AN OUTLINE OF BIBLIOGRAPHICAL STUDIES ON CASSAVA

---A Guide to Cultivation of Cassava---

Lampung Agricultural Development Project

by

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February, 1977

Japan International Cooperation Agency

(JICA)

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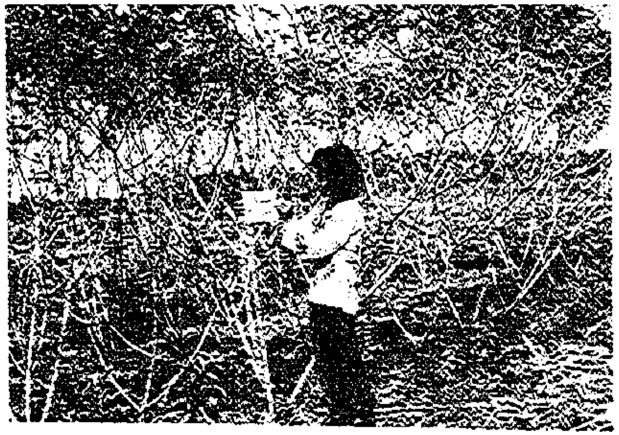

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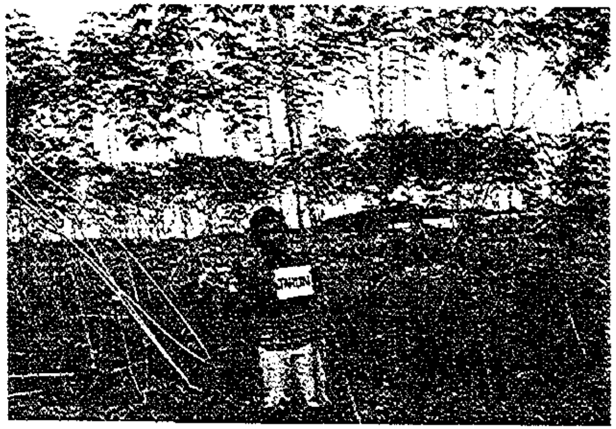

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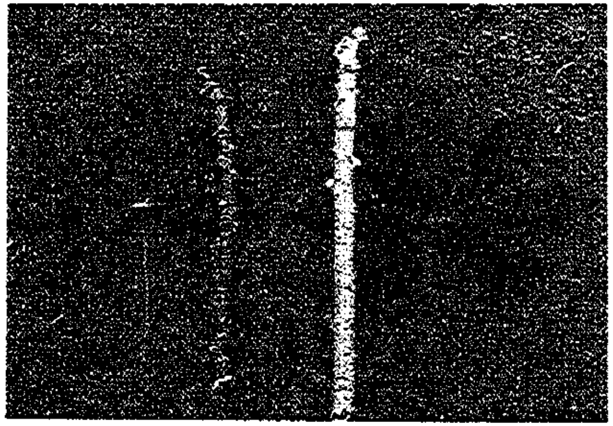

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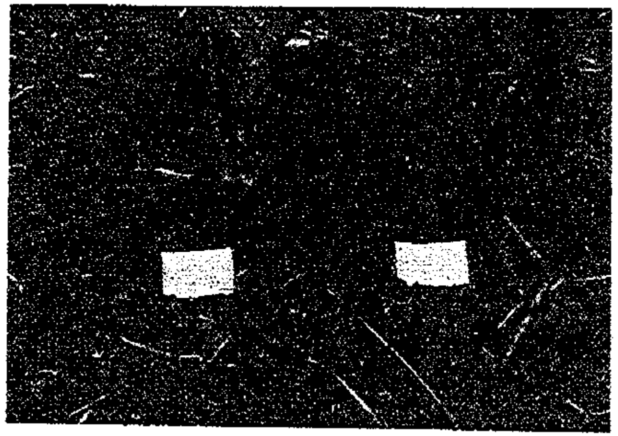

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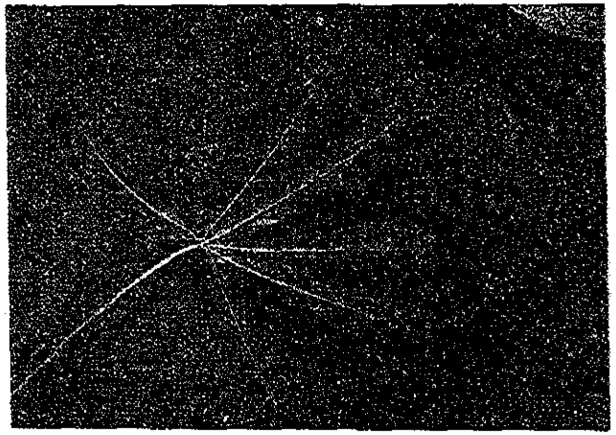

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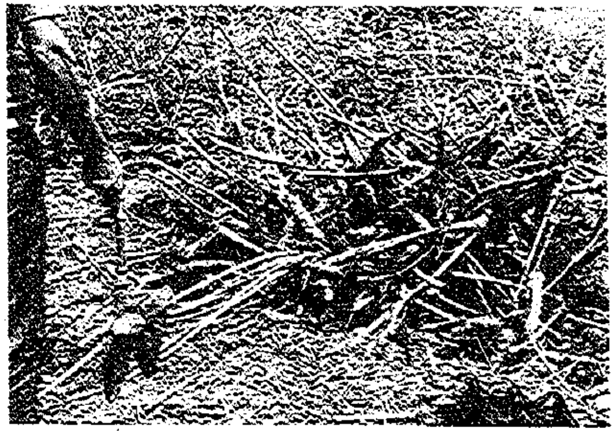

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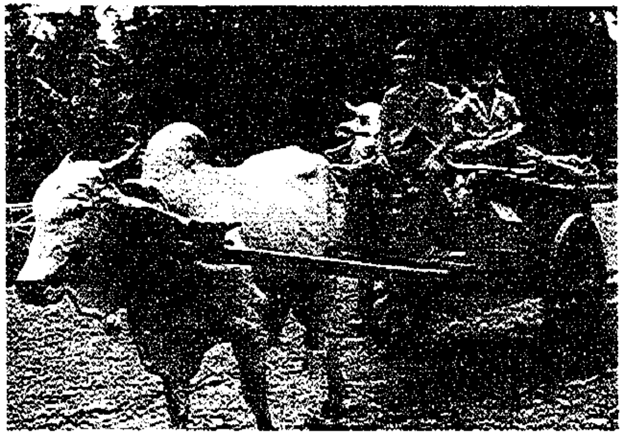

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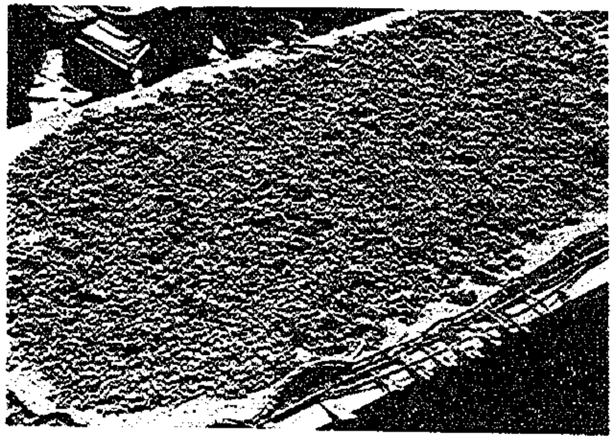

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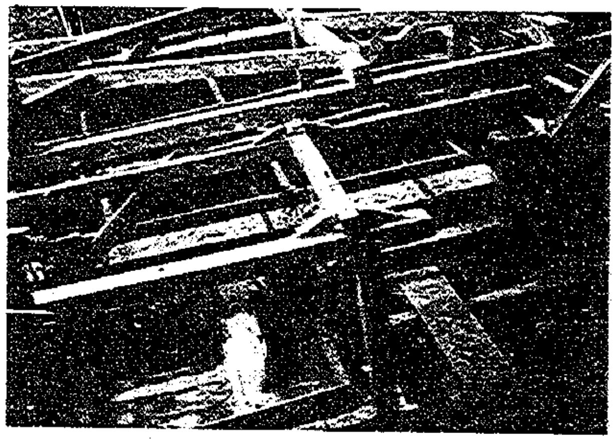

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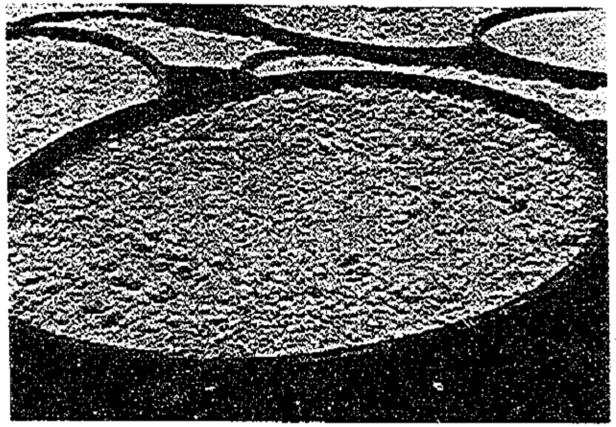

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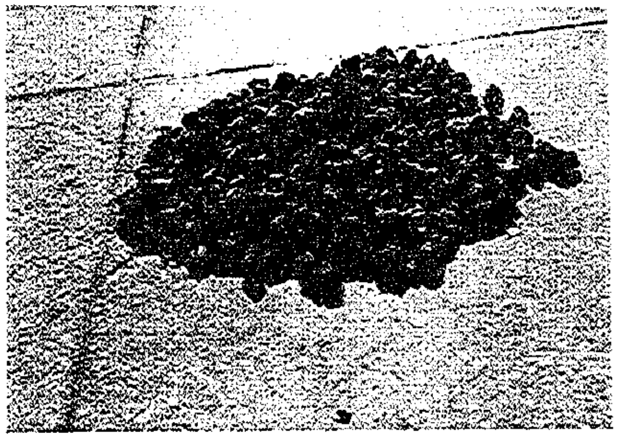

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AUTHORS' NOTE

A leaflet entitled "Cassava, A Starch Crop--A Study of Upland Farming in Southeast Asia" and published by the present authors has received a warmer welcome than expected. As issuance of a new edition became necessary, considerations have been given to correcting misprinting, redundancy, and the lack of necessary phtographs, etc. and improving the edition by adding the latest information.

The purpose of this publication is the same as that described in the previous edition. It is hoped that this pamphlet will be utilized widely in areas where shortage of foodstuffs calls for urgent measures.

February, 1977

Kazuma Nojima
Shohei Hirose

Lampung Agricultural
Development Project Team

PREFACE

With an increase in population and the advent of abnormal weather, the food question has come to assume greater importance as a problem calling for urgent solution on a world basis. Today, when reevaluating the food situation and promoting production increase on a global basis is required, the Japan International Cooperation Agency has cooperated in the fields of agriculture and agricultural studies in developing countries as part of its overseas cooperation activities.

Dr. Kazuma Nojima and Dr. Shohei Hirose, the authors of the present pamphlet, are specialists in agricultural development, who have been dispatched to work in the Agricultural Development Project in Lampung, Indonesia. Dr. Nojima is serving in Lampung as leader of the Project.

"Cassava, a Starch Crop--A Study of Upland Farming in Southeast Asia" (March, 1975) compiled by them has been favorably received by those interested in cassava, which occupies an important position as a foodstuff containing starch. I am very happy to present here the second edition, which, I am convinced, will be fully utilized as a reference document for those who involved in the cultivation of cassava.

February, 1977

Michio Nakahara, Director
Agricultural Development
Cooperation Department

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Appendix : List of Literature on Cassava

Photographs of Cassava and Its Cultivation Method

1. Production and Origin

Cassava, with which the Japanese are not fully familiar, ranks seventh in production among world food crops (See Table 1).

