farm animal manure and the effect of ipil-ipil (*Leucaema leucephela*) fertilizer on the growth and yield of cassava are underway. A long-term fertility study on cassava is also being conducted.

Studies on cultural practices and fertilization have answered many of the basic needs of farmers. However, there are still many areas needing attention. Sooner or later, cassava fields will have to be fertilized to remain productive. To make fertilizer rate studies applicable over a wide area, soil tests have to be undertaken in various areas and correlated with fertilizer recommendations. Around 42% of the area planted to root crops is hilly and therefore, susceptible to erosion. Although some studies are ongoing, more research is needed to facilitate development of suitable cultural practices in these areas.

Basic research

Basic physiological studies such as the relationship between carbohydrate translocation and yield and flower induction, which are necessary for the advancement of applied research, are also being conducted. Other basic research where breakthroughs are imminent will be strongly supported.

Strategy for Implementation

The national R&D programs are implemented by a network of research centers and stations complemented with infrastructure and manpower resources. Strategies for implementation are described below.

Research network for cassava

The Philippine Root Crop Research and Training Center (PRCRTC) based at the Visayas State College of Agriculture (ViSCA) in Leyte is the national research center for root crops research, cassava included. As a national research center, it is responsible for carrying out basic and applied research to generate technologies which will later be verified in the different regional and cooperating research stations. To support PRCRTC, a network of stations with regional responsibilities and cooperating stations in different regions in the country has been identified (Figure 1).

The regional research centers conduct applied studies to answer the needs of the region where the center is located and other studies to verify findings from the national research centers. Packages of technology conceptualized in the national research center are fine-tuned at the regional centers for application or adaptation to the needs and conditions of the region.

The cooperating stations provide facilities and/or sites where adaptive trials or field experiments are undertaken to assess micro-enviromental differences. These stations also assist in disseminating mature or tested technologies to end users.

The Regional Integrated Agricultural Research System (RIARS) under the Ministry of Agriculture tests cropping patterns involving cassava on farmers' fields for adaptability to specific locations. They also evaluate component technologies related to cropping patterns, such as on-farm cassava varietal testing and fertilizer trials.

Guided by the national R&D programs, researchers from various research centers and stations submit proposals to PCARRD for evaluation and approval prior to implementation. Approved research proposals are then recommended to the Office of Budget and Management (OBM) for fund allocation. There is a standing agreement between PCARRD and OBM that only those recommended by PCARRD will be allotted funds.

A yearly evaluation of ongoing research is conducted by PCARRD to determine the progress of the work and identify new research opportunities and promising technologies.

International agencies and programs

Supporting the national network of stations are international agencies and programs which provide financial as well as technical assistance. Notable among these agencies are the International Development Research Centre (IDRC) of Canada, the International Institute for Tropical Agriculture (IITA) in Nigeria, and Centro Internacional de Agricultura Tropical (CIAT) in Colombia. The ESCAP Coarse Grains, Pulses, Roots and Tuber Crops Centre (CGPRT) also coordinates a regional program involving cassava, among other crops.

Collaborative efforts with these agencies are in the form of germplasm exchange, provision of funds for research projects, manpower development and training, equipment support, and exchange of new technologies, research findings, and methodologies.

Budget allocations

Root crops, along with seven other crop commodities, are accorded the first priority among the 36 commodity groupings used by PCARRD. Table 1 summarizes the number of research studies and the research budget allocations for different root crops from 1982 to 1985. It shows that the budget for cassava research increases yearly.

Table 2 breaks down cassava research and budget allocations by disciplines. Most projects are clustered in major disciplines such as cultural management, varietal improvement, and processing and utilization. The data show that most of the budget for cassava research goes to cultural management and varietal improvement. It is also quite apparent that during the earlier years very little work was done on socioeconomics and marketing. However, there is a remarkable increase in budgetary allocations in 1985, an indication that socioeconomics is becoming an important component of the overall R&D program for cassava.

Conclusions

The prospects for expanded cassava production in the Philippines are promising in light of the present efforts to use cassava in livestock feed formulations in place of yellow maize and in bakery products to partly replace wheat flour. The Philippine National Research System through PCARRD strives to answer the needs of cassava growers and the cassava industry in general by providing a strong R&D program for cassava to provide a data base for policy formulations.

Table 1. **Summary of number of research studies and corresponding budget for various root crops in the Philippines, 1982-1985 (000 pesos).**

Crop	1982		1983		1984		1985	
	Budget	No. of studies	Budget	No. of studies	Budget	No. of studies	Budget	No. of studies
Sweet potato	2187	90	3423	112	3524	108	2964	103
Cassava	1727	85	2090	154	2233	94	2258	91
White potato	2566	85	3324	113	2821	127	2661	96
Minor root crops	884	58	1307	59	1571	87	1514	71

US $1.00 = ₱14.00.

Table 2. **Summary of number of studies and corresponding budget for cassava research in the Philippines, by discipline, 1982-1985 (000 pesos).**

Discipline	1982		1983		1984		1985	
	Budget	No. of studies	Budget	No. of studies	Budget	No. of studies	Budget	No. of studies
Varietal improvement	412	15	487	22	467	27	676	28
Cultural management	658	36	695	27	820	31	658	28
Processing and utilization	203	11	268	12	409	15	358	13
Crop protection	159	13	260	7	151	7	96	7
Postharvest handling and storage	200	6	280	6	270	9	147	6
Design, dev't, and tools and equipment	75	2	100	3	66	3	159	5
Socioeconomic and extension	20	2	-	-	50	2	164	4
Total	1727	85	2090	77	2233	94	2258	91

US $1.00 = ₱14.00.

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Past Performance and Future Prospects of Cassava Production in Asia and the Pacific Region

R.B. Singh

Introduction

Cassava (*Manihot esculenta* Crantz), like other major root and tuber crops, is one of the most efficient converters of solar energy and soil nutrients into carbohydrates and thus has a great potential to meet food and energy needs. No serious efforts have, however, been made to unlock this tremendous potential. However, with the unprecedented demand for food, feed, and fuel, new avenues for producing more and more of these commodities should be explored.

Cassava is a uniquely endowed crop capable of producing exceptionally high economic and biological yield even under marginal and low-input conditions. Further, its flexible agronomic requirements and its diversified use as food, feed, industrial raw material, and possibly an invaluable energy source, render cassava a very versatile crop. The potential for exploitation of cassava in its many uses in the Asian Pacific region is examined in this paper.

The paper analyzes production, productivity, and area under cassava in 26 countries of the Asian-Pacific region for the period 1973 to 1983. The average annual figures for the triennium ending 1973 have been taken as the base figures. Similarly, the average annual figures for the triennium ending 1983 have been treated as the terminal figures. This methodology was used to even out annual fluctuations caused by seasonal factors. The constraints on cassava production and possible ways to overcome them are also analyzed, and the FAO activities related to improved production of cassava in the region are briefly enumerated. Finally, the prospects of improving cassava production in the Asian-Pacific region are discussed.

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Production

Table 1 presents production of cassava in the individual countries of the Asian-Pacific region, the region as a whole, the rest of the world, and the world as a whole for the periods 1971-1973 and 1981-1983. It may be seen from the table that 13 of the 23 developing countries in the region produce cassava, while none of the three developed countries in the region produce it. With its annual production of about 48 million tons, the region accounts for about 38% of the world's cassava production. Production in the region more than doubled during the past 10 years, attaining an impressive compound annual growth rate of 7.4% against zero growth rate in the rest of the world.

The magnitude and growth of cassava production varied remarkably from country to country. Thailand more than quadrupled its cassava production in the past 10 years from about 4 million tons in 1973 to about 18.5 million tons in 1983, registering a high growth rate of 15.6% per annum, and accounted for 30% of the region's production. The other major producers were Indonesia (13 million tons), India (5.6 million tons), China (4 million tons), Vietnam (3 million tons), and the Philippines (2.3 million tons). Of these, China, the Philippines, and Vietnam registered high growth rates of 29.1, 17.1, and 10.4%, respectively, while Indonesia recorded a low growth rate of 2.3% and India even showed a negative growth rate. Laos, which usually had low growth rates for most crops, showed as high as 16-17% annual growth rates during 1973-1983.

Yield and Area

Table 2 presents the yield and area for the periods 1971-1973 and 1981-1983. The yield in the region as a whole increased at a compound annual growth rate of 2.3% (accounting for 31% of the increase in production), whereas in the rest of the world it decreased by 2% per year during the same period. Yield gains of more than 4% per annum were recorded in the Philippines (8.9%), Sri Lanka (5.3%), and Laos (4.7%). Indonesia showed a growth rate of 2.8%. The rest of the cassava-producing countries registered negligible or even negative growth rates in yields.