Table 1. Production of Major Food Crops in the World (FAO's estimate included partly for 1974)

Crop	Area (million ha)	Average Yield (ton/ha)	Production (million ha)
Grain			
Wheat	224.7	1.603	360.2
Rice (Un-hulled)	136.8	2.363	323.2
Barley	88.9	1.922	170.9
Corn	116.7	2.510	293.0
Rye	17.5	1.865	32.6
Oats	30.7	1.669	51.2
Millet	68.4	0.675	46.2
Sorghum	42.5	1.103	46.9
Root Crop			
Potato	21.9	13.393	293.7
Sweet Potato	19.3	6.970	134.2
Cassava	11.9	8.831	104.9
Yam	2.0	5.689	19.1
Taro	0.8	5.711	4.3
Leguminous Crop			
Soybean	44.5	1.277	56.9
Peanut (Un-shelled)	18.9	0.931	17.6

Source : FAO, Production Yearbook Vol. 28-1 1974.

According to the statistics issued by FAO in 1974, the world production of cassava (wet tuberous roots) was approximately 105 million tons. Total production, however, is expected to increase to more than the abovementioned figure, since it is surmised that the statistics are lacking in the production data on cassava which people in the tropics cultivate in and around their habitation as a vegetable or subsidiary food.

Brazil produces most--a little less than 29 % of the world production, and is followed by Zaire, Nigeria, Indonesia, India and Burundi. The production of cassava in these six countries accounts for 68 % of the total production (See Table 2).

Table 2. Production of Cassava in the World
(FAO's estimate included partly for 1974)

	Production (1,000,000 ton)	% Against World Production
Brazil	30.0	28.6
Zaire	12.0	11.4
Nigeria	10.0	9.5
Indonesia	9.4	8.9
India	6.4	6.0
Burundi	4.0	3.8
		68.2
Thailand	3.8	3.6
Tanzania	3.5	3.3
Ghana	2.9	2.7
Mozambique	2.2	2.0
Angola	1.6	1.5
Madagascar	1.4	1.3
Colombia	1.3	1.2
Paraguay	1.1	1.0
Uganda	1.1	1.0
Sudan	1.1	1.0
Central Africa Rp.	1.1	1.0
Cameron	1.0	0.9
		20.5
World Production	104.9	100

Source : FAO, Production Yearbook Vol. 28-1, 1974

A glance at the situation in Southeast Asian countries reveals a rapid increase in production attained by Thailand. For instance, production is roughly doubled from 1.47 million tons in 1965/66 to 3.08 million tons in 1969/70, and further to 6.24 million tons in 1974/75, five years later. A rapid expansion in cultivation area resulted in this production increase (See Fig. 1). Major producing provinces in Thailand are Cholburi, Rayong and Nakornrajsima.

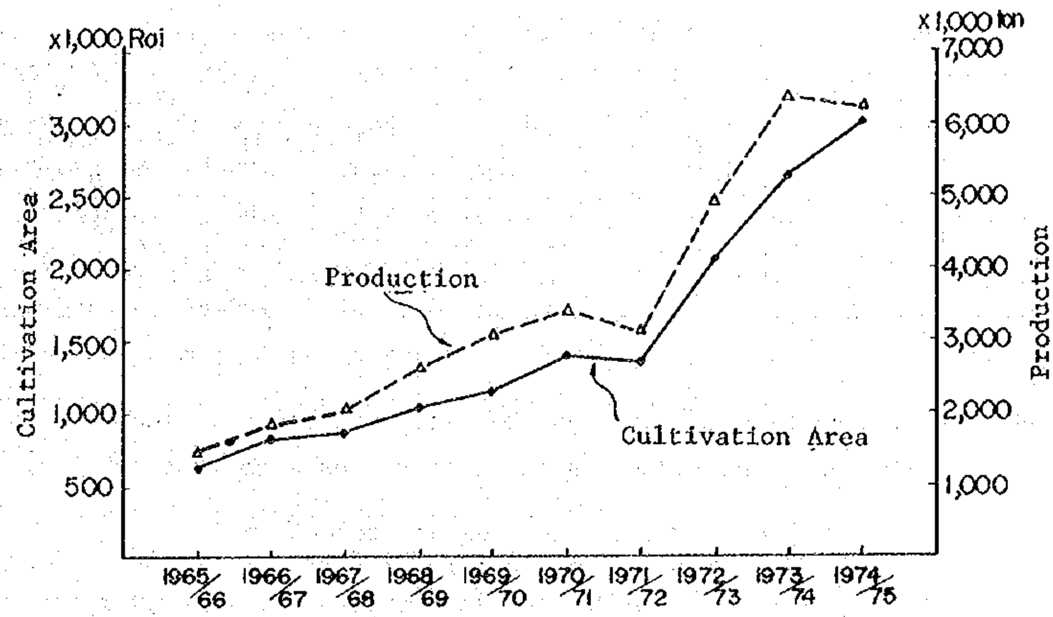


Fig. 1. Cultivation Area and Production of Cassava (Wet Tuberous Root) in Thailand.

Source: Agriculture Statistic of Thailand Crop Year 1974/75

Malaysia (West Malaysia) had a cultivation area of 42,000 ha according to the figures compiled in 1968 (Chan Seak Khen 1969). There is a very large difference in figures between Khen's in 1969 and those reported by Kitsutaka in 1976, which are as follows:

1968	1969	1970	1971	1972
17,022 ha	17,518 ha	17,653 ha	14,846 ha	13,141 ha

Cassava produced in Malaysia totaled 180,000 tons according to the FAO (1974), or 279,259 tons in 1972 by Kitsutaka. There is also a considerable difference in these figures.

Figures for the Philippines show a rapid expansion of cultivation area from 80,000 ha in 1971 to 140,000 ha in 1972, from which 500,000 tons of cassava were produced (Horibata 1976). The production in the Philippines registered 485,000 tons according to the FAO (1974), a slight decline from 1972.

In Indonesia, despite a generally declining trend in both cultivation area and production, (cassava) production increased in Lampung, Sumatra, under the strong production increase policy of the Government. Cassava is an important foodstuff in Indonesia, after rice and corn (Table 3).

Table 3. Harvest Area and Production of Cassava in Indonesia
(1000 Ha, 1000 ton)

	Harvest Area Production	1967	1968	1969	1970	1971	1972	1973
Indonesia	Ha	1,524	1,503	1,467	1,398	1,406	1,468	1,413
	ton	10,746	11,356	11,034	10,042	10,042	10,384	9,399
Lampung (Indonesia)	Ha	27	26	34	34	36	43	65
	ton	191	223	295	311	388	465	734

Source : Statistics Bureau of Indonesian Government and Agriculture Extension Service, Lampung

The worldwide cultivation area exceeds 11.9 million ha. The crop is enjoying increases both in production and cultivation area (See Table 4).

Table 4. Changes in Cassava Production
(World)

	Producing Area (million ha)	Yield kg/ha	Production (million ton)
1970	9.8	9,400	92.2
1972	11.0	9,590	105.4
1974	11.9	8,830	104.9

Source : FAO, Production Yearbook 1970, 1972, 1974.

The origin of cassava requires explanation: until the latter half of the 18th century, cassava was generally considered to be a plant indigenous to the American Continent. In 1772, however, Raynal proposed that the plant had been introduced from Africa, in opposition to the prevailing theory. Lack of evidence for his view, however, led to a rise of opposing ideas in the 1800's, and a theory affirming the American continent as the origin became dominant. Once this theory was accepted, discussion focused upon the question of the exact place of origin in tropical America. Today, it is restricted to northeastern Brazil/Paraguay, northern South America and Mesoamerica. Renvoize (1972) wrote that the places of domestication of sweet and bitter cassava were different. He wrote that sweet cassava was first domesticated in Mesoamerica as a species of various vegetatively propagated crops. Sweet cassava, constituting a part of a crop complex dominated mainly by corn, was later introduced to south America by emigrants, together with corn. Bitter cassava is likely to have first come under cultivation in the northern region of South America (the interior of

Venezuela) and to have achieved prominence as a major crop in horticultural systems depending mainly on vegetatively propagated crops. He wrote that migration of people and their mutual interchanges promoted a wide distribution of both sweet and bitter cassava in Central and South America. According to Renvoize, varietal diversity is seen in Brazil, and the existence of many varieties of the genus *Manihot* created favorable conditions for hybridisation, the development of new varieties. He, however, drew the conclusion that Brazil is probably not the first place of domestication for bitter cassava. Although the home of cassava is conjectured to be Central or South America, it is now grown and cultivated throughout the tropical regions.

Cassava was introduced into Southeast Asia in the middle of the 17th century. It was the Portuguese who transplanted it to Africa, from which it was later brought to Ceylon, India and then to the Philippines by the Spanish. There are documents in Penang, Malaysia, referring to cultivation of bitter cassava in 1846, records in Singapore show its introduction from South America in 1886.

Sosrosoedirdjo (1970) wrote that saplings of several cassava varieties were planted in the present Bogor Botanical Garden in 1852, and propagated over the entire island of Java in 1854. The history of cassava cultivation in Southeast Asia is comparatively young--about 100 years or so.

2. General Characteristics--As a Foodstuff

Nestel (1974) writes that "55 million tons of cassava out of 98 million tons produced on a world basis are consumed by humans today, according to the FAO," which means more than half of total production is directly utilized as a foodstuff. This observation is supported by Phillips (1974), who said that approximately 71 million tons of cassava will be consumed by people in 1980. Table 5 shows the amount taken by the people of 14 countries in the mid-1960's although the figures are probably low.

Table 5. Intake of Cassava as Food (1964-66)

Country	Human Population (million)	Cassava Calorie Intake/day	% ag. Total Calorie Intake	Annual Intake of Cassava
Congo (Brazzaville)	0.84	1,184	54.8	470
Zaire	15.63	1,193	58.5	437
Central African Rep.	1.33	1,057	48.7	354
Gabon	0.46	1,027	47.0	342
Mozambique	6.96	908	42.6	304
Angola	5.15	659	34.5	220
Liberia	1.08	600	26.2	201
Togo	1.64	590	26.5	197
Dahomey	2.36	438	20.1	148
Paraguay	2.03	540	19.7	181
Ghana	8.14	380	18.2	130
Brazil	80.77	274	10.8	107
Nigeria	58.48	306	14.1	103
Indonesia	105.74	269	15.3	92
Total or Average	304.15	374	19.4	124

Source : FAO, Food Balance Sheets 1964 - 66.

Cassava, which will play an important role as a foodstuff, is characterized by a high calorie output per unit area compared with other staple crops. Comparison of calorie output made by Coursey and Haynes in 1970 is as follows:

Cassava	250,000 cal/ha/day
Rice	176,000 cal/ha/day
Wheat	110,000 cal/ha/day
Corn	200,000 cal/ha/day

It is not easy to compare calorie output precisely; there is a difference in the results of studies made under existing conditions and those made under ideal conditions for comparing biological capacity. The following is therefore an extremely rough calculation of calorie output on the general understanding that cassava's calorie output is very high.

Table 6 shows calorific value per 100 g of major crops taken from the

Food Composition Table compiled by the FAO;

Table 6. Calorific Value of Major Tropical Food Crops

Crops	Calorific Value/ 100 g
Millet & Sorghum	345
Maize	360
Rice (Polished)	359
Cassava	109
Sweet Potatoes	97
Taro (Cocoyam)	86
Yams	90

Source : FAO, Food Composition Tables, Minerals and Vitamins Nutr. Stud. No. 11, Rome 1954.

Table 7 indicates principal ingredients of cassava taken by Holeman (1956)

Table 7. Ingredients of Cassava and Other Agriculture Products

Kind	Calorific Value	Protein	Fat	Carbohydrate	Ash	Moisture Content	Fibre	Vitamin A I.U.	Vitamin B mg/100 g	Vitamin C mg/100 g
Wet Cassava Root	127	0.8 - 1.0	0.2 - 0.5	32	0.3-0.5	65	0.8		-	-
Peeled Cassava Root	-	-	-	-	-	-	-	-	10	20
Cassava Chip	355	1.5	1.0	85	0.8	15	-	-	10	-
Cassava Starch	307	0.5 - 0.7	0.2	85	0.3	15	0.5	-	-	-
Potato	89	2.1	0.1	20	1.0	77	0.7	40	30 - 80	13 - 15
Potato Starch	331	-	0.3	82	0.3	15	0.4	-	-	-
Husked Rice	347	8.0	2.5	73	1.5	15	0.7-1.0	-	100 - 150	-

Source : Holleman, L.W.J. & A. Aten (1956) Processing of cassava and cassava products in rural industries. FAO, Rome

from the FAO. Reference to other relevant data shows the calorific value of cassava per 100 g to be 109 (Table 6), 127 (Table 7) and 148 (Montalds, 1973). Average calorific value is therefore understood to be around 130/ 100 g.

Assuming the calorie ratio of cassava to other crops to be 3 : 1, calorie output can be roughly compared by the following method.

Production statistics of Lampung, Indonesia, will serve as an example. Yield/ha and growth duration (days) of the major three crops in Lampung are shown below:

Crops	Average Yield	Growth Duration
Rice (milled)	1.35 ton/ha	140 days
Corn (dry grain)	1.23 ton/ha	120 days
Cassava (wet tuber)	11.20 ton/ha	300 days

Calorific value of these crops being 360 cal, 360 cal, and 130 cal for rice and corn, and cassava, respectively, calorie output per ha per day is as follows:

Rice	34,714 cal/ha/day
Corn	36,387 cal/ha/day
Cassava	48,533 cal/ha/day

So far as is shown by the existing situation in Lampung, Indonesia, cassava has a higher calorie output than other major crops. On the basis of the calorific value and growth duration mentioned above, yield ensuring equivalent calorie value/ha/day of cassava and rice will be calculated below (cassava's yield indicated as Y and that of milled rice as X_1):

$$Y = 5.93\ X_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots(A)$$

If the milled rice yield is calculated in terms of unhulled rice yield using an hulling rate of 70 %, the formula will be:

$$Y = 4.15\ X_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots(B)$$

Again on the basis of the calorific value and growth duration mentioned above, yield ensuring equivalent calorie value/ha/day of cassava and corn will be calculated as follows (cassava's yield indicated as Y and that of corn as X_2):

$$Y = 6.92\ X_2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots(C)$$

On the basis of (A), (B) and (C) in the above formulas, yield of milled rice, unhulled rice and corn equivalent to 25 tons of cassava is 4.22 tons, 6.02 tons and 3.61 tons, respectively.

"6.02 tons of unhulled rice" is not a very high Yield, nor is "3.61 tons of corn." The highest yield of hulled rice is said to be ten tons, while the average yield of corn in the United States is around 6 tons. Although "average yield of cassava as 25 tons" does not currently offer high calorie output, high calorie output is foreseen when cultivation technology is improved in the future--50 tons on the average. The possibility of increasing cassava yield will be studied in later pages, but attention should be drawn to information by Cock, who said a 47 ton yield was achieved in Colombia in 1973.

Attention should be given also to cassava's high tolerance to unfavorable conditions and production stability. Cassava can be cultivated on arid land with scanty rainfall. For example certain cassava varieties can grow with as little as 500 mm of annual rainfall, while others are adapted to regions with 5000 mm of rain. Especially it has strong resistance to drought: once it takes root in the soil, it stands well even in protracted drought that ruins normal crops; growth resumes when rain starts. This means that cassava can be cultivated at any time throughout the year in tropical regions; it changes little in its ingredients even when its harvesting time is delayed; it can be easily stored in the ground. It is not surprising farmers in the tropics grow it around their huts since it is a crop tolerant to unfavorable conditions.

In evidence of the above, no death from hunger was reported from cassava-producing Kerala, India, at the time of the drought in 1943, while more than one million people died of starvation in Bengal where no cassava had been cultivated.

Cassava is said to have strong resistance to disease, and insects; it grows in poor soil and is cultivated easily.

Farmers pointed out the following five points for reasons of their positive cultivation in answer to the questionaire distributed in Lampung, Indonesia in 1973:

(1) Cassava is a staple food second only to rice,

(2) It is easy to cultivate, and has a comparatively high production capacity,

(3) It suffers little from disease and insects of all kinds,

(4) It stands well even in long droughts,

(5) It requires only simple post-harvest measures.

The five points put forward by farmers themselves clearly explain the nature of cassava.

Cassava is rich in starch content, but poor in protein content. Further, it is not good as a foodstuff to be taken independently as it is short of sulfa contain amino acids (See Table 8). Addition of protein and other nutrients is necessary when cassava is used as foodstuff. As explained later, due attention should be given to enriching its nutritive qualities.

Table 8. Amino Acid Content in Food (per 100 g)

	Water (g)	Nitrogen (g)	Protein (g)	Lysine (mg)	Methionine (mg)	Threonin (mg)	Tryptophane (mg)	Essential Amino Acid (mg)	Total Amino Acid (mg)
GRAIN									
Wheat	12.0	2.09	12.2	374	196	382	142	4,280	12,607
Rice (Polished)	13.0	1.13	6.7	255	150	234	95	2,695	6,785
Corn	12.0	1.52	9.5	254	182	342	67	3,820	9,262
Sorghum	11.0	1.62	10.1	204	141	306	123	3,945	9,756
Barley	12.0	1.88	11.0	406	196	389	180	4,203	11,118
ROOT CROP									
Potato	78.0	0.32	2.0	96	26	75	33	667	1,572
Sweet Potato	70.0	0.21	1.3	45	22	50	22	414	994
Taro	72.5	0.29	1.8	70	24	74	26	707	1,737
Yam	72.4	0.38	2.4	97	38	86	30	821	2,009
Cassava (Meal)	13.1	0.26	1.6	67	22	43	19	404	1,184
LEGMINOUS CROP									
Kidney bean	11.0	3.54	22.1	1,593	234	878	223	8,457	20,043
Broad bean	11.0	2.74	23.4	1,513	172	786	202	8,244	20,951
Chick pea	11.0	3.22	20.1	1,376	209	756	174	7,802	19,290
Cow pea	11.0	3.74	23.4	1,599	273	842	254	8,640	21,086

Source : FAO, Amino-acid Content of Foods and Biological Data on Proteins. Nutritional Studies No. 24 Rome 1970

3. Botanical Characteristics

Cassava is a perennial shrub of the spurge family, together with para rubber, and castor beans, etc. It is botanically classified as *Manihot esculenta* Crantz or *Manihot utilissima* Pohl. Its English name is cassava, cassava or manioc, and is called mandioca or yuca in South America, ubi kayu in Indonesia and Malaysia, and kamoteng kahoy in the Philippines. In Japan, it is pronounced kyassaba, but should be pronounced as "kasahba" in strict accordance with the English pronunciation.

Leaving detailed explanations on botanical features to other handbooks, remarks shall be made only on a few important points.

The flowers of cassava are unisexual female flowers open 7 - 8 days earlier than male flowers. Cross-pollination is necessary. There are 8 - 10 male flowers to two female flowers. Some species bear flowers as early as 3 - 7 months after the planting of stem cuttings, but they usually bloom much later if growth conditions are favorable.

The following are the results of experiments made by an experimental station in Serdang, Malaysia, on the blooming habits of varieties collected since 1964 (Chan Seak Khen 1969). The experiments also made clear the existence of varieties that bear no flowers.

(1) Varieties that frequently bloom and bear fruit:
Medan, Jurai, Berat, Batang Puteh, Lemak, Ubi Melaka, Sakai

(2) Varieties that seldom bloom and bear fruit:
Black Twig, Green Twig, Ubi Puteh

(3) Varieties that never bear flowers or fruits:
Un-named -32 (no blossom from 1946 to 1969)

Cassava is propagated by stem cutting. If crossing for the purpose of breeding is necessary, it is cultivated on high land, as it accelerates flowering at lower stems (about breast high) and increases quantity, to make crossing easier. When planted on high land, flower abscission is also avoided. Chances of success by crossing, however, is generally very low-- 25-26 % at best.

Seeds are in ligeous capsules, look greenish when young and mature to a dark brown (See Photo 1). Seeds look very much like those of castor beans, slightly smaller in size and lighter in weight. When capsules are ripe and fully dried, they crack and seeds burst out. Some 57 % of a dried seed is a kernel; 47 % of the dried kernel is lipid materials, 98 % of which are triglycerides. Protein accounts for 34 % and starch content is only 0.3 % (Nartey et al. 1973).

A Mature root tuber consists of three parts: outer periderm, cortical region and pith. They are colored differently according to variety. For instance, the outer periderm of a certain varieties is light brown, while that of others is yellowish gray or brown; cortical region is sometimes white, reddish, light gray or light gray with brown stripes.

The pith, occupying a greater part of the root tuber, contains much starch and consists of parenchyma cell, with vascular elements and lactiferous tubes. Pith is white, creamy-colour or milk-white (See Photo 2). Starch grain is 2 - 25 in diameter and unique in possessing a stellate hilum shape. Size and length of root tuber differ according to variety, cultivation conditions etc. Generally, it is 5 - 15 cm in diameter and 50 - 100 cm in length.

The top part differs considerably; some varieties have stems more than 300 cm high and the number of branches is also variable. (See Photo 3).

Three to four shoots come out of one stem, and have a number of branches at their top. Some, however, have no branches at the top.

Leaves differ by varieties: some have deep lobes and others shallow ones. Colours as well as petiole of leaves are also varied (See Photo 4). During ten months of growth, they bear an average of 120 - 200 leaves, but old ones are shed one by one, leaving young leaves at the top of branches.

An interesting observation was made by Enyi in 1972 in Tanzania on cassava stems planted on January 8: LAI (Leaf Area Index) measured, on May 29, was 8 and over for Msitu Zanzibar and 5 - 6 for Amani 4026/16 and Aipin Valenca. LAI fell sharply thereafter to 1 (approx.) one month before harvest (in October). The value tended to increase slightly, irrespective of variety, when planting density was increased.

4. Varieties, Hydrocyanic Acid Contents and Other Characteristics

More than 1,000 cultivars are said to be cultivated in the world. As cassava is propagated by the vegetative reproduction method, cultivars are named differently and classified as different varieties when introduced to other regions of the world. Under these circumstances, it is very difficult to clarify features by variety.

If cassava is utilized as food or feedstuff, the question of the toxicity of hydrocyanic acid contained in it must be answered. Cyanogenic glucoside is contained in all cassava plants and tuberous roots, showing a wide variation by variety. Cyanide includes linamarin and lotaustralin. Cassava contains enzyme--linamarase--which changes these to hydrocyanic acid (HCN) through hydrolysis. Cyanide is more or less stable in sound cells, but it forms hydrocyanic acid with the help of linamarase when cells in leaves or roots destroyed by external injuries. The toxicity of linamarin and lotaustralin is not yet fully understood today (Coursey 1973).

Nijholt pointed out in 1932 that hydrolysis of linamarin takes place inside digestive organs and, therefore, linamarin may become toxicent to people or cattle when they ingest it. There is much room for further study in this respect. Cassava is widely used as food as well as a feedstuff, particularly in Europe. Although research is very incomplete, serious problems may remain.

For instance, reports have been made of outbreaks of tropical ataxic neuropathy, goitre, cretinism in Africa where cassava is heavily consumed, according to which a certain substance of cassava seems to have been one of the factors in the outbreak of these diseases (Osuntokun 1973, Ekpechi, 1973 and Ermans et al. 1973).

Added to these, there is information on adverse affects on the growth of pigs and fowl when cassava is given in great quantity without the supply of methionine (Maner and Gomez 1973).

Under these circumstances, much discussion on the chronic toxicity of cassava has taken place at various workshops, particularly with regard to the biosynthesis of cyanogenic glucoside, physiological problems caused by cassava toxicants, its detoxification mechanism, breeding of low-cyanide varieties and sensitivity to harmful insects and disease etc. (Nestel, 1974).

Cassava cultivars are divided largely into two types according to the amount of hydrocyanic acid content: sweet and bitter types. Classification by way of hydrocyanic acid content, however, is not precise as the content changes according to drought or fertilizers applied.

Classification into sweet and bitter types depends upon the content of cyanide or hydrocyanic acid, and not "sweetness or bitterness in taste." Sinha and Nair reported in 1968 on the overlapping classification resulting from different methods used in classifying the crop: one by the original method and the other by cyanide content.