The average yield (12 tons/ha) was more than one-half times that of the rest of the world. The yield levels in the individual countries varied considerably. India recorded the highest yield of more than 18 tons/ha whereas it was as low as 6 tons/ha in Vietnam. China, Laos, and Thailand, in that order, were the other countries with yields of about 15 tons/ha.

Table 1. **Cassava production (000 t) in the Asian-Pacific region, 1971-1973 and 1981-1983.**

	Annual avg. for 1971-1973	Annual avg. for 1981-1983	Compound annual growth rate (%)	Yearly values for 1981	1982	1983
Developing countries						
Bangladesh	-	-	-	-	-	-
Bhutan	-	-	-	-	-	-
Burma	13.0	49.7	14.3	48	50	51
China	306.0	3925.7	29.1	4159	3718	3900
Fiji	88.0	95.0	.8	94	95	96
India	5813.3	5645.0	-.3	5868	5567	5500
Indonesia	10442.0	13163.0	2.3	13673	12800	13016
Korea, DPR	-	-	-	-	-	-
Korea, Republic of	-	-	-	-	-	-
Laos	13.7	72.0	16.1	70	72	74
Malaysia	202.7	370.0	6.2	360	375	375
Maldives	-	-	-	-	-	-
Mongolia	-	-	-	-	-	-
Nepal	-	-	-	-	-	-
Pakistan	-	-	-	-	-	-
Papua New Guinea	80.0	98.0	2.1	96	98	100
Philippines	473.3	2285.0	17.1	2255	2300	2300
Samoa, W.	23.5	-	-	-	-	-
Sri Lanka	446.0	548.7	2.1	526	550	570

(Continues)

Table 1. **(Continued)**

	Annual avg. for 1971-1973	Annual avg. for 1981-1983	Compound annual growth rate (%)	Yearly values for 1981	1982	1983
Thailand	4371.0	18581.3	15.6	17744	21000	17000
Tonga	11.7	-	-	-	-	-
Vanuatu	-	-	-	-	-	-
Vietnam	1061.7	2843.3	10.4	3165	2665	2700
Subtotal	23345.9	47676.7	7.4	48058	49290	45682
Developed countries						
Australia	-	-	-	-	-	-
Japan	-	-	-	-	-	-
New Zealand	-	-	-	-	-	-
Subtotal			-	-	-	-
Asia-Pacific total	23345.9	47676.7	7.4	48058	49290	45682
Rest of world		79118.3	0.0	79067	80263	78025
World total	102423.7	126795.0	2.1	127125	129553	123707

Table 2. **Cassava yield and area in the Asian-Pacific region, 1971-1973 and 1981-1983.**

	Yield (t/ha)			Area (000 ha)		
	Annual avg. for 1971-1973	Annual avg. for 1981-1983	Compound annual growth rate (%)	Annual avg. for 1971-1973	Annual avg. for 1981-1983	Compound annual growth rate (%)
Developing countries						
Bangladesh	-	-	-	-	-	-
Bhutan	-	-	-	-	-	-
Burma	10.7	9.2	-1.5	1.3	5.3	14.9
China	15.1	15.8	.4	20.3	248.7	20.5
Fiji	12.4	12.0	-.3	7.0	8.0	1.3
India	16.4	18.2	1.1	351.0	310.3	-1.2
Indonesia	7.5	9.9	2.8	1394.0	1330.7	-.5
Korea, DPR	-	-	-	-	-	-
Korea, Republic of	-	-	-	-	-	-
Laos	9.5	15.0	4.7	1.3	5.0	14.1
Malaysia	9.8	10.6	.8	20.7	35.0	5.4
Maldives	-	-	-	-	-	-
Mongolia	-	-	-	-	-	-
Nepal	-	-	-	-	-	-
Pakistan	-	-	-	-	-	-
Papua New Guinea	10.5	10.6	.1	8.0	9.0	1.2

(Continues)

Table 2. **(Continued)**

	Yield (t/ha)			Area (000 ha)		
	Annual avg. for 1971-1973	Annual avg. for 1981-1983	Compound annual growth rate (%)	Annual avg. for 1971-1973	Annual avg. for 1981-1983	Compound annual growth rate (%)
Philippines	4.6	10.9	8.9	106.0	210.3	7.1
Samoa, W.	12.5	-	-	0.0	-	-
Sri Lanka	5.5	9.2	5.3	81.3	59.3	-3.1
Thailand	15.0	14.7	-.3	290.7	1283.3	16.0
Tonga	9.6	-	-	2.7	-	-
Vanuatu	-	-	-	-	-	-
Vietnam	7.2	5.9	-2.0	146.7	480.0	12.6
Average & subtotal	10.45	11.8	1.2	2431.0	3985.0	5.1
Developed countries						
Australia	-	-	-	-	-	-
Japan	-	-	-	-	-	-
New Zealand	-	-	-	-	-	-
Average + subtotal	-	-	-	-	-	-
Asia-Pacific total	10.45	11.8	1.2	2431.0	3985.0	5.1
Rest of world	9.3	7.6	-2.0	8528.3	10370.7	2.0
World total	9.8	9.7	-.4	10959.3	14355.7	2.7

The area under cassava in the region increased from 2.4 million hectares in 1973 to 4 million hectares in 1983, a growth of 5.1% per annum. In the rest of the world, during the same period the area increased by 2% per annum. The area increase in the region accounted for about 69% of the increase in cassava production. Thailand increased its cassava area more than four times (growth rate of 16% per year) between 1973 and 1983, occupying the second highest area (1.28 million hectares) under cassava in the region. Indonesia, with 1.33 million hectares, had the highest area, although a marginal decrease of 0.5% per annum occurred during 1973-1983. Among the other major cassava-producing countries, from more than 100,000 hectares in 1973, the Philippines and Vietnam increased their areas respectively by 7.1 and 12.6% per year, whereas in India area declined by 1.2% per year, reducing the area from 351,000 ha in 1973 to 310,000 ha in 1983. Although from small base levels, the area under cassava in China, Burma, and Laos increased by growth rates ranging from 14 to 29% per annum. During the same period, the cassava area in Sri Lanka decreased from 81,000 to 60,000 ha (3.1% per annum) but the total production increased by 2.1% per annum because of a high growth rate of 5.3% in yield.

Production Constraints

The constraints to production can be grouped into the following three major groups: agro-ecological, biotechnical, and socioeconomical.

Agro-ecological constraints

Cassava is customarily a rainfed crop raised under marginal soil and input conditions. The very fact that cassava can give better returns than a majority of the crops under marginal conditions has gone against improvement in production. For example, in Thailand and Indonesia, the two main cassava-producing countries, cassava is usually grown on highly leached soils with poor N-P-K availability.

Biological and technical constraints

The biotechnical constraints may be summarized as follows:

- Narrow germplasm base

- Lack of varieties with high yields, pest resistance, drought tolerance, and early maturity

- Incidence of cassava bacterial blight, cercospora leaf spot, and mites (unlike other regions, this region is fortunate in not having many cassava diseases and pests)

- Relatively low dry matter content in the roots
- Poor postharvest handling and processing
- Lack of efficient and economical diversified uses
- Inefficient transfer and poor adoption of known technologies
- Lack of appropriate agricultural tools and machines for timely and economical operations

Socioeconomic constraints

It must be stressed that no technology works in a vacuum. Price incentives and established markets are the foremost forces of production. Increasing protectionism and market uncertainties have lately tended to destabilize cassava production, especially in the exporting countries. Further, government policies and institutional support for cassava production are usually not very favorable.

FAO Activities Related to Production and Use

Several FAO activities in improved crop production, farming systems, and postharvest handling are directly or indirectly related to increased and sustained production of cassava in the Asian-Pacific region. Regional projects on production and protection of root and tuber crops have been operational in the Pacific Island countries since the mid-1970s. These projects have assisted member countries in developing suitable manpower, establishing research facilities, introducing germplasm, and streamlining quarantine procedures and facilities.

Development of efficient cropping patterns based on cassava is one of the major activities in the ongoing FAO projects on rainfed agriculture in Thailand and Indonesia. It is also a major activity of the project on integrated farming systems operational in several countries of the region since 1983. Further improved methods of postharvest handling of cassava are being developed under an intercountry regional project launched recently.

The International Board of Plant Genetic Resources (IBPGR) and the FAO Centre for Plant Genetic Resources work in close collaboration with CIAT and national cassava germplasm centers through their Cassava Group. This group reviewed the current status of cassava germplasm, identified the priority areas for collection, designated base and duplicate centers of storage, and prepared and published a list of cassava descriptors.