According to the experience of the authors of this pamphlet, the sweet type is not really sweet in taste. It is fibrous and tastes like potatoe. It does not cloy the palate. The bitter type of cassava, on the other hand, is not used as a food due to its high hydrocyanic acid content. Farmers who plant this type for industrial use say that their mouth and body become numbed when bitter-type cassava is consumed raw. The word "bitter", therefore, does not apply to "bitterness" in taste.

Sweet cassava is consumed by farming people in the tropics using various processing procedures: it is chopped, ground, soaked in water or squeezed after grinding, exposed to the sun, heated, boiled or fermented to make it innoxious.

Sweet and bitter cassava are further divided into the following four groups by hydrocyanic acid content:

(1) Hydrocyanic acid content of less than 50 mg per 1 kg of chopped tuberous root,

(2) Hydrocyanic acid content of 50 - 80 mg/kg

(3) Hydrocyanic acid content of 80 - 100 mg/kg

(4) Hydrocyanic acid content of 100 mg and over

Some classify groups (1) and (2) as sweet and (3) and (4) as bitter, while Koch (1933), Bolhins (1954) and De Bruijin (1971) show little interest in classification into sweet and bitter types and divide it according to toxicity as group (1) innoxious, groups (2) and (3) moderately poisonous and (4) dangerously poisonous.

Hydrocyanic acid presence in periderm is 2 - 9 times that in central pith. Table 9 shows the distribution of hydrocyanic acid as compiled by an experimental station in Serdang, Malaysia (Chan Seak Khen. 1969). For instance, hydrocyanic acid content is 70 mg/kg in root pith in cultivar Native-4, while 630 mg (630 ppm) is contained in periderm. Peeling the periderm is said to reduce hydrocyanic acid content to a considerable extent.

Table 9. HCN Content in Periderm & Flesh (Pith) of Cassava Cultivated by Agricultural Station in Serdang, W. Malaysia

Variety	HCN Content in Periderm (A) %	HCN Content in Flesh (pith) (B) %	B/A Ratio
Constantin	0.028	0.010	2.8
Negrita 17	0.058	0.009	6.4
Cabesadura	0.040	0.006	6.7
Native 4	0.063	0.007	9.0
Native 13	0.045	0.014	3.2
Native 8	0.035	0.005	7.0
Native 3	0.021	0.011	1.9
Manioc de table	0.038	0.007	5.4
Native 5	0.036	0.017	2.1
Bereum	0.037	0.010	3.7
Native 1	0.018	0.003	6.0
Mauritius 29	0.032	0.005	6.4
Butter Sticks	0.022	0.004	5.5
Native 6	0.039	0.016	2.4
Icery			

Source : Extract from Group A, Table 6 of Statistics on Tapioca Investigations at Federal Experiment Station, Serdang (Chan Seak Khen - 1969)

Note : HCN Content : 0.028 % = 280 mg/kg

Leaves of cassava play an important role as a subsidiary food for people in the tropics as it contains protein--20.6 to 36.4 % on dry matter base. Cassava protein is high in lysine content although it is short of tryptophane and methionine. Leaves, however, contain hydrocyanic acid: more in young leaves (up to 0.1 % -- 1,000 mg/kg) than old leaves. Exposure of collected leaves to the sun or boiling in hot water largely destroys toxicity (See Table 10).

Table 10. HCN Content in Cassava Leaves After Boiling

Sample No.	Variety	HCN Content (Leaf) mg/kg		
		Fresh Leaf	Steaming 15 min.	Boiling 25 min.
1	SPP	838	692	161
2	"	1,074	479	284
3	Mangi	427	188	60
4	"	343	247	54
5	"	379	294	30
6	Valenca	477	242	53
7	"	350	278	12

Source : Sorrosoedirdjo, (1970); Ketela Pohon

Cassava leaves are widely consumed as vegetables in Indonesia also. They are widely marketed. They taste like spinach, although a little bit bitter. Table 11 shows hydrocyanic acid content in leaves (both young and old) of cassava grown in Indonesia.

Table 11. HCN Content in Cassava Leaves

Sample No.	Variety	HCN Content in Young Leaf (mg/kg)		
		Young Leaf	Mid-age Leaf	Old Leaf
1	Mangi	168	119	-
2	"	156	88	6.5
3	"	427	343	34.0
4	"	542	379	-
5	Valenca	477	350	-
6	Betawi	206	74	-

Source : Same with Table 10.

As mentioned above, hydrocyanic acid content is higher in leaves than in root tubers, but a close relation seems to exist between the content in leaves and root tubers (Fig. 2). The regression line in Fig. 2 indicates that the hydrocyanic acid content in tuberous roots approachs zero when it is 100 mg in leaves. Rogers reported in 1963 that, in some varieties, only

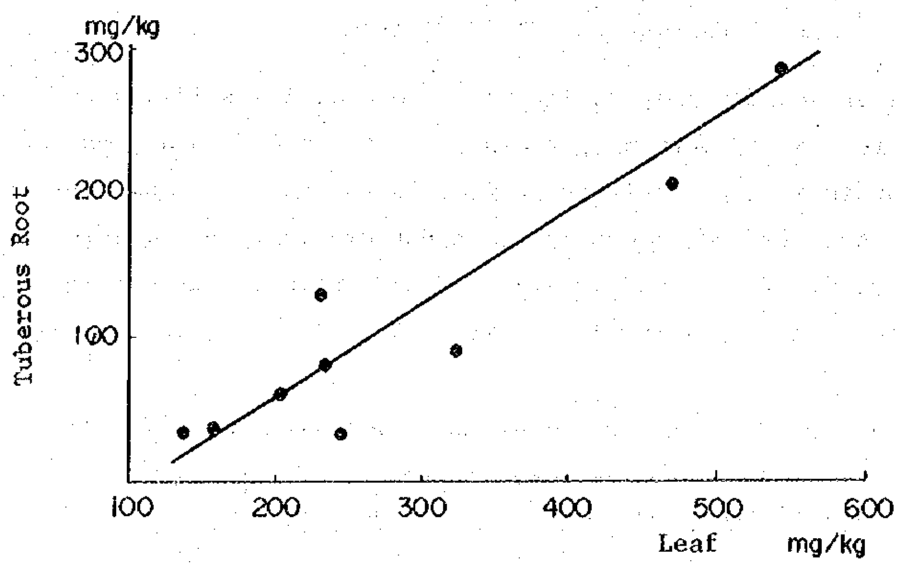


Fig. 2. Comparison of Hydrocyanic Acid Content in Tuberous Root and Leaf

Source : Socrosoedirdjs. R.S. (1970); Ketela Pohon

10 mg or less of hydrocyanic acid was found in tuberous roots tested.

Those data suggests the possibility of growing cassava without hydrocyanic acid in the roots.

As already explained, hydrocyanic acid in root tubers is reduced by heating and boiling. Table 12 shows one example of such changes. For instance,

Table 12. Disappearance of HCN in Root by Boiling

Variety No. Treatment	HCN Content before Boiling mg/kg	HCN Content Disappeared by Boiling mg/kg	%
12 1)	175	92	52.6
20 2)	264	116	43.9
101 1)	185	97	52.4
250 2)	212	159	75.0

Source : Same with Table 10.   1) Soak in boiling water
2) Boil in boiling water

Collens (1915) wrote that hydrocyanic acid could be entirely removed from samples of sweet type cassava by ordinary processing, although, in the case of bitter-type, 20 mg of hydrocyanic acid remained even after food. There are a number of reports on the relation between methods of cooking and hydrocyanic acid content, although information on the relation between hydrocyanic acid content and non-pretreated tuberous roots is lacking.

Charavanapavan (1944) reported that 90 % of hydrocyanic acid was removed when sliced cassava root tubers were dried at 60°C but that little effect was shown when dried at temperatures close to 100°C. He explained in this regard that high temperature drying changed denatured the enzyme systems, preventing autolytic hydrolysis of cyanides. Paula and Rangel (1939) succeeded in reducing hydrocyanic acid content from 39 mg to 17 mg by the exposure of smaples to the sun, and to 6 mg by drying them in an oven. Pandittesekere (1944) wrote that one-third of hydrocyanic acid content was lost by drying samples at 60°C, but drying at higher temperature was not so successful. According to Razafimahery (1953), two-thirds of the hydrocyanic acid disappeared as the result of exposure to the sun for 7 days.

Boiling, as a part of food preparations, reduces hydrocyanic acid content to a considerable extent. Raymond et al. (1941) boiled cassava cultivars containing 332 mg of hydrocyanic acid and reduced the content to 10 mg. Joachim and Pandittesekere (1944) reported on their findings, stating that cultivars containing 103 - 232 mg of hydrocyanic acid was boiled and the content was reduced to 27 - 87 mg, although no definite correlation was found between these figures and initial hydrocyanic acid content in respective smaples.

As mentioned above, a wide range of variation exists in analysis results owing to different preparation methods, varieties, etc. Here, consideration should be given to methods of analysis.

For instance, Joachim and Pandittesekere (1944) pointed out that in the method for estimating hydrocyanic acid content in materials containing cyanide, there was a tendency to estimate content conservatively, as they found that the amount of hydrocyanic acid released autolytically in the analysis increased considerably with the period allowed for autolysis.

Wood (1965, 1966) developed the most reliable method to analyze cyanide and hydrocyanic acid, in which the accuracy of the final results is also biased to a certain extent when liberation of hydrocyanic acid for experimental materials is incomplete. Cassava root tubers require a particular method of analysis.

In breeding, simple methods of determining hydrocyanic acid content are necessary to select low cyanide varieties out of the many cultivated at experimental stations. Various methods have been tried for this purpose: for instance, Esquivel and his group (1973) compared a color reaction by the Benzidine blue test (Feigl 1954) and HCN content by alkaline determination method (AOAC method), and found an extremely high correlation between the two methods. Benzidine blue test proved to be particularly efficient as it is simple, taking only a couple of minutes to complete the examination (Table 13).

Table 13. Relation of Color Intensity and Yield of HCN for Cassava Root Tubers

Variety	HCN Content by AOAC Method (ppm)	Degree of Toxicity	Color Intensity by Benzidine Blue Method
Palmeiras	377.5	Poisonous	Intense blue
CEPEC-62	313.0	"	Strong blue
IAC-780	200.0	"	Medium blue
Itapecuru	68.5	"	Weak blue
Engole boi	41.0	Tolerable	Very weak blue
CEPEC	27.0	Innocuous	Almost no color

Source : Esquirel, T.F. et al.(1973)

Some description should be given to varieties cultivated in a few countries in Southeast Asia, particularly in relation to their hydrocyanic acid content: Mangi grown in Indonesia is good for consumption with approximately 40 mg/kg in HCN content. Mentega cultivated for foodstuff in Lampung, Indonesia, has a yellow central pith, which is called "kuning" meaning yellow" in Indonesian. SPP (Brazilian variety--Sao Pedro Preto) having high hydrocyanic acid content is cultivated for starch production. It is also used for chip production. Its central pith is white, differing from Mentega (See Photo 2). Table 14 shows the characteristics of cassava

Table 14. Characteristics of Cassava Cultivated in Lampung, Indonesia

Character / Variety	Colour of Young Stem	Colour of Petiole	Colour of Young Leaf	Branching at Top	Flowering & Fruiting	Colour of Root: Outer periderm	Colour of Root: Cortex	Colour of Root: Central Pith	Type
SPP	Dark green	Pink on upper surface green on under surface of petiol	Green	Frequent	Frequent	White	White	White	Bitter
Un-named	Pale green	Green with slight tinge of pink on upper surface of petiol	Yellowish	Frequent	Frequent	-	-	-	Sweet
Mentik Urang	Brown	Red	Brownish green	Frequent	Not so Frequent	Yellowish white	White	White	Sweet
Mentega	Pale green	Pink on upper surface, green on under surface of petiol	Brownish green	Frequent	Seldom	Yellowish white	Yellowish brown	Yellowish white	Sweet
Tahun	Pale green	Red	Yellowish green	Seldom	Seldom	Dark brown	Pink	White	Sweet
Genjah Putih	Dark green	Pink	Brownish green	Frequent	Frequent	Grey	White	White	Sweet
Mali	Dark green	Green	Brownish	Not so frequent	Seldom	Dark brown	Yellowish white	White	Sweet

Source : Hirose (1976)

varieties studied in Indonesia by the present authors, and Table 15 indicates varieties recommended by the Central Research Institute for Agriculture in Indonesia (Bogor).

Table 15. Characteristics of Recommended Variety, Indonesia

Variety	Origin	Type	Average Yield (t/ha)	HCN Content (mg/ha)	Starch Content (%)	Protein Content (%)	Growth Duration (month)	Plant Height (m)	Resistance to Disease	Others
Valenca	Brazil	Sweet	10 - 12	40	36.5	0.60	10 - 12	2 - 3	Weak in Bacterial disease	
Sao Pedro Preto/spp	Brazil	Bitter	20 - 25	150	27.8	0.57	10 - 12	1 - 2	Weak in leaf blight & bacterial disease	
Bogor	Maleka x Basiorao	Bitter	20 - 25	90	30.0	0.38	10 - 12	1 - 2	Weak in bacterial disease	
Muara	Bogor x Basiorao	Bitter	Some 30	100	35.2	0.48	7 - 10	1 - 2	"	Easy to dig out
Gading	W. Java	Sweet	Some 30	31.4	36.0	0.56	7 - 10	1.5 - 2.5		
Ambon	Ambon (Mark Islands)	Sweet	20 - 25	32	37.0	0.68	8 - 10	1 - 2		
Y-629	Ambon X Gading	Sweet	25 - 30				8 - 10	1 - 2		
W-78	Mangi X Ambon	Sweet	25 - 30				7 - 10	1 - 2		
M-236	Mangi X Ambon	Bitter	Some 30				8 - 12	2 - 3		
NON-RECOMMENDED										
Mangi	Brazil	Sweet	20	30	37.0	0.34			Non-sensitive to bacterial disease	
Betawi	Mleka X Basiorao	Sweet	20 - 30	Over 30	33.4	0.32			Sensitive to Virus	
Basiorao	Brazil	Bitter	30	Over 80	31.2	0.29			Weak in B. Disease	
Mantega										Variety similar to SPP
Tapicuru								Very high		Scarcely cultivated today.
Mania		Slightly sweet					Short			Cultivated by farmers as food
Begog		Sweet								Cultivated mainly around Bogor

Source : 1) Central Institute of Agricultura : Pamphlet on Recommended Varieties.
2) Soerosoedirdjo, R.S. 1970, Bertjotjok tanaman ketela pohon. (on Cultivation of Cassava). Quoted from Mikoshiba (1975)

Local varieties in Malaysia are also classified into sweet and bitter types. Chan Seak Khen et al (1969) found, however, that their analysis did not coincide with that of their predecessors: Black Twig, classified as a bitter type had an unexpectedly small HCN content (51 mg/kg), while 10 other varieties such as Medan, Sakai that are considered to be sweet-type showed little difference in HCN content when compared with Black Twig. Table 16 shows characteristics of the Malaysian varieties.

Table 16. Characteristics of Cassava Cultivated in West Malaysia

Variety	Colour of Stem		Colour of Petiole	Colour of Young Leaf	Branching at Top before Flowering	Colour of Root		Type Sweet & Bitter
	Young	Old				Residern	Flesh pith	
Un-named	Pale green	Pinkish	Pale green with slight tinge of pink on upper surface of petiole	Brownish	Seldom	Brown	White	Sweet
Lemak	Green	Grey	Dark purple at the base, reddish patches at middle and tip with green coloration between them.	Brownish green	Frequent	Light brown	White	Sweet
Ubi	Dark green	Grey	Dark purple at base, slightly reddish along upper surface	Brownish green	Frequent	Brown	Pinkish white	Sweet
Black Twig	Dark green	Dark brown	Green with reddish stains at both ends	Purple	Seldom	Brown	White	Bitter
Green Twig	Green	Grey	Green	Brownish green	Seldom	Light brown	White	Bitter
Jurat	Dark green	Brown	Green with reddish stains at both ends	Green	Frequent	Dark brown	Pinkish	Sweet
Medan	Dark green	Grey	Dark red	Green	Frequent	Brown	Pink	Sweet
Berat (Betawi)	Pale	White	Red with narrow band of green at base of petiole	Brownish	Frequent	Light brown	White	Sweet
Ubi puteh (Tiga Bulan)	Pale green	Pinkish	Pale green	Green	Seldom	Brown	Pinkish	Sweet
Puteh	Pale green	White	Pale green with red stain at the base	Brownish	Frequent	White	White	Sweet
Pokut	Green	Grey	Red	Brownish	Seldom	Light brown	White	Sweet
Sakai	Dark green	Pinkish	Dark red	Brownish green	Frequent	Light brown	White	Sweet

Source : Tapioca Investigations at the Federal Experimental Station Serdang (1969) from Table 15.

In Thailand, Jatropha manihot (bitter type) and Jatropha culcis (sweet type) are most typical. Their adaptation to conditions in Thailand is excellent, showing higher yield than any varieties introduced from overseas and tested in the country (Harper. 1973).

According to studies made by the International Center for Tropical Agriculture in Colombia, a generally-held view that greater yield is enjoyed by bitter type cassava in both Indonesia and Malaysia is not entirely correct.

Reports on cassava varieties have been made only sporadically. However, efforts have recently been made to systematically classify, by computor, data collected by the University of Colorado over the past 18 years.

5. Specific Characteristics as a Crop--Growth Pattern and Yield

By how much can the yield of be cassava increased? In answering to this question, Dulog (1971) reported on an increase in yield to 70 tons per ha in Madagascar, while Cock (1973) reported 47 tons/ha in Colombia. Late cassava varieties (14-18 months) are said to produce up to 70 - 80 tons/ha of wet tubers if fertilizers are appropriate.

Daya-Ito Farm in Lampung, a joint Japan-Indonesia venture, succeeded in obtaining 73.3 tons/ha yield as the result of a series of fertilizer tests (N-150 kg, P_2O_5 - 100 kg and K_2O - 50 kg for a small-sized test plot).

Statistics show very low wet root tuber weight: world average was only 8.8 tons/ha according to the FAO in 1974, 8.7 tons/ha in Asia, 7.2 tons/ha in Africa and 13.0 tons/ha in South America. Fig. 3 shows the result of yield tests over 25 varieties conducted in 1971 by the Central Research

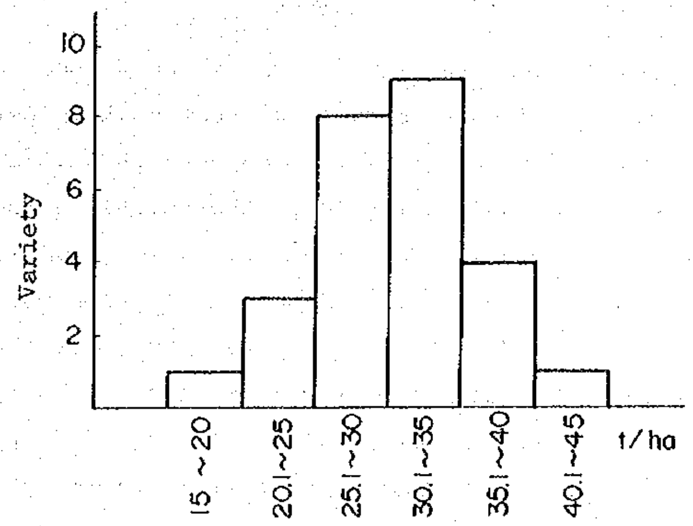


Fig. 3. Distribution of Yield in Varietal Performance Test

Source : Central Research Institute for Agriculture in Indonesia (1971)

Institute for Agriculture at its branch experimental station in Lampung, Indonesia. The test was performed by applying fertilizers composed of N (45 kg), P_2O_5 (18 kg), K_2O (50 kg), and the average yield reached 30 tons/ha.

According to information obtained from Thailand, an average 18.1 tons/ha yield was achieved from 10 month varieties and a 26.9 tons/ha yield from 12 month varieties (Harper 1973). The authors of this pamphlet also succeeded in acquiring a yield close to 40 tons/ha at an experimental field (0.5 ha) in Tegineneng, Lampung. Table 17 shows the results of an experiment at an experimental station in Serdang, Malaysia, which registered a yield of

Table 17. Experiment Results on Vairetíes, Serdang, W. Malaysia

Variety	Characteristics	Monthly Yield ton/ha		Average ton/ha
		12 months	14 months	
Green Twig	B (Bitter)	35.8	42.5	39.1
Black Twig	"	33.6	38.9	36.3
Berat	S (Sweet)	35.3	35.4	35.4
Medan	"	34.6	31.3	32.9
Jurai	"	30.2	33.4	31.8
Un-named - 32	"	30.0	24.0	27.0
Lemak	"	26.2	26.4	26.3
Pulut	"	22.5	24.1	23.3
Ubi Melaka	"	23.8	22.8	23.3
Puteh	"	22.4	22.3	22.4
Sakai	"	17.9	16.2	17.1

Source : Same with Table 9.

30 tons/ha for many varieties under fertilization.

When cassava stem cuttings are planted, their roots come out, increase in number and then become more bulky during the root bulking period. About two months after planting, dry weight of the roots reaches 10 % of the weight at harvest, but it accounts for 40 % of the weight at the harvesting time in three months later. Within 3 to 4 months after planting dry weight increases rapidly. The increase in dry weight of Malaysian varieties is shown in Fig. 4 (Williams 1972). The figure indicates that the root weight against total dry weight (including the top and roots) at the time of harvest (12 months after planting) was 50 - 60 % (Enyi, 1973 and Williams, 1972). On the eighth month after planting, the root weight constituted the largest percentage, with some exceptions according to varieties.

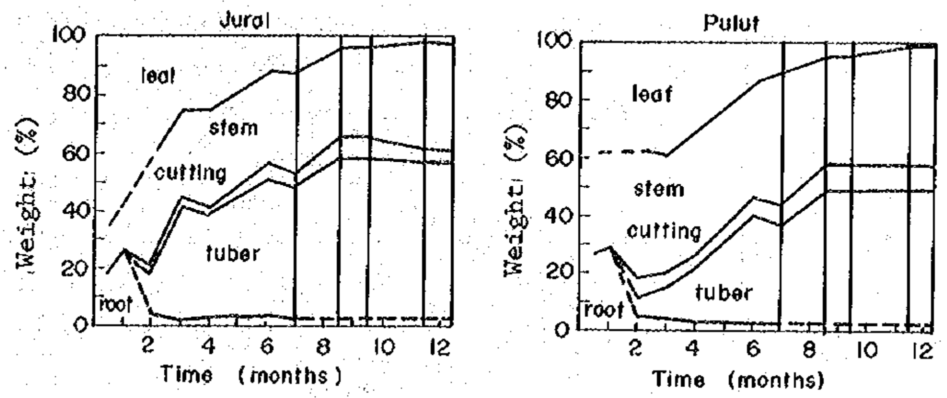
The percentage of dry weight of tuberous roots against the total dry matter production is defined as harvest index. As clearly indicated in the test result by Williams (1972), harvest index increased for 8 - 9 months after planting, remaining more or less stable in succeeding months.

Generally speaking, the final yield of root vegetables is determined by two factors: bulking rate and bulking duration. Enyi (1973) reported on a highly positive correlation between tuber yield and bulking rate: if, for instance, tuber yield (ton/ha) is Y and bulking rate (kg/ha/week) is B, the regression equation will be:

$$Y = 0.0053 B + 10.3$$

Coefficient of correlation of the two will be:

r = 0.866



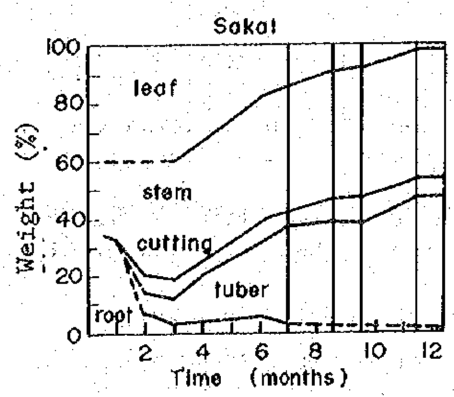


Fig. 4. Comparison of Weight (%) by Growth Duration of Three Varieties of Cassava
Source : Williams, C.N. (1972)

LAI (Leaf Area Index) rises for about 5 - 6 months after planting, and bulking rate increases parallel to the LAI. The most favourable LAI for maximum bulking rate differs by varieties: Msitu Zanzibar indicates 7.8, Aipin Valenca 6.0, and Amani 4026/16 5.3.