Several countries in the region were assisted in further collection, exchange, evaluation, and documentation of the germplasm. The IBPGR is also supporting tissue culture research to develop suitable *in vitro* techniques to facilitate transfer and conservation of root and tuber crop germplasm. The FAO has been giving increasing attention to improved production of roots and tubers in the developing countries, and will soon be launching a Special Root and Tuber Improvement Programme to increase food and agricultural production in developing countries in the tropics.

Prospects of Improved Production

The prospects of improved production of cassava are closely linked with future consumption-utilization patterns, export potential, cost-effectiveness of production and processing, and price incentives. These individual aspects and their probable impacts on future cassava production in the Asian-Pacific region are discussed in this section.

Utilization patterns

Thailand, Indonesia, India, China, the Philippines, and Vietnam together account for 96% of the total cassava production in the Asian-Pacific region. The pattern of cassava use in these countries varies remarkably. Table 3 presents the prevalent use patterns in selected

Table 3. **Pattern of cassava use in selected countries of the Asian-Pacific region, 1981-1983 average.**

	Production (millions of tons)	Net export (%)	Domestic consumption (%)		
			Food	Starch	Feed
China	3.9	27	n.a.	n.a.	n.a.
India	5.6	-	82	6	-
Indonesia	13.2	9	50	25	2
Philippines	2.3	-	62	23	5
Thailand	18.6	80	-	6	1
Vietnam	2.3	-	76	-	9
Other[a]	1.9	-	-	-	-
Asia-Pacific	47.8	36	-	-	-
Rest of world[b]	79.1				

Note: On an average, 12-15% is waste, although it may range from 5-25%.

a) Mostly used as food, except in Malaysia where about 20% is used as animal feed.

b) Mostly used as food, except in Brazil where less than 1% is used for gasohol production.

n.a. = not available.

cassava-producing countries of the region. Nearly all of the world's export of cassava comes from the Asian-Pacific region. Thailand alone accounts for more than 85% of the world's exports. The European Economic Community (EEC) imported about 95% of the world's cassava, which it uses in animal feeds. Indonesia and China are the other two countries which jointly account for most of the remaining 15% of the world's exports. This too goes primarily to EEC countries as a feed source.

Thailand, the major producer, consumes less than 10% of its total production domestically. The domestic use is mostly confined to starch; negligible quantities are used as food and feed sources, although the bulk of its production is exports in the form of pellets for animal feed. In the other cassava-producing countries, cassava is consumed domestically as a food source. In Indonesia and the Philippines, about one-fourth to one-fifth of the production is used for starch.

Prospects as a food crop

Cassava will continue to be an important food source for poor farmers in rainfed and marginal areas where it performs better than other crops. Under such conditions, the production is expected to increase at rates analogous to those of population growth. In countries with expanding land frontiers, such as Indonesia, Burma, and a few others, most of the increase in cassava production may come through increases in area. But in those countries where there is limited scope for increasing the area, the production increase must accrue through yield increase.

The relative contribution of cassava to the national food baskets will, however, decrease. This is primarily because, in the past decade or so, the growth rate of cereal production has been equal or slightly higher than the growth rate of food demand in the Asian-Pacific region as a whole. Further, income elasticities of demand for cassava as food are not only low, but have declined and even become negative in some cases. Therefore, in the Asian countries, cassava as a staple food may not receive high enough priority to boost its production, although in specific pockets its production will continue to grow.

Prospects as a feed crop

About 15-17 million tons (about 13% of the world's production) of fresh cassava roots (equivalent to 6-7 million tons of pellets) are used for compounding animal feeds in the EEC countries. Most of this cassava comes from Thailand. An additional 1 million tons of fresh roots are used as animal feed within the region itself. No other country or group of countries, whether producing or non-producing, uses dried cassava as a major source of animal feed.

The development of a suitable tapioca export market, starting in the late 1960s in the EEC, was primarily responsible for the rapid increase in Thailand's cassava production, rendering the crop as one of the major exports of the country alongside rice, maize, rubber, and tin. It is a good example of how a market pull can cause dramatic increases in the production of a commodity. But of late, due to domestic grain surpluses and price adjustments, the EEC is undergoing a re-adjustment to restrict cassava imports. An agreement between the EEC and Thailand was reached in 1980 that Thailand would limit its export to EEC countries to 5 million tons of pellets (equivalent to 12 million tons of fresh roots) each year during 1983 and 1984. Further, new market opportunities for pellets are limited. At best, in the next few years the export market of cassava pellets will remain static or even slightly decline. Therefore, the exporting countries, especially Thailand, will find it difficult to increase their cassava production under the existing settings unless some other economical uses are developed.

The other alternative is to increase the use of cassava domestically as a feed crop. This will depend on two things: the rate of increase in animal production in the individual countries and, the comparative price advantage and availability of other feed sources, such as coarse grains.

As regards animal production in the developing countries of the Asian-Pacific region, meat and milk production increased at annual compound growth rates of about 5 and 4% respectively, between 1972 and 1982. Tables 4 and 5 present production of meat and milk in the countries of the region. It may be seen from the tables that the developing countries (barring Sri Lanka for meat) registered positive growth rates, ranging from 1.4-16.7% per annum in the case of meat and from 0.7-21.6% in the case of milk.

The increase in animal production must be accompanied with increases in animal feed production. Part of this increased demand is being met from domestic production of coarse grains and part from imports of coarse grains. With the impressive increases in rice and wheat production in the past 15 years or so, and their demand for food being much more income-elastic than that of coarse grains, a higher proportion of coarse grains is probably becoming available for feed purposes. Imports of coarse grains into the region increased from 13 million tons in 1972 to about 28 million tons in 1982 (Table 6). Japan accounted for two-thirds of the total coarse grain imports into the region. Imports by the developing countries as a whole quadrupled during this period. The increases were most conspicuous in China, Malaysia, the Philippines, and the Republic of Korea, besides Japan. It is in these countries that significant increases in animal

Table 4. **Meat production (000 t) in the Asian-Pacific region, 1970-1972 and 1980-1982.**

	Annual avg. for 1970-1972	Annual avg. for 1980-1982	Compound annual growth rate (%)	Yearly values for 1980	1981	1982
Developing countries						
Bangladesh	231.3	311.3	3.0	300	310	324
Bhutan	2.0	2.0	0	2	2	2
Burma	161.7	205.0	2.4	200	205	210
China	14345.0	23555.7	5.1	22753	23481	24433
Fiji	5.3	7.0	2.8	7	7	7
India	712.7	911.0	2.5	870	916	947
Indonesia	376.7	453.7	1.9	444	454	463
Korea, DPR	106.3	184.0	5.6	181	185	186
Korea, Republic of	175.3	523.7	11.6	556	490	525
Laos	53.0	83.7	4.7	78	85	88
Malaysia	117.0	236.0	7.3	231	235	242
Maldives	-	1.0	-	1	1	1
Mongolia	179.0	246.3	3.2	239	248	252
Nepal	58.0	69.3	1.8	69	69	70
Pakistan	462.0	745.0	4.9	712	751	772
Papua New Guinea	32.0	42.3	2.8	42	42	43
Philippines	469.0	766.0	5.0	736	772	790

(Continues)

Table 4. (Continued)

	Annual avg. for 1970-1972	Annual avg. for 1980-1982	Compound annual growth rate (%)	Yearly values for 1980	1981	1982
Samoa, W.	2.0	-	-	-	-	-
Sri Lanka	33.7	31.3	-.7	31	31	32
Thailand	348.7	709.0	7.4	651	715	761
Tonga	1.0	4.7	16.7	4	5	5
Vanuatu	-	-	-	-	-	-
Vietnam	532.3	611.0	1.4	596	608	629
Subtotal	18404.0	29699.0	4.9	28703	29612	30782
Developed countries						
Australia	2289.7	2632.3	1.4	2671	2612	2614
Japan	1659.7	3061.7	6.3	3028	3022	3135
New Zealand	1025.3	1179.7	1.4	1126	1199	1214
Subtotal	4974.7	6873.7	3.3	6825	6833	6963
Asia-Pacific total	23378.7	36572.7	4.6	35528	36445	37745
Rest of world	82530.0	106436.7	2.6	105515	106971	106824
World total	105908.7	143009.4	3.0	141043	143416	144569

Table 5. **Milk production (000 t) in the Asian-Pacific region, 1970-1972 and 1980-1982.**