On the other hand, Williams et al. (1969, 1971) studied structural attributes of the canopy of high, medium and low yield varieties and found correlations between yield and the features mentioned above.

Leaves fall towards the latter half of the growth duration, and LAI drops to 2 or less after the tenth month (Enyi 1973). As leaf falls influence dry matter production, prevention of leaf falls may be important to increase yield. The period of maximum yield varies according to variety.

The results of studies made by an experimental station in Serdang on tuber yield and growth duration are shown in Fig. 5, and relations between starch content and starch yield are shown in Table 18.

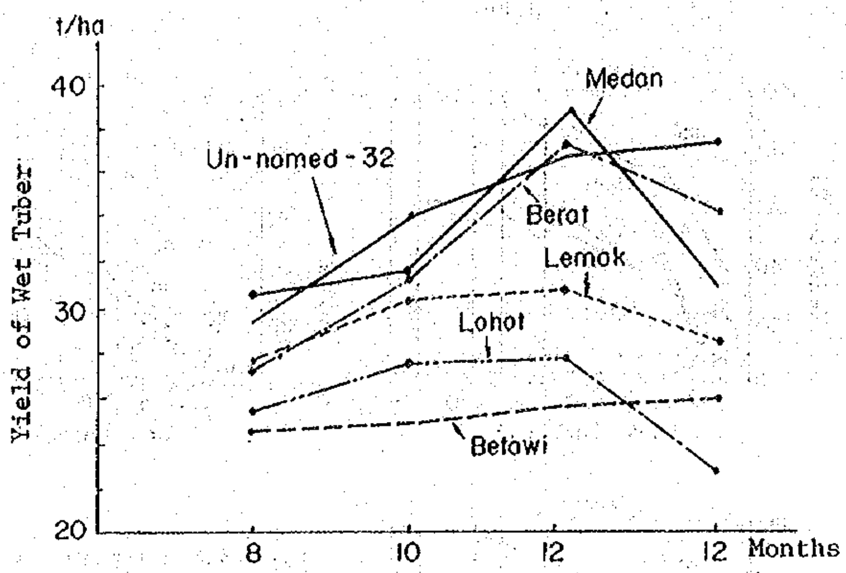


Fig. 5. Relations between Growth Duration (Days) and Yield Increase

Source:: Tapioca Investigations at the Federal Experimental Station, Serdang. (1969)

Table 18. Starch Content and Yield/ha by Month

Variety	Starch Content & Yield	Number of Months			
		7	8.5	10	11.5
Valenca	Starch Content %	32.7	33.2	34.0	33.0
	Starch Yield kg/ha	3,165	6,148	11,842	12,573
Muara	Starch Content %	20.2	25.0	24.1	24.1
	Starch Yield kg/ha	3,595	8,375	10,502	10,003

Source : Wargiono J. Hadi (1974) Ubi Kayu Dan Cara Bercocok Tanamnya

Ketiku and Oyennga (1972) studied changes of carbohydrate contained in tubers during the period of growth and found maximum starch increase in the eighth month. They found whole sugar accounted for 5.7 % in the ninth month (Table 19).

Table 19. Relation Between Carbohydrate Content in Root and Plant Age

	Plant Age (No. of Months after Planting)				
	5	6	7	8	9
Total Sugar	3.1	5.1	2.6	3.5	5.7
Starch	71.8	67.2	72.5	81.0	77.6
Hemicellulose	1.0	1.0	0.9	0.8	1.0
Cellulose	4.5	5.4	3.7	3.2	3.4
Total Carbohydrate	80.4	78.7	79.7	88.5	87.7

Source : Ketiku, A.O. and V.A. Oyenuga (1972)

6. Method of Cultivation

Cultivation of cassava is easy; it grows under all of the conditions described. Its strong durability to drought makes it the only crop consumed by farming people in the tropics in the dry season.

(1) Method of Planting

Cuttings taken from the stems of plants that have grown for at least 8 to 10 months are used for cultivation. Correlation seems to exist between the age of cuttings and yields of starch per ha. Yield tests on three portions of stems including young top, middle part and bottom part showed that starch yield was highest in a plot where the bottom part of stems was used as nursery plants, and was poorest in the plot where top-most stems were planted.

Similar results were obtained in another test. Yield ratio of a plot where bottom part stems were planted was 1.75 against 1 for a plot where top-most stems were planted.

During the initial period, the growth of cassava is heavily influenced by the amount of carbohydrate and inorganic matters stored in the stem cutting. Enyi (1970) reported on a positive correlation between tuber yield and the age of cuttings. It is recommended that cuttings be cut from the bottom part of well-grown stems.

Stems used for cultivation should be stored upside down at airy, shady and cool place after harvest. When stored in this way, they may be kept for eight weeks. Stems that are harvested in a period of heavy rainfall can be stored for only seven to ten days.

The length of stem cuttings is about 15 cm (6 inches) to make planters easier to handle. Experiments in Jamaica showed cuttings of 20 cm in length offered higher yield than longer plants (Krochmal 1969). Though a report from Brazil recommends 50 cm stem cutting, it is not possible to indicate the exact length of cuttings because the optimum length of cuttings is determined by the method of planting. In the Philippines and Indonesia, 20 - 25 cm cuttings are widely used.

Planting methods vary: generally, cuttings are planted vertically, slanted at an angle of 30 - 40° to the ground, or planted horizontally under the soil surface (Photo 5).

Experiments were performed in Jamaica by planting cuttings vertically, slantedly and horizontally in the soil. The results were as follows: the highest germination rate was observed, root tubers came out close together at the soil surface and the yield was highest for cuttings that were planted horizontaly in the soil. Reports obtained from Thailand proved the advantage of horizontal, underground planting. The report indicates that the highest yield was obtained in plots where cuttings were planted under the soil surface and covered with soil of 5 - 7.5 cm deep. Krochmal (1963) compared slanted planting with horizontal underground planting in the Virgin Islands and found the yield was poorer in plots where slanted planting was tried.

In Ceylon, however, the survival percentage (sprouting) as well as yield was higher in plots where vertical planting was tried. As described above, the effects of planting methods on yields were different depending upon the location in which trials were conducted. Climatic or geological conditions such as soil moisture, rainfall, etc. seem to decide the relations between yields and planting method. In Thailand and other areas, horizontal planting seems to be best, particularly during the dry season (Sato 1951).

Table 20. Relation between Method of Planting and Yield (in Brazil)

Method of Planting	Length of Stem Cuttings inch	Yield ton/ha	
Vertical Planting	20 - 24	38.37	38.12
Slanted Planting	20 - 24	37.62	
Cross-slanted Planting	6	28.96	25.74
Vertical Planting	6	26.98	
Slanted-horizontal Planting	6	26.73	
Slanted Planting	6	23.27	
Horizontal Planting	6	21.29	

Source : Krochmal, A. (1969)

Table 20 shows the results of experiments in Brazil on the relation between methods of planting and length of stems cuttings upon yield. The figures show that stem cutting length affects yield more than planting method. Krochmal (1969) reported that it would be most favorable to plant cuttings of 20 - 25 cm in length with three sprouts horizontally at 5 - 10 cm under the soil surface. Stem cuttings planted upside down easily perish, and if grown, they bear immature root tubers with a poor yield (See Photo 6).

(2) Ridge Culture

Planting is generally done immediately after plowing, but occasionally, it follows ridge culture, which has several advantages. Ridge culture makes planting easier; it reduces damage from excess moisture during rainy season and it prevents stem cuttings just planted and bulking root tubers from root that may be caused by dead water. Although the range where root tubers can grow is more or less limited by ridge culture, it helps to reduce damage to root tubers and makes harvesting easier, particularly when machines are used. Japanese enterprises in Lampung have also introduced a ridge culture method.

(3) Planting Density

A number of reports have dealt with planting density and system. Density and system vary according to variety and soil conditions. Enyi (1972) experimented on three different varieties in three-level planting density tests in Tanzania (See Fig. 6). He attained the highest yield for Aipin Valenca and Msitu Zanzibal by planting 18,500 cuttings/ha.

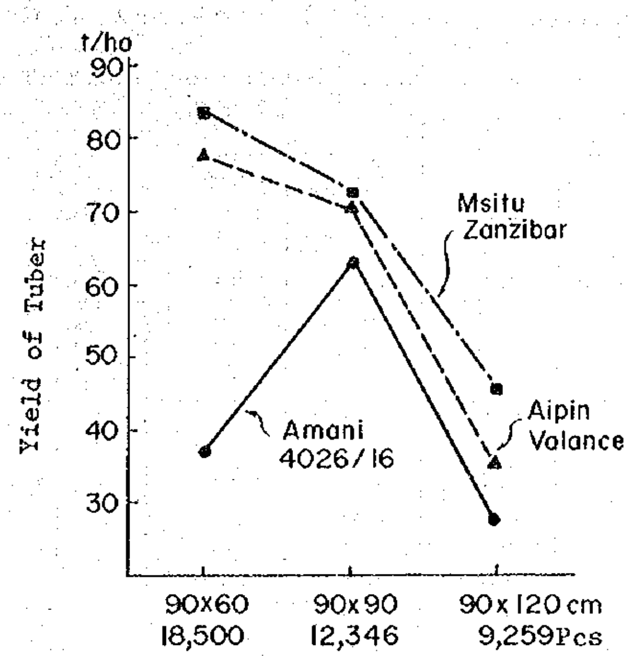


Fig. 6. Planting Density Test in Tanzania

Source : Enyi (1972)

The effect of close planting is desirable in this testing method. The highest yield for Amani 4026/16 was attained by planting 12,346 per ha. On the basis of his experiments, he drew a conclusion as to the most appropriate planting density to gain maximum yield--16,750 pcs, 16,000 pcs and 14,000 pcs for Aipin Valenca, Msitu Zanzibal and Amani 4026/16, respectively.

Experiments conducted by the authors in Indonesia on SPP in 4-level density tests proved that maximum yield would be attained from a density of 12,500 pcs/ha in a non-manuring plot and 16,660 pcs/ha for a manuring plot.

CIAT reported that yield on the eleventh month after planting differs by plant height and the number of branches. They said that the density of some 10,000 pcs/ha guaranteed the best yield for CMC 84 which is medium in plant height with few branches, 5,000 pcs/ha for Lkanera; which has many branches and CMC 39 which grows high.

These experiments show differences in favorable planting density by region--Tanzania, Indonesia and areas tried by CIAT. Higher planting density generally decreases root tubers weight per plant, although it increases plant height. Only a few reports have been made on relation between planting density and harvest index. Results concerning planting density and yield reported by Enyi (1972) are shown in Table 21.