	Annual avg. for 1970-1972	Annual avg. for 1980-1982	Compound annual growth rate (%)	Yearly values for 1980	1981	1982
Developing countries						
Bangladesh	980.0	1546.3	4.7	1493	1536	1610
Bhutan	15.0	18.7	2.2	18	19	19
Burma	231.0	291.7	2.4	286	292	297
China	4989.0	7948.7	4.8	7703	7963	8180
Fiji	43.0	53.0	2.1	53	53	53
India	22890.0	31873.3	3.4	30930	31940	32750
Indonesia	33.7	78.3	8.8	74	79	82
Korea, DPR	17.0	58.7	13.2	54	60	62
Korea, Republic of	72.7	515.7	21.6	458	513	576
Laos	5.0	6.7	2.9	6	7	7
Malaysia	25.0	33.7	3.0	33	34	34
Maldives	-	-	-	-	-	-
Mongolia	196.0	254.0	2.8	247	253	262
Nepal	633.7	730.0	1.4	728	728	734
Pakistan	6865.0	9139.7	2.9	9014	9195	9210
Papua New Guinea	1.3	-	-	-	-	-
Philippines	27.0	29.0	.7	31	28	28

(Continues)

Table 5. **(Continued)**

	Annual avg. for 1970-1972	Annual avg. for 1980-1982	Compound annual growth rate (%)	Yearly values for 1980	1981	1982
Samoa, W.	1.0	1.0	0.0	1	1	1
Sri Lanka	206.7	248.3	1.9	245	245	255
Thailand	9.3	12.0	2.5	12	12	12
Tonga	-	-	-	-	-	-
Vanuatu	-	-	-	-	-	-
Vietnam	39.3	78.0	7.1	74	78	82
Subtotal	37280.7	52916.8	3.6	51460	53036	54254
Developed countries						
Australia	7276.0	5259.3	-3.6	5398	5181	5199
Japan	4849.0	6621.3	3.2	6504	6610	6750
New Zealand	6004.3	6620.0	1.0	6708	6506	6646
Subtotal	18129.3	18500.6	.2	18610	18297	18595
Asia-Pacific total	55410	71417.4	2.6	70070	71333	72849
Rest of world	348072.0	403533.3	1.5	400089	401129	409382
World total	403482.0	474950.7	1.6	470159	472462	482231

Table 6. **Imports and exports (000 t) of coarse grains in the Asian-Pacific region, 1970-1972 and 1980-1982.**

	Imports		Exports		Trade	
	Annual avg. for 1970-1972	Annual avg. for 1980-1982	Annual avg. for 1970-1972	Annual avg. for 1980-1982	Annual avg. for 1970-1972	Annual avg. for 1980-1982
Developing countries						
Bangladesh	-	8.3	-	-	-	-8.3
Bhutan	-	.5	-	-	-	-.5
Burma	-	-	12.5	10.7	12.5	10.7
China	1408.0	5056.3	19.5	116.3	-1388.5	-4940.0
Fiji	-	11.3	-	.1	-	-11.2
India	15.7	16.0	2.5	5.0	-13.2	-11.0
Indonesia	24.3	45.7	183.8	18.8	159.5	-26.8
Korea, DPR	10.0	-	.4	-	-9.6	-
Korea, Republic of	434.0	3692.3	2.4	-	-431.6	-3692.3
Laos	-	-	-	-	-	-
Malaysia	245.7	491.0	1.5	-	-244.2	-491.0
Maldives	-	-	-	-	-	-
Mongolia	-	-	-	-	-	-
Nepal	-	-	3.5	.8	3.5	.8
Pakistan	3.0	9.0	7.4	51.3	4.4	42.3
Papua New Guinea	-	10.0	-	-	-	-10.0
Philippines	86.3	285.3	-	-	-86.3	-285.3

(Continues)

Table 6. **(Continued)**

	Imports		Exports		Trade	
	Annual avg. for 1970-1972	Annual avg. for 1980-1982	Annual avg. for 1970-1972	Annual avg. for 1980-1982	Annual avg. for 1970-1972	Annual avg. for 1980-1982
Samoa, W.	-	1.3	-	-	-	-1.3
Sri Lanka	5.0	3.0	-	.9	-5.0	-2.1
Thailand	3.2	1.2	1759.0	2807.3	1755.8	2806.1
Tonga	-	-	-	-	-	-
Vanuatu	-	-	-	-	-	-
Vietnam	99.7	5.0	-	26.0	-99.7	21.0
Subtotal	2334.9	9636.2	1992.5	3037.2	-300.4	-6599.0
Developed countries						
Australia	.5	6.0	2131.8	3136.7	2131.3	3130.7
Japan	10666.0	18691.7	.4	-	-10665.6	-18691.7
New Zealand	14.0	5.3	3.6	74.0	-10.4	68.7
Subtotal	10680.5	18703.0	2135.8	3210.7	-8544.7	-15492.3
Asia-Pacific total	13015.4	28339.2	4128.3	6247.9	-8845.1	-22091.3
Rest of world	40569.2	80524.7	49282.2	104345.4	8713.0	23820.7
World total	53584.6	108863.9	53410.5	110593.3	-132.1	1729.4

production occurred during the same period, thus suggesting close association between rate of increase in animal products and rate of availability of coarse grains for feed.

The second aspect, i.e., competitiveness and availability of cassava as against other feed sources, mostly coarse grains, could be examined by analyzing the situation in Thailand. It may be seen from Table 4 that meat production in Thailand increased by 7.4% per annum during 1972-1982. Further, the country is a major exporter of both cassava and corn. But, it is important to note that hardly any of its cassava production is used for animal feed, most of that demand being met by maize, fishmeal, and soymeal. In fact, more than 200,000 tons of soymeal is annually imported to supplement the feed demand. Clearly, coarse grains and oilseed meals are preferred over cassava for feed purposes. This is largely because, on calorie-to-calorie basis and on an overall nutritional basis, cassava prices do not compare favorably with those of coarse grains and other feed resources, primarily because of the price distortions caused by the EEC import market.

Given cassava's wide adaptability, especially under the vast rainfed and marginal crop-raising conditions in the region, and the high productivity of cassava, the question is how to improve the competitiveness of cassava. The most plausible solution would be to decrease cassava production costs by increasing productivity, leading to a reduction in its domestic and international market prices, and thus bringing it on par with coarse grains and other feed products.

Prospects for uses other than food and feed

Other than as a conventional food and feed source, cassava is used for producing starch and could also be used to produce gasohol, fructose sweetener, and single-cell protein. Again, maize and sugarcane compete with cassava in production of these items. Therefore, comparative cost-effectiveness and feasibility of large-scale commercial exploitation of these products would have to be thoroughly studied before any reliable projection for increased demand of cassava could be made.

The demand for cassava starch in the traditional export markets of the U.S.A. and Japan has declined over the past few years. However, in the developing countries, the demand for starch is likely to increase both for industrial and food uses. But, once more, cassava will find maize as the main rival, and the price factor will again decide the balance. In some countries that import wheat and also produce cassava, cassava starch or flour is mixed with wheat flour to make bread. But this does not seem to have any significant impact on the wheat imports into the region. For instance, import of wheat and wheat flour into the developing countries of the region increased from 13.4 million tons in 1972 to 23.6 million tons in 1982. It would be useful to know whether cassava flour could be substituted for some of this wheat. Further, some of the nontraditional wheat-producing countries, such as Thailand, the Philippines, and Indonesia are trying to grow wheat commercially, which may also affect the use of cassava flour in bread.

Strategies for Increasing Productivity and Cost-Effectiveness

In recent years, from 1980 to 1983, the rate of growth of cassava production in the Asian-Pacific region has decelerated considerably. This may be attributed to (1) stagnation or even decline in cassava exports, (2) increased rate of cereal production combined with low or even declining income elasticities of demand for cassava, (3) unfavorable competitiveness of cassava with maize and other crops, (4) shrinking frontiers of arable land and deceleration in the growth rate of area expansion, (5) negligible improvement in cassava productivity, and (6) poor developmental and policy support for increased production of cassava.

The potential productivity of cassava can be seen in yields as high as 80 tons/ha reported by CIAT scientists under intensive management. Average yields in several pockets of Tamil Nadu (India) under irrigated conditions are about 50 tons/ha or so. The experimental plot yields in some of the Southeast Asian countries are about 25 - 30 tons/ha under rainfed and low-input conditions. Against these, the average yield in the Asian-Pacific region (although one-half times that in the rest of the world) is only 12 tons/ha and varies widely from country to country, suggesting great scope for improvement.

Given the desired market and price incentives and government support, the approaches to increased yield in farmers' fields would essentially consist of effective transfer of current production practices, generation of new technologies for maximization of input/output ratios, and increased availability of inputs. Adoption of non-monetary inputs, such as the use of healthy planting material of the most efficient variety for specific agro-ecological conditions, appropriate spacing, weeding (where surplus family labor is available), and timely harvesting should help bridge the yield gap considerably. Even small doses of fertilizer, with proper and timely placement, are bound to increase the productivity significantly.

Improved varieties

Development of improved varieties with appropriate crop canopy, shorter maturity, tolerance to drought and soil stresses, high harvest index, and increased dry matter content in the roots will go a long way towards increasing productivity. CIAT is already playing a significant role in this direction by diversifying the germplasm base, and country programs should take advantage of this activity by intensifying screening and testing programs. Effective linkages should also be established with other international institutions, such as IITA, and national centers for exchange of improved varieties and other breeding materials. Hybridization programs involving locally adapted lines and elite exotic lines followed by screening under diverse agro-ecological settings, particularly the marginal conditions where cassava is mostly grown, should be undertaken. Appropriate national facilities for this purpose should be developed.

Fertilizer use

Cassava productivity can be greatly enhanced by increasing the use of fertilizers. While cassava is highly responsive to fertilization (as measured in terms of yield increases), fertilizer use will depend on its availability, competition with the primary crops (such as rice, wheat, maize, and plantation crops), and its cost-effectiveness.

Table 7 gives the fertilizer use for the period 1969-1971 and for 1980 in countries of the Asian-Pacific region *vis-a-vis* the world as a whole. The present level of fertilizer use varies a great deal from country to country, from as low as 1 kg N-P-K/ha in Bhutan to as high as 1,018 kg/ha in New Zealand. As many as 14 of the 26 countries used less than 50 kg N-P-K/ha. Ordinarily, the major portion of increased fertilizer availability will be apportioned to the main food or commercial crops. In order to convince the development agencies and the farmers that applying fertilizer to cassava is cost-effective, suitable recommendations for levels of the macro- and micro-nutrients and their mode and time of applications must be developed for specific soil types and growing conditions, and their efficacy must be demonstrated in farmers' fields.

Increased water use efficiency

Besides low yields, wide fluctuations in production are not uncommon under the erratic and scarce rainfall conditions of much cassava cultivation. Techniques to catch, conserve, and recycle water should be developed to improve water use efficiency. Reports suggest than even one irrigation at the most critical stage can increase cassava yield by 30-50%. Therefore, on-farm irrigation development and determination of critical stages for irrigation will prove highly useful. Appropriate water management, in addition to its direct effect on yield, will have synergistic interactions with fertilizer use and inputs, and hence deserves high research priority.

Table 7. **Use of mineral fertilizer (kg/ha) in the Asian-Pacific region, 1969-1971 and 1980.**

	Annual avg. for 1969-1971	Annual avg. for 1980	Compound annual growth rate (%)
Developing countries			
Bangladesh	14.2	46.3	12.5
Bhutan	-	1.1	-
Burma	3.4	10.0	11.4
China	41.8	154.6	14.0
Fiji	28.4	60.6	7.9
India	11.4	30.9	10.5
Indonesia	11.9	63.0	18.1
Korea, DPR	148.4	325.5	8.2
Korea, Republic of	246.6	375.7	4.3
Laos	0.4	7.8	34.6
Malaysia	43.6	105.1	9.2
Maldives	-	-	-
Mongolia	1.8	8.6	16.9
Nepal	3.0	9.7	12.5
Pakistan	16.8	49.5	11.4
Papua New Guinea	7.6	14.8	6.9
Philippines	21.4	33.7	4.6
Samoa, W.	-	-	-
Sri Lanka	49.6	77.0	4.5
Thailand	7.6	16.2	7.9
Tonga	-	-	-
Vietnam	51.2	40.7	-2.3
Average	37.2	71.1	6.7
Developed countries			
Australia	24.6	27.7	1.2
Japan	384.9	372.1	-0.3
New Zealand	887.5	1,017.7	1.4
Average	432.3	472.5	0.9
Asia-Pacific average	91.1	123.9	3.1
World average	48.5	79.9	5.1

Quarantine measures and crop protection

Cassava was introduced into the Asian-Pacific region from Latin America (its center of origin and diversity). While cassava is attacked by several diseases and pests in this region also, the losses are not as high as in Latin America. Very strict precautions, therefore, should be made to exclude such diseases and pests when introducing germplasm and other materials. Effective quarantine facilities and expertise should be established in each cassava-producing country. Tissue culture techniques, Third-Country Quarantine*, and expanded international cooperation will be useful in preventing the introduction of new cassava diseases and pests and in facilitating germplasm exchange. Problems like leaf blight, mites, and the mosaic disease can sometimes become serious in certain areas. In order to keep the cost of production low and also to ensure durable protection against the pests and parasites, integrated pest and disease management practices should be developed and widely adopted.

Cropping intensity and cassava-based cropping patterns

Cropping intensity in erratic rainfall areas is far below 100%. Under such conditions, cassava, being an 8 to 12-month crop and amenable to planting and harvesting throughout the year, keeps the field continually occupied. There are emerging trends showing that, with suitable management, cassava intercropped with grain legumes yields almost as much as a monocrop, and in addition, the farmer harvests a protein-rich crop as a substantive bonus. The legume intercrop also helps to stabilize the soil, prevent soil erosion (which often occurs during the early growth of cassava and is labeled as one of the disadvantages of cassava farming), and improves soil fertility. This combination is particularly useful from the point of view of the nitrogen economy (considering that generally a negligible amount of N is applied to the cassava crop). It also represents an additional source of income and nutrition to the small farmers. In Thailand, paired rows of peanuts with 10 cm between rows and a hill spacing of 10 cm (one plant per hill) within the row, planted between two rows of cassava 100 x 100 cm apart is tentatively recommended. More research on developing efficient, cassava-based cropping systems is needed.

Cassava is already an important intercrop in plantations in Kerala, India. Plantation areas are increasing and the areas earlier planted to cassava are being diverted to perennial crops. For instance, in the central provinces of Thailand, cassava lands are being diverted to rubber plantations. Cassava could still be grown on these lands as an intercrop, provided suitable varieties and cultural practices are developed. Screening for shade-tolerant varieties with a high photosynthetic efficiency and harvest index would be very helpful.

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* Third-Country Quarantine is a procedure in which a third country serves as a quarantine area for two other countries that want to exchange germplasm. The crop of interest is not grown in the third country, and thus if the germplasm proves to be carrying crop-specific diseases or pests, they cannot spread or do damage in that country.

A large number of landless and small farmers grow cassava as a home garden crop for food. Appropriate technologies for home garden production would help in increasing the food supply of the resource-poor rural masses. The Mulibat cassava system in Indonesia is such a technology ideally suited for home garden production.

Summary and Conclusions

The Asian-Pacific region accounts for about 38% of the cassava produced in the world. Cassava production in the region increased at a high annual growth rate of 7.4% during 1973-1983, against a zero growth rate in the rest of the world. About 70% of the production increase was attributed to increase in area and the remaining 30% to increase in yield. The rate of growth of cassava production has, however, decelerated in recent years.

Market restrictions, inadequate price and institutional support, low-productivity under rainfed conditions, narrow germplasm base, lack of high-yielding, stress-tolerant and widely-adapted varieties, inadequate application and inefficient management of fertilizer and water, and lack of appropriate technology for low-input conditions are the major production constraints.

Besides being an important staple food, especially in marginal areas, cassava could emerge as a major feed source to meet rapidly expanding animal production in the region. However, this will depend to a large extent on the price competitiveness of cassava with coarse grains. Increased productivity and reduction in unit costs of production are the most viable approaches to increase the competitiveness of cassava.

Starch, sweeteners, gasohol, and single-cell protein are other products of cassava. But, as yet, commercial production of these items, except starch, is not quite economical. Hence, additional research is called for to diversify the utilization of cassava roots. Further, cassava-related economic, agricultural, and nutritional policies should be kept under continuing review to get the best out of this remarkable root crop.

Rapporteur's Summary of Discussions

Gerald Nelson

The session dealt first with two general research areas, cropping systems development and post-harvest processing technology, and then with the specific approaches taken by two national programs to the problems of research organization and dissemination. Many of the themes mentioned in earlier discussions were highlighted again—the need to reduce production costs by increasing yields, the importance of environment-specific cassava research, the need to identify and develop "new" uses of cassava, the low priority given to cassava by national research programs despite its importance in some of the countries.

In his presentation on research needs for cassava-based cropping systems, Roche argued that area expansion was unlikely to be a significant source of growth in the future in most countries and any increase in production would have to come from yield increases. Furthermore, he argued that cassava will continue to be grown on marginal lands by poor farmers, even if relative price changes cause total cassava area to decline. Hence, both from a welfare point of view and because cassava lands would be primarily marginal lands, he felt that research should be devoted to increasing yields on marginal lands.