Table 21. Relation between Planting Density and Yield (Tanzania)

	Planting System	Density	Variety			Average
			Amani 4026/16	Aipin Valenca	Msitu Zanzibar	
Yield t/ha	90 x 60 cm (S_1)	18,500	37.2	78.1	84.6	66.6
	90 x 90 cm (S_2)	12,346	63.9	70.1	73.2	69.0
	90 x 120 cm (S_3)	9,259	27.9	35.2	45.3	36.1
Yield/plant (kg/plant)	S_1	18,500	2.6	4.2	4.6	3.8
	S_2	12,346	4.5	5.6	5.9	5.8
	S_3	9,259	4.8	8.0	10.3	7.7
Bulking rate kg/ha/week	S_1	18,500	8,250	15,510	11,520	11,760
	S_2	12,346	7,730	11,890	11,310	10,310
	S_3	9,259	3,230	5,680	4,770	4,560
Total Dry Matter Weight g/m^2 (A)	S_1	18,500	3,088	4,190	4,981	4,082
	S_2	12,346	3,318	3,504	4,477	3,763
	S_3	9,259	1,356	1,756	2,089	1,731
Dry Stem Weight g/m^2 (B)	S_1	18,500	1,529	1,510	1,682	1,572
	S_2	12,346	1,491	1,440	1,618	1,516
	S_3	9,259	550	607	757	637
Dry Root Weight g/m^2 (C)	S_1	18,500	1,370	2,524	3,074	2,323
	S_2	12,346	1,612	1,883	2,640	2,043
	S_3	9,259	738	1,094	1,197	1,009
Ratio of Root (harvest index) C/A x 100 %	S_1	18,500	44.7	60.2	61.7	56.9
	S_2	12,346	48.5	53.7	58.9	54.2
	S_3	9,259	54.5	62.3	57.3	58.2

Source : Compiled from Enyi B.A.C. (1973)

Cassava is intercropped with other crops in Indonesia (Photo 7). Under such circumstances, favorable planting density differs according to the type of crops intercropped with cassava, their growth type (branching and plant length, etc.) and speed of maturity, etc. The following is the planting density recommended by the Ministry of Agriculture of Indonesia:

Early Maturing Variety	Late Maturing Variety
80 x 80 cm = 15,625/ha	100 x 100 cm = 10,000/ha
100 x 40 cm = 25,000/ha	125 x 100 cm = 8,000/ha
100 x 60 cm = 16,666/ha	150 x 100 cm = 6,666/ha
150 x 40 cm = 16,666/ha	

(4) Fertilizer Application Method

In Southeast Asian countries, no fertilizers are applied for cassava. As mentioned before, cassava is generally intercropped with upland rice or corn in Lampung (Fig. 7), and straw left over after rice

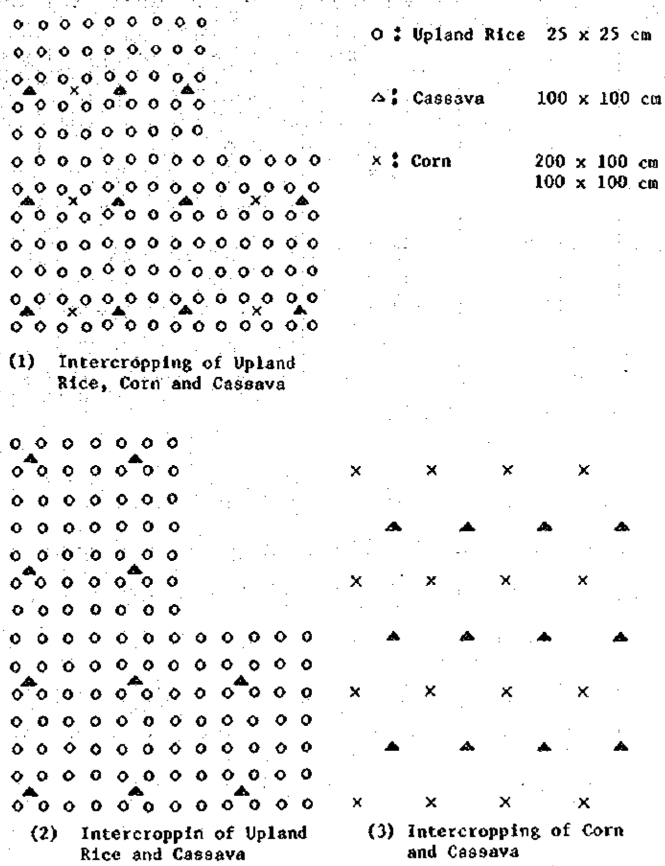


Fig. 7. Intercropping of Cassava and Other Crops in Lampung, Indonesia

is harvested is the only matter applied to the soil. Generally, settlers in Lampung reclaim plains where Alang[2] (*Imperata cylindrica*) and other shrubs grow, and cultivate uplant-rice, corn and cassava as their food. As years go by, rice and corn diminish in yield or come to produce nothing, with cassava alone remaining.

Cassava favors soil rich in organic matter and nonclayish or deep subsurface soil. It absorbs much soil nutrients and rapidly exhausts fertility unless nutrients are supplied (Jacob et al. 1958).

The following figures indicate the amounts of nutrients removed after harvesting 40 tons/ha of wet tubers in Thailand (Harper, 1973).

N = 85 kg/ha　　P_2O_5 = 62 kg/ha

K_2O = 280 kg/ha　　CaO = 75 kg/ha

A report from Indonesia explains similar characteristics (Wargions, 1974) in which the relation between growth duration and absorption of nutrients is shown, although it does not mention yield (Table 22).

Table 22. Relation between Growth and Nutrient Absorption

Growth Duration (Month)	Absorption of Soil Nutrients (kg/ha)				
	N	P_2O	K_2O	C_aO	MgO
1	7.7	1.8	10.5	6.5	1.8
2	27.7	9.2	38.4	21.3	7.4
4	97.1	33.8	165.0	79.4	23.1
6	128.0	51.9	309.0	114.0	35.5
8	134.0	62.9	408.0	140.0	41.4
10	136.0	79.9	408.0	179.0	59.0
12	124.0	94.6	480.0	201.0	62.0

Source : Same with Table 18.

They clearly show cassava's strong absorption of soil nutrients, and its high reaction to fertilizer. Like other starch or sugar producing crops, cassava needs K_2O besides N and P_2O_5. Table 22 shows that 400 kg/ha or more of K_2O was absorbed in 10 - 12 months, 3 - 4 times N absorption and 5 - 6 times that of P_2O_5. Lack of K_2O is said to lower not only yield but also starch content. Absorption of N is also high, but application of excessive N appears to cause high growth of top parts, hindering the growth of tuberous roots (Krochmal et al. 1970).

Many researchers have reported on their fertilizer tests. Many show cassava's high reaction to N (Chan 1969, Chew 1970, Cock 1973;

da Silva and Freire 1968, Vijaya & Aiyer 1969, Yong 1970, Anon 1971). High reaction to N, however, is not reported in other studies.

Not many reports deal with a standardized fertilization plan. DeGens (1967) recommended that the ratio of N, P_2O_5 and K_2O for cassava cultivated on soil which lacks P_2O_5 and K_2O should be 1 : 1 : 2, respectively, as follows:

N = 45 - 90 kg/ha P_2O_5 = 45 - 67 kg/ha K_2O = 90 - 165 kg/ha

Since there is no shortage of K_2O in soil in Thailand, Harper (1973) suggested that the ratio of N, P_2O_5 and K_2O should be 2 : 2 : 1. In India, the ratio of N, K_2O should be 1 : 1.75 on the basis of NPK fertilization tests at Kerala (Chadha, 1958). It is natural that the fertilization plan should differ according to soil conditions. Much remains to be studied in Lampung, Indonesia; the limiting factors in increasing yield from average 10 ton/ha to 30 ton/ha, the amount of fertilizers to be applied and the ratio of their ingredients must be determined.

The results of fertilization tests in Indonesia are quoted below from Progress Report (1971) of the Central Research Institute for Agriculture. They formed a part of the experiments on the time of fertilization. Fig. 8 shows the amount of fertilizers tested, according to which an increased supply of N and K_2O led to an increase in yield in Western and Eastern parts of Java, while no yield increase was registered in Lampung. Whether the difference results from soil conditions, varieties, soil fertility, or observational errors are not clear. (The reason the yield was less than 14 ton/ha in plots where fertilizers were heavily applied is not clear.) Fertilizer application plan recommended by the Ministry of Agriculture of Indonesia is as follows:

N = 45 - 75 kg/ha P_2O_5 = 30 kg/ha K_2O = 50 - 100 kg/ha

Satisfactory data have not been obtained as to the period of fertilizer application. According to instructions in Indonesia, one-third of the entire quantity of N, the entire amount of P_2O_5 and K_2O are applied as a base, and the remaining N and K_2O are applied two months later.

Fertilizer application requires consideration of weather conditions at the time of planting--whether it is in the beginning, middle or the end of rainy season, etc. It appears, however, fertilization should be

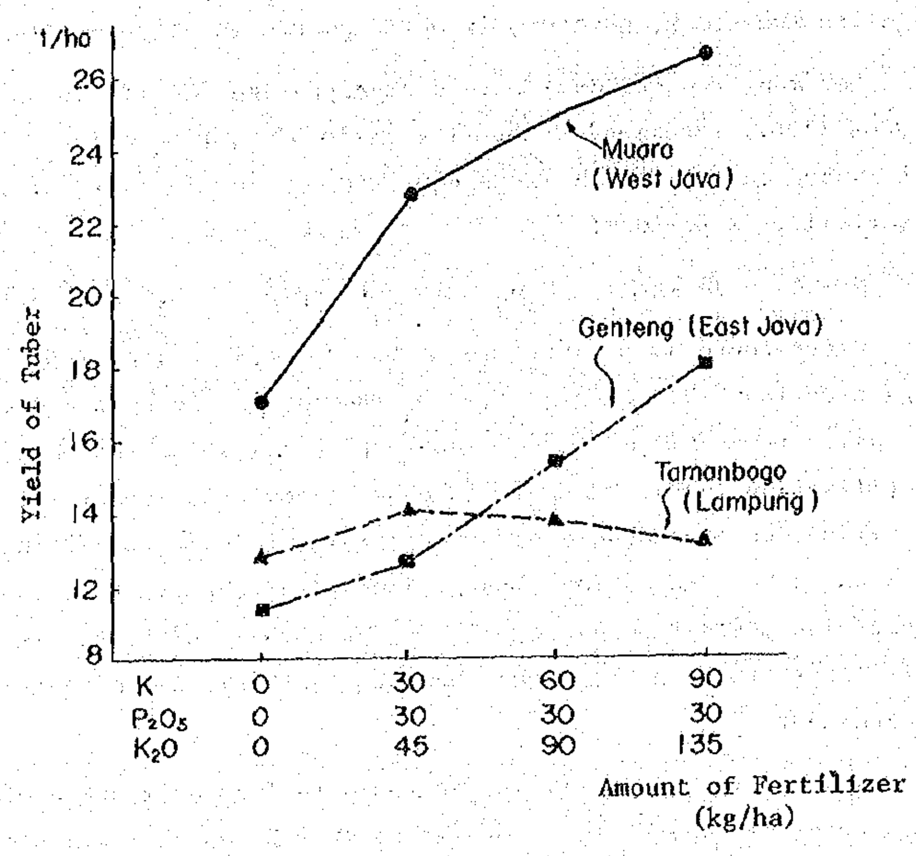


Fig. 8. Relations between Manuring and Yield of Wet Root Tuber

Source : Lembaga Pusat Penelitian Pertanian (1971); Progress Report Tanaman Ubi-ubian (Indonesia)

divided into two parts: basal application and top dressing. This is quite understandable because cassava yield is largely determined by the development of tuberous roots, their growth and bulk. At the same time, as the growth duration of cassava extends from 8 to 10 months, fertilizers may lose or reduce their effect by leaching if the total amount is applied only in the very beginning. Da Silva, Freire (1968) disclosed that their tests showed that application of P_2O_5 and K_2O before planting would reduce survival percentage.

Although the application of fertilizers as described above has been proved efficient and necessary, cassava is said to grow in any infertile land. For instance, farmers of Lampung grow cassava without applying manure, in infertile areas where neither uplant-rice nor corn grows. It seems that their production drops year by year as a result, although detailed data are not supplied.

Table 23 is the experiment data from Malaysia for continuous cropping over three years (1966 - 1969). At each cropping season, fertilizers including N, P_2O_5 and K_2O were applied but a decline in the yield of tuberous roots occurred in the second and the third croppings.

Table 23. Relation between Continuous Cropping and Yield

Cropping Period	Supplied Fertilizer			Yield ton/ha
	N	P_2O_5	K_2O	
1st Period	44.7	33.5	78.2	37.9
	89.4	67.0	156.4	38.1
2nd Period	44.7	33.5	78.2	34.9
3rd Period	54.9	33.5	78.2	25.3
	109.8	67.0	156.4	29.1

Source : Same with Table 9.