Roche felt that technologies already exist that could give substantial yield increases (new varieties, weeding, fertilizer use, improved germination rates), but that inadequate attention has been given to dissemination. Extension efforts are made more difficult (than for rice technologies, for example) by the fact that cassava-based cropping systems must be developed for specific agro-climatic zones and with very careful attention paid to socioeconomic issues, such as market outlets and availability of intermediate inputs, labor, and capital. He described the case of a cropping pattern in southern Sumatra that both increased profitability substantially and reduced income variance, yet had not been adopted by any farmers because its labor and credit demands were larger than the current factor markets could meet at existing factor prices. In order to simplify the research on environment-specific cropping patterns, Roche suggested the development of a classification system for cassava production environments that could be used throughout South and Southeast Asia. This classification system could be used to facilitate transfer of research results about appropriate varieties and cultural practices.

During the discussion period, the issue of what crops to include in a cropping system program was brought up. It was emphasized by several participants that use of existing practices should constitute the basis for new systems.

In her paper on postharvest processing, Barrett emphasized the diversity of end uses of cassava in the countries of southeast Asia, but pointed out that some transfer of technology among countries could be useful. For example, in Indonesia a very successful household starch-making technique is widely used, and should be relatively simple to transfer to other countries. Chipping and pelleting technologies are well developed in Thailand. Each product has its own processing problems and Barrett discussed the more important of these. Both in her presentation and in the discussion period, the issues of short shelf life for fresh roots and gaplek (dried cassava) and quality problems for cassava starch and gaplek were mentioned. None of the technologies that have been developed to extend the shelf life of fresh cassava have yet found market acceptance. Little research has been done on reducing storage losses for gaplek.

The presentation by Gapasin and Ghosh provided interesting insights into two related problems—development of research priorities for a national agricultural research system, and dissemination of research results. Gapasin described the highlights of the Philippine research system, how it determines research priorities, and how and to whom research projects are allocated. She noted that cassava research, which began only in 1973, falls into the larger root crops category which is placed in the highest priority group of commodities. For each commodity, research work in specific areas is also given a priority ranking.

As Gapasin pointed out, "Having a well planned R and D program is one thing and having a working system for implementing a program is another thing." The list of research priorities given in her paper seemed to give higher priority to processing than to agronomic and breeding research. However, the budget allocations listed in her paper showed that most funds have been spent on varietal improvement and cultural management. In any case, the amounts allocated were small.

Ghosh described the innovative "lab-to-land" program, initiated by the Indian Council of Agricultural Research in 1979. The program was designed to get researchers out of the laboratories and onto the fields of small farmers in order to test new technologies, to make an explicit effort to extend the fruits of research to the most disadvantaged farmers, and to allow the scientists to see firsthand the problems of the small farmers. From the cassava research program, the technology to be extended included two new cultivars and new cultural techniques. For the first two years the scientists supervised the farmers' activities and free fertilizers were provided. In the second two-year period, the fertilizer subsidy was removed.

Rapid adoption of the various components of the technology and substantial yield increases were reported initially. After the withdrawal of the fertilizer subsidy, fertilizer use dropped and yields declined. However, the new cultural practices were maintained and yields were higher than before the program.

The benefits of this kind of a program undoubtedly extend well beyond the increased incomes for the poorest farmers. Providing researchers the chance to interact extensively with poor farmers will help to ensure that appropriate technologies eventually emerge from the laboratories.

V. Conclusion

Conclusions and Recommendations*

The much heralded Green Revolution that swept through tropical Asia during the 1970s was based quite appropriately on high-yielding rice varieties for irrigated conditions. The improvements in both consumer welfare and farmer incomes that followed were large and in turn stimulated other sectors of local rural economies. However, the growth potential of this technology has been largely exhausted in most countries and research efforts have shifted to maintenance activities to preserve these yield gains. Moreover, the producer benefits of this technology were largely limited to the irrigated areas, that is areas and farmers which already had more productive resources and higher levels of income. The challenge for the 1980s thus shifts to identifying future sources of agricultural growth, especially for the upland areas of tropical Asia, and it is exactly in this light that cassava is considered.

Cassava is particularly adapted to filling such a role. On the production side the crop has both extremely high-yield potential and yet can be grown under a very wide range of upland conditions. Cassava is particularly well adapted to areas where soil fertility or drought is a constraint on growth of other crops. For these reasons cassava is already the second most important carbohydrate staple crop grown in the Asian tropics. Moreover, there has been limited past research on cassava, so that the potential for increasing productivity is large. Such yield increases are the key to increasing the incomes of small-scale farmers in upland areas.

On the demand side cassava also retains the adaptability it has in production. Cassava has a multiplicity of end uses, including direct human consumption, as a carbohydrate source in animal feeds, as starch, and more recently as a high-fructose sweetener. These multiple uses for either domestic use or export give cassava a certain flexibility in adapting to changing economic and market conditions. Thus, for example, it can be a cheap source of calories for low-income consumers, such as is the case in Indonesia and India, or it can contribute to the growing demand for meat and dairy products.

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* Compiled and summarized by John K. Lynam.

The workshop recommended that cassava research and development be strengthened in the region to (1) fully exploit the crop's potential productivity through breeding, agronomic and socioeconomic research, and extension and training; (2) improve present postharvest and processing technologies, and (3) explore the potential for the crop in new markets.

The workshop further recommended that, in view of the present scarcity of available resources for agricultural research in general and cassava in particular, greater cooperation be encouraged between national research programs themselves and between national programs and regional and international research centers, organizations, and agencies. Such cooperation is viewed as necessary to maximize benefits from research and avoid duplication of effort. It could be achieved through network activities focused on effective interchange of genetic materials, relevant expertise, and efficient dissemination of information.

Having thoroughly examined the agronomic, socioeconomic, and institutional constraints on the development of cassava in the region, the workshop recommended that the areas described below receive priority attention:

Germplasm Development and Varietal Testing

Breeding and selection leading to varietal improvement and increased productivity is a principal means of increasing production (especially where potential for area expansion is limited) and reducing production costs to make cassava more competitive with other carbohydrate sources. Collaboration between breeding programs would be beneficial in the following areas.

Germplasm development

The potential of local germplasm should be recognized to ensure its fuller utilization in breeding programs. There should be collection, characterization, evaluation, selection, and identification of recommendable clones and useful crossing parents. It should be emphasized that local germplasm contains genes for local adaptation which are invaluable in the development of new clones. In the area of collecting and characterizing local germplasm, it was noted that funding from IBPGR through CIAT was available to help finance national collection efforts.

The common constraint of most, if not all, Asian cassava breeding programs is the narrow genetic base of their local materials. As the center of origin of cassava is in Latin America, it is appropriate to introduce germplasm from this area to enrich local germplasm. Particularly useful are CIAT's advanced hybrid populations, appropriately tailored to suit the needs of national programs and containing desirable genes for characteristics such as high harvest index, resistance to diseases, and high starch content. Such populations would contain the favored genes in higher frequency than in the unselected original germplasm. The need for local selection of these materials will ensure identification of clones suited to local environments.

The succeeding step would be to generate elite gene pools from hybridizations between specific local cultivars and locally selected CIAT clones. This would be an invaluable means of attaining clones which are productive as well as adapted to specific agro-ecological conditions of a country.

The exchange of elite germplasm having desired characteristics common to two or more countries could be carried out between national programs through appropriately organized channels of varietal transfer, probably in the form of meristem culture.

Germplasm maintenance and transfer

As the maintenance of germplasm is a costly operation, it was suggested that CIAT develop and maintain an Asian germplasm bank. This would entail the dispatch of materials by meristem culture and would therefore entail training of national scientists in these techniques as well as minor investments in laboratory facilities in the respective countries.

There should be coordination of germplasm exchange for both local clones and elite materials, especially where there are common selection targets between programs.

Identification and management of selection sites

It was stressed that the central breeding station of a national program should be located in the most representative cassava-growing area. Highly productive and fertile environments should be avoided as major selection sites because cassava is cultivated largely in more marginal areas. Regional evaluation sites for testing advanced materials should cover major cassava-growing areas (including potential production areas).

Exceptional and unrealistic growing conditions and treatments (e.g., irrigation) should be avoided during the evaluation of materials. In the same vein, input levels of major selection trials should be within the reach of the average farmer. However, possible responses to higher input levels at later selection stages should be considered.

Selection targets

Selection targets common to most national programs include:
- high yield
- early maturity (often associated with high harvest index)
- high dry matter content (to be balanced against postharvest deterioration)
- adaptation to intercropping
- diversification of cultivars to broaden the germplasm base (e.g., incorporating resistances to CBB, cercospora, and possibly white root)

Selection targets specific to particular national programs include:
- adaptation to various soil and climatic conditions
- tolerance to shade (with respect to cassava intercropping with perennial tree crops, for which much interest is shared by several countries)
- better quality tubers for fresh consumption (e.g., low HCN)
- root shape/size, ease of harvesting
- characteristics which need to be more clearly defined to facilitate selection.

Early maturity is important to countries with climatic constraints during certain times of the year, such as dry seasons or typhoons, to increase the rate of return on production costs and to intensify certain cropping systems.

It was stressed that final selection should be basically location-specific, although the possibility of selection for widely adapted cultivars should not be eliminated. Furthermore, it was recognized that although each national program had a generally acceptable germplasm evaluation scheme, attempts should be made wherever possible to reduce the time to final evaluation and release of new cultivars.

Final stage of varietal release

It was suggested that there was a need to re-examine whether a strictly controlled release scheme was appropriate, or whether a loosely controlled scheme, enabling farmers themselves to select acceptable cultivars, should be adopted. It was proposed that the choice of either scheme should be left to national programs to be in line with government policies.

Agronomic and Cropping Systems Research

The potential returns to investment in breeding are directly related to improvements in agronomy and cropping systems. Research in this area is best considered in terms of constraints, either on cassava productivity or on farmer management of the crop. In this context, research areas can be distinguished as follows: (1) research on constraints specific to the cassava crop; (2) research on constraints that involve the cropping systems in which cassava is grown; and (3) research on constraints at the level of development projects and extension of improved agronomic practices.

Crop-specific constraints

Soil fertility. Management of soil fertility is of critical importance in cassava, particularly since it has traditionally been grown on less fertile soils often with little or no fertilizer application. Because cassava is particularly adapted to such conditions, the crop has undeservedly gained the reputation of being a soil-depleting crop. Maintenance of soil fertility in cassava production systems is not well understood at either the experimental level or at the farm level. For cassava there is a need to move away from 1 year fertility trials to address the more complex issues of the effects of previous cropping history and of previous fertilizer application.

Maintenance of soil fertility through the use of crop rotation and organic fertilizers should be studied at both the experimental level and at the farm level. The principles of fertility maintenance should be established by a regionally based research effort that should (1) collect and analyze the existing data in the region on fertilizer trials, farm level practices, and soils and (2) use this base to design a series of key trials in different countries. The data from this research would then be used as the basis for developing trials to establish economic recommendations for each individual country or region.

The critical role of mycorrhiza in cassava nutrition has been well established. Response to phosphorous fertilization in the region has generally been low and the question is raised whether this is due to ineffective mycorrhiza, especially since Asia is not the center of origin of the crop. Testing of mycorrhiza strains collected and evaluated by CIAT in Latin America could begin to answer this question.

Germination and early plant vigor. In many growing areas poor germination and lack of early plant vigor are dominant constraints on productivity. Since cassava is vegetatively propagated, management of planting material is critical to achieving high yields. In an Asian setting the effects of the monsoon climate on the quality of stake production and their subsequent germination and vigor—both in terms of the effect on the donor plant during its growth as well as on the stakes during storage—have not been elucidated and should therefore be researched.

If lines with early maturity are developed, then management practices for stake storage and production of high-quality planting material need to be developed. Technology to overcome this constraint can probably be developed on a regional basis and refined on a local basis.

There is an obvious need to investigate the extent to which germination ability under stress conditions is genetically determined. Introducing this as a selection target may thus be warranted for certain countries.

Weed control. A potential constraint for a crop such as cassava where full canopy is so delayed is control of weeds. The priority for development of chemical or other weed control measures varied markedly in the region depending on labor costs and availability. Nevertheless, preliminary screening of new chemicals and mulching methods could effectively be done in one center or institute, thus reducing to a small number the products that each national program should test. If minimum tillage is recommended for erosion control (see below), additional research would be necessary on appropriate forms of weed control.

Cropping system constraints

Soil erosion. Undoubtedly a serious problem per se, soil erosion is also a major constraint in maintaining cassava yields. However, to recommend that farmers do not grow cassava on sloping terrain is unrealistic where more profitable alternatives do not exist.

The general principles of erosion control such as minimum tillage, multiple cropping, vegetation barriers, and strip cropping need to be established as a very high priority research effort. These basic principles should be widely applicable but will need local adaptation to fit in with local cropping systems, conditions of input availability, and local demand for the products of intercropping. Since erosion control involves either investment or reduction in short run profits, the importance of land tenure and its effect on attitudes of farmers to long-term soil conservation should also be studied. There is a clear role for on-farm research activities in developing erosion control methods.

Intercropping. Cassava is intercropped with a range of crops, at least in certain areas in the region. Of increasing importance is intercropping with perennial tree crops. Lack of knowledge on the longer term effects of cassava intercropping in the establishment phase or the subsequent performance of the tree crop is constraining cassava cultivation in this system. This can be determined most cost-effectively by a series of key trials, the results of which could be regionally disseminated.

Lack of shade-tolerant cassava lines is a major constraint to growing cassava under mature tree crop stands. The basic physiology of cassava growth and development in shade conditions should be established and used to determine if (1) it is possible to attain good yields of cassava grown under tree crops and (2) the characteristics that breeders should look for in order to achieve such a goal.

In spite of much research effort on annual intercrop systems these have not been widely adopted by farmers; this is probably due to lack of attention to those intercrops that have a ready market in the region, and insufficient analysis of the availability of purchased and other inputs required in the newly developed systems. Moreover, with the advent of early-maturing varieties, additional research may be needed in developing optimal relay cropping systems.

Research and extension system constraints

There has been a natural emphasis on rice in both research and extension systems in the region. This rice focus has resulted in the development of experimental stations at optimal locations and in the use of high input levels. This bias may seriously constrain the development of appropriate technology for cassava, where stress tolerances are more important in varietal development. Moreover, extension and input delivery systems tend to be biased toward irrigated rice-growing areas and away from the more marginal upland conditions where cassava is grown. These potential biases should be recognized in developing cassava research in the region.

The heterogeneity in production conditions and systems for cassava increases the complexity of the research process and argues strongly for farmers to be brought more effectively into the research effort. This closer linkage between the farmer and experimental design and evaluation is clear in the case of fertility management, erosion control, intercropping systems, and the final stages of varietal selection. Collaboration on developing appropriate methods of effecting this linkage is probably warranted in the region.

The development of more on-farm research activities would aid in countering the rice-induced biases in both research and extension. Such research would often be relatively location-specific but the development of a typology of cropping systems in the region could lead to more effective transfer of information obtained in one system to similar systems in the region as a whole.

Postharvest Research

Unlike other crops, where research focuses almost exclusively on production research, cassava development requires attention to post-harvest research. Cassava roots need to be transformed into a stable product to be widely marketed, and the multiple uses of cassava depend on processing specific to each end use. Postharvest technology research thus includes the development of cost-effective techniques both to reduce losses between the farm and the final end use and to increase the derived demand for cassava through processing into novel forms.

Reduction in postharvest losses

Commercially viable technology to extend storage of fresh roots has been a goal of both national and international research efforts for some time but none of these technologies has yet been commercially adopted. If promising new technologies emerge, they should be tested and evaluated in the region; however, substantial new research efforts in this area do not seem warranted at the present time.

Only little research has been done on extension of the shelf life of dried cassava, either in factory warehouses or farm or family storage, despite the fact that dried cassava is highly susceptible to both insects and mold under Asian conditions. Additional research in this area would be most cost-effective if organized at a regional level.

Both small-scale starch production and dried cassava processing methods have been successfully developed by countries in the region, but high-quality techniques are not currently utilized by all countries. It should be possible to share these improved techniques among the countries in Asia and hence eliminate duplicate research efforts.

Utilization of starch by-products occurs to a limited extent in the region but research could lead to significant expansion in by-product use. Moreover, in many starch-producing areas waste water disposal produces a significant water pollution problem; low-cost recycling or detoxification methods are critically needed.

Novel end uses

Various novel products derived from cassava which have received attention in Asian countries include composite flour, modified starch, alcohol, single cell protein, and high-fructose sweetener. Attention currently devoted to these products differs by country. There is need to define the technical and economic parameters that most influence the market feasibility of the product.

A multitude of cassava products exist within the Asian region and elsewhere throughout the world. However, information dissemination on processing techniques and characteristics of final products has been negligible. For example, *krupuk* and fermented cassava, which are popular products in Indonesia, are rarely found elsewhere. Cassava cakes and snacks currently produced in the Philippines would most likely be acceptable throughout Asia.

There is a potentially large demand in the region for cassava in animal feed rations. The basic technology is well-known and probably requires little further study. Fine-tuning of existing technology such as drying systems and operational sizes for particular countries may, however, be necessary. Moreover, as cassava moves more into domestic animal feed concentrate industries, there may be a demand for information on cassava characteristics, for animal feed trials, and for information on managing the product within the mill and within the feed rations.

Economics Research

The agenda for economic research in cassava should focus on its input into technological —that is, biological, agronomic, and utilization— research, the planning of cassava development programs, and overall food and agricultural policy. As such the research agenda can be divided into five major topic areas: production, utilization and demand, price analysis, international trade, and policy research. The principal research topics in each area can be summarized as follows.

Production

Technology development for production relies heavily on identifying those factors most constraining productivity. This agro-economic research should provide a continuous input into the technology development process. In the initial phases of research, identification of the factors responsible for the variation in cassava yields, both between regions and within a region, is a principal means of identifying yield constraints. There is also the broader need to establish the constraints on cassava within both the cropping system and the whole farming system. A key issue is an evaluation of the competition between cassava and other crops for land, labor, and capital, particularly fertilizer. Timing of cultural practices, cropping and rotation systems, and on-farm uses versus cash sales are other principal areas of study.

As varieties and cultural practices are developed, they should move into a direct on-farm research and evaluation phase. Here the focus should be not only on the evaluation of the yield potential of varieties but on how appropriate both varieties and management practices are to different farming systems. Besides providing early feedback on the validity of research priorities and selection targets, some early evaluation of the potential impact on production costs can be established.

Adoption studies of new technologies serve to identify constraints to farmers' adoption. Particularly important is the identification of constraints on input availability, resource constraints within the farm, credit, and farmer understanding of the new technology.

Utilization and demand

Demand research provides more of an input into the broader planning of cassava development. Particularly important in this area is the development of an accurate and consistent set of statistics on cassava production and area planted and on cassava utilization in the different end markets. Without this statistical base much of the research in demand analysis is hampered.

Demand research can be divided by end market. For the markets and countries where cassava is consumed directly as a human food, the principal research topics are the estimation of demand parameters for cassava in order to gauge growth prospects in this market. An estimation of the cross-price elasticity with rice is important in determining whether cassava might play a role in rice pricing policies. Finally, consumer preference studies are a necessary component to the development and launching of novel cassava products.

In the starch market, principal research topics include an economic evaluation of the appropriate scale of processing and the role that government policies play in determining the profitability of different scales of processing. Secondly, some understanding of the consistent underutilization of capacity in starch processing is in order as a means for achieving further cost reductions. Thirdly, an evaluation of demand growth parameters is completely lacking, both in terms of the end uses for cassava starch and the competition with maize starch. Finally, given that many countries in the region import sugar, an economic evaluation of high-fructose sweeteners derived from cassava and their ability to compete with sugar prices is crucial to defining future investment in this market.

Animal feed probably offers the most immediate growth prospects for cassava and for this reason many workshop participants felt that this should be the first priority in demand research on cassava. A principal issue in this market is the role that international grain prices versus domestic price policies play in determining the potential for cassava, that is, the price at which it would be competitive with grain substitutes. Least-cost feed formulation models are a valuable tool in such an analysis but the computing capacity and technical coefficients were felt to be widely available, so that providing such a service did not appear necessary.

Price analysis

Research in price analysis should bring together the production and demand research to gauge at a relatively macro-level the price cassava will have to compete at in alternative markets and, after taking account of processing costs, the implications this has for farm-level prices, costs of production, and yield targets. This research is of highest priority in future planning of the crop and in generating increased government support for cassava research.

A research area of lower priority is the issue of price formation, particularly the role that international cassava prices vis-a-vis domestic food prices play in the determination of cassava prices. Related to this is an understanding of the integration of cassava markets across different forms, through time, and across locations.

International trade

This issue is most relevant to Thailand because of the EEC quota on cassava imports; however, resolution of the internal pricing of cassava in Thailand in relation to the EEC and international grain markets (a two-tier pricing structure was suggested as a focus of study) could have implications for other cassava producers in the region, particularly in respect to exports of cassava products. Another major research area is an evaluation of the potential for cassava exports in the Asian region, particularly to Japan, Korea, and Taiwan, and an assessment of the barriers to trade.

Policy

Research in this area should aim to provide input into government policy, which would subsequently form the basis for further government support of cassava. The latter makes this research of relatively high priority. Each country needs to establish in what regard cassava may contribute to government policy objectives. In turn, a definition of policy goals for cassava will have implications for both biological and utilization research priorities. A part of such an evaluation would be a social benefit and cost accounting of cassava's potential within the economy and the potential distribution of social benefits, especially to low-income producers and consumers. Particularly relevant may be a social costing of cassava's effect on soil erosion and, in areas where starch is produced, water pollution.

Research and Network Development

The dominant theme of the workshop was the urgent need in cassava research for integration, not only at the country level between disparate disciplines and research areas but particularly between the different institutions in the region working on cassava. It was the concern of the participants that CIAT and the ESCAP/CGPRT should play a catalytic coordinating role in the development of the regional cassava network. How that integration might be achieved is set forth in the following guidelines:

Organization of cassava research and development

- Utilization research is fundamental and should be fully integrated with production research in the overall cassava research program.

- The cassava research and development program should be organized in a farming systems approach, in which not only the place of cassava in a cropping system is studied but also how cassava-based cropping systems interact with livestock and household systems to form integrated farming systems.

- The two organizational principles above imply an interdisciplinary approach to research, in which the relevant disciplines collaborate not only in identification of constraints and research problems but also in testing of research results.

- An interdisciplinary approach together with a farming systems approach in cassava research will have to fully integrate research and extension at the specialist level. Training and involvement of village level extension staff needs to be provided.

Network requirements

A fully integrated approach to research will require more resources, both human and financial, than any of the countries in the region has available to allocate to its national cassava program. Therefore, it is imperative that the countries of the region pool their resources through the development of an integrated and coordinated regional approach to cassava research and development in the form of an Asian cassava network.

Such a network will permit the national programs of the participating countries to design their research programs in a manner that will avoid unnecessary duplication in effort but yet permit necessary testing of results in local areas. A study group may be formed to evaluate the capabilities of the various national centers for undertaking specific mission-oriented projects of common interest.

The national programs collaborating in the network should also endeavour to obtain resources, both human and financial, from external sources. Examples include donor foundations, organizations, and agencies, such as the FAO, ESCAP/CGPRT Centre, and CIAT. In this connection, the workshop was pleased to note that in addition to its ongoing activities on roots and tubers and farming systems, the FAO has proposed a Root and Tuber Improvement Program which is soon to be launched to increase production in developing countries in the tropics. This would supplement the efforts of other organizations and institutes.

Network activities

Breeding and germplasm exchange. A CIAT cassava breeder based in Thailand is currently coordinating breeding and germplasm exchange, both between the Latin American germplasm bank and national breeding programs, and between national programs themselves. Training and technical assistance in structuring breeding programs are also provided. Expansion of this effort is seen as necessary in developing the wide range of improved cassava varieties needed in the Asian tropics.

Cassava agronomy. Because a large number of regional research priorities in agronomy were identified, it was felt that a regional liaison officer or agency is required to (1) assist in planning regional research activities, (2) ensure rapid dissemination of results in the region, (3) organize working groups so as to guarantee that activities of common interest are appropriately managed, organize training opportunities in the development and refining of the new technologies developed.

Cassava-based farming systems. Need was expressed for a mechanism to develop common methodologies for cassava-based farming systems, especially to ensure comparability in information interchange between country programs. Periodic conferences would be invaluable in reaching such consensus. The suggestion was made that the CGPRT Centre might play a coordinating role in this area.

Utilization. Research on postharvest processing and product diversification is already being carried out in a range of different institutions in Asia. There is a need to bring together this body of research and technology as a means of sharing work that has already been done. Moreover, since most of this type of research has regional relevance, there is a need to assess priorities and coordinate research efforts between the different institutes. At an initial organizing conference one of these institutions should be selected as the coordinating body in utilization research in the network.

Economics. Specific conditions in each country will naturally dictate the type of economic research to be conducted. There is, however, significant scope for collaboration on methodology development and sharing of analytical techniques. Moreover, there may be expertise in one country that could be utilized in another country. Information exchange, moreover, is vital to stimulating broader based research interest in cassava. A regionally based economist is necessary to coordinate these efforts.

Another significant issue in each country is the identification of institutions to undertake what is a relatively broad economic research agenda. These institutions will be different, depending on the topic, but there should be assurance that there are appropriate linkages both to the agronomic and utilization research and to policy formation and planning. The production research should involve an economist closely linked to the national cassava research program. On the other hand, the other research areas could involve universities, planning offices, or statistical agencies.

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