It would be hasty to conclude that the unfavorable yield mentioned above is an injury resulting from continuous cropping. There is much room for further study in this respect. Cassava is a crop which heavily absorbs nutrients. If further information on continuous cropping is available, together with data on analysis of soil, it would be very significant for the prevailing continuous cropping in Southeast Asia.

As cassava growing farmers in Southeast Asia practice continuous cropping without fertilizers, the application of fertilizers would definitely bring about tremendous yield increases. Economic considerations, however, have prevented them from cultivating cassava with sufficient fertilizers.

Cassava growers in Sukadana, Lampung say that they cultivate on reclaimed land without fertilizers, and generally, suffer a sharp decline in yield for the first several years, but the yield stabilizes at around 8 ton/ha when cropping continues for more than ten years.

As mentioned above, increased application of N does not bring about an increase in the weight of roots in proportion to that of the top part. It is important to determine the relation between the growth of the top part (plant height, number of leaves and diameter of stems) and root yield, in order to estimate yield. In this connection, an experimental station in Serdang reported the results of its studies as follows (Chan Seak Khen 1969):

Stem cuttings of Black Twig (bitter type) were planted at a density of 90 x 90 cm. They selected 40 plants having one stem with branches at the top, and examined the following:

1. Weight of roots : W

2. Height of plants : H

3. Number of leaves on the plant : L

4. Diameter of stem at 1/2 above ground level : T

Correlation among the above four characteristics and partial correlation between weight of roots and other characters of the top part were calculated. As a significant partial correlation coefficient exists between root weight and plant height as well as the number of leaves, the multiple regression equation is sought to estimate the weight of roots with the help of two characters, i.e. height of plants and the number of leaves. The result was :

$$W = -3.95297 + 0.61677\ H + 0.1832\ L$$

Oka (1974) measured the following six characteristics in September (harvesting time) with variety SPP in Sidokarts and Rengas, Lampung, Indonesia:

1. Yield of roots (kg)

2. Number of leaves at harvest time

3. Number of roots

4. Length of stem (cm)

5. Number of branches

6. Wet top weight (kg)

Plants with higher yield had a greater number of leaves and longer stems. Therefore, it is thought that a close relation exists between yield and growth conditions of the top part. The number of roots per plant was also higher on well grown plants (Table 24).

Table 24. Correlation Coefficient of Major Characters

	Item Studied (per plant)	Y	X_1	X_2	X_3	X_4	X_5	Average Value	Coefficient of Variation
Sidohart Village (n = 200)	Root Yield (kg) Y	1,000	0.365**	0.401**	0.235**	0.191**	0.540**	1.862	38.3 %
	No. of Leaf at Harvesting Time X_1		1,000	0.396**	0.106	0.611**	0.661**	61.9	44.2
	No. of Root X_2			1,000	0.154*	0.392**	0.431**	7.1	29.7
	Stem Length X_3				1,000	-0.115	0.365**	267.9	15.8
	No. of Branches X_4					1,000	0.488**	1.9	46.7
	Top (Weight-kg) X_5						1,000	1.660	45.2
Rengas Village (n = 200, n = 100 for X_1)	Y	1,000	0.296**	0.563**	0.399**	0.225**	0.795**	2.658	38.2
	X_1		1,000	0.489**	-0.010	0.259**	0.375**	62.1	58.9
	X_2			1,000	0.226*	0.201**	0.534**	9.7	29.6
	X_3				1,000	0.013	0.436**	315.8	11.3
	X_4					1,000	0.354**	2.0	32.1
	X_5						1,000	2.706	35.7

Note: "Tuberous root yield" stands for weight of root with periderm. Planting conditions : 2m x 0.5 m

**, * Significant at 1 %, 5 % respectively

Source : Oka, H. (1974) Upland Farming and Cassava in Lampung, Indonesia Agricultural Technology No. 29-12.

The above data were obtained from fields planted at the planting density of 200 x 50 cm for fertilizer application tests. Carrying out other experiments under conditions different from the above (varieties and cultivation methods) is necessary. It is also important to study these problems under the condition of fertilizer application, including relation between the growth of the top part and the bulking rate of tuberous roots. However, the results of the above two experiments show the possibility of estimating tuberous roots yield from the growth status of the top part of cassava.

(5) Weeding

Weeding usually is done three times during the cultivation period; one month after planting (this serves for molding, also), 3 - 4 months after planting and 5 - 6 months after planting (sometimes omitted).

If weeding is perfectly performed at the beginning of the growth period, growth of crop canopy will prevent the bottom weeds from growing thick. Thus, cassava plays the role of a cleaning crop in tropical regions.

Weeding is performed with the help of herbidide in Thailand as shown in Table 25.

Table 25. Comparison of Weeding by Herbicide and Weeding Cost (Rayong, S.E. Thailand (Sandy loam Soil)

Treatment	Application Volume			No. of Weeks after 1st Application and Green Cover (%)										Relative Cost (Hand Weeding = 100)
	1st Application 1) (ℓ/ha)	2nd Application (ℓ/ha)	3rd Application (ℓ/ha)	2) 2	4	6	8	10	2) 12	16	20	24	3) 28	
Hand Weeding	-	-	-	0	5	9	22	44	57	10	6	13	31	100
Gramoxone	1.0	1.0	2.8	20	3	11	15	27	40	9	13	20	30	65
"	1.4	1.4	2.8	15	2	9	14	29	38	6	10	20	29	75
"	2.0	2.0	2.8	9	2	11	15	30	40	5	12	15	26	91

Note 1) 1st Application = 3 months after planting
2) 2nd and 3rd application period
3) Harvesting time
4) Relative cost includes application cost of Gramoxone

Source : Harper (1973)

In the tropics where cassava is cultivated by intercropping, stem cuttings are planted 1 - 2 months after seeds of crops to be intercropped are sown or immediately before harvesting of the preceeding crops. Weeding is therefore generally done in compliance with the requirements of the intercropped crops.

(6) Cultivation by Machines

For many years, cassava has been cultivated by peasants around their huts for food. Therefore, large area cultivation with the use of machines has not been developed for years. Just recently, however, cultivation areas have become larger in Mexico, Brazil, Nigeria, etc. In Lampung, Indonesia, also, machines have been introduced in cultivating cassava with a trend for developing larger areas. Information on mechanical cultivation is still lacking Krochmal (1966) reported as follows:

In Mexico, two-wheeled mechanized cassava planters have been introduced. They are two-row planters and need two workmen besides an operator. Workmen aboard the machine, which is drawn by a tractor, take cuttings out of reserve bins and put them into the hopper installed in ring form on top of a rotating planting turn-table. Rotation is transmitted from driving wheels by chain. Underneath the rotating planting turn-table, there is a hole to discharge cuttings, which are sent to a tube from the above hopper when they pass the discharging hole. Cuttings are dropped into the furrow opened by a simple furrower. They are covered with soil with the help of a pair of disks and floats pulled by chains. A gasoline-powered table-saw is used for cutting stems. About 134 stem cuttings are output per minute.

Much labor is needed for weeding. Post planting herbicide is applied with the help of a sprayer drawn by a tractor. The mechanical spraying of herbicide drastically reduces labor. Harvesting also equires much labor. Topping is performed to make harvesting easier. Instead of hatchets, which have been widely used, rotary mowers are now used to simplify the work. Care must be taken so that topping is done at the right time, as early topping is likely to reduce yield. Krochmal (1966) reported on the results of experiments in Thailand in this respect:

Period of Topping	Yield (%)
One day before harvest	100
15 days before harvest	92.5
30 days before harvest	88.6

Harvesting of cassava by machines is not yet economical. Therefore, the invention of machines specially for cassava has been delayed. Bates (1957) suggested the use of a modified beet or potato harvester, but it has not been in practical use. Krochmal (1966) proposed using a moldboard plow (bottom plow).

Cassava's roots spread in areas of 100 - 150 in diameter and 40 - 60 cm deep. Special care must be taken in digging the soil so that roots are not damaged. If damaged, discoloration or putrefaction would result. Therefore, study is required before introducing harvesters for roots. Krochmal (1966) conducted a series of studies to compare labor by machine and hand labor, which is shown in Table 26.

Table 26. Comparison of Labor by Hand and Machine (Man hours/acre)

Hand		Mechanised	
Soil preparation	12.0	Ploughing	2.5
		Disking	1.5
		Furrowing	1.2
Preparation for cutting stakes	9.6	Cutting stakes	3.0
Planting	12.0	Planting	2.0
Covering	8.0	Herbicide (1x)	2.0
Weeding (3x)	72.0		
Topping	8.0	Topping	1.0
		Ploughing	1.0
Digging	50.0	Digging	30.0
	171.6		44.2

Note: Result in Experiment at Caribbean Area, Cassava Cultivated : 3 ft x 3 ft

Source : Krochmal, A. (1966)

Japanese companies in Lampung are now practicing ridge culture to improve harvesting operation.

(7) Method of Propagation

Cassava is basically a cross pollination crop. As some varieties, however, show no flowering and fruiting, stem cuttings are widely used these days for propagation, except for the specific purpose of improving varieties. If stems are cut to 20 - 25 cm long, only 6 to 7 cuttings are obtained from each one. To enhance this poor propagation rate, a number of methods of vegetative reproduction are under examination.

For instance, Wholey and Cock (1973) developed a simple method to produce approximately 18,000 stem cuttings from one plant per year. Their original work is not at hand at the time of this writing, so the following description of their method (including an illustration - See Fig. 9) is taken from Yamada (1975):

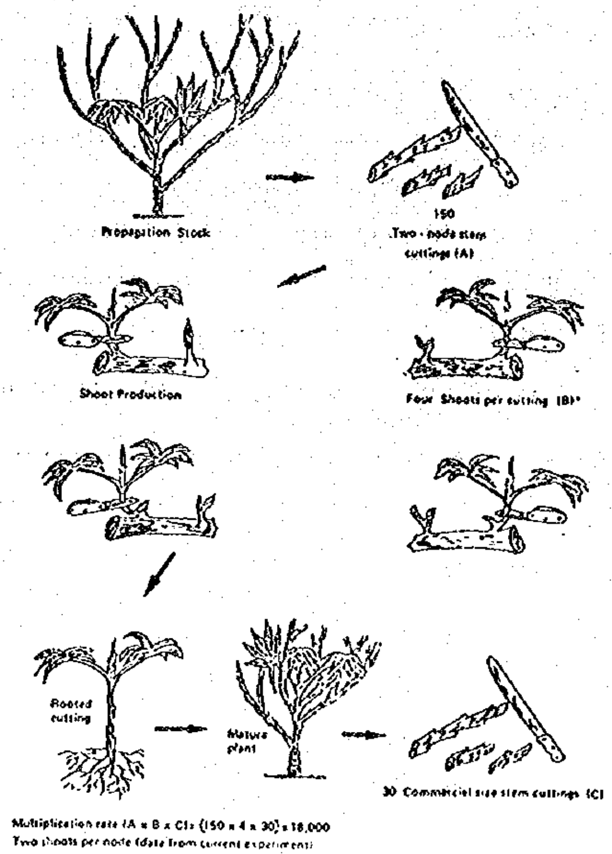


Fig. 9. Method of Vegetative Propagation of Cassava (CIAT Method)

Source : Cassava by Yamada (1975)

"First of all, cuttings with two nodes are taken from mature stem. Cuttings with only one node do not result in satisfactory sprouting. Each cutting gives out four branches one after another, and these transplanted to beds composed of disinfected sand and earth and saturated with water. The beds are surrounded with concrete blocks and covered with vinyl cloth. After the roots come out, they are temporarily transplanted to peat pots which contain soil and then moved to fields. Approximately 30 cuttings are obtained from an original stem for propagation. Cuttings can be planted directly in peat pots without temporary plantation in beds. If 150 cuttings are attained from the initial mother plant, the rate of propagation will be: 150 x 4 x 30 = 18,000. Sprouting capacity remains for 2 to 3 weeks the cuttings are put in bags and left in shady places. The longer the cuttings, the longer the life they have. Sprouting ability declines as water content is reduced and/or fungi enter. Cuttings should therefore be soaked in 1,000 ppm solution of CIPC, (available on the market) for 5 minutes and put into polyethylene bags, which prevents the sprouting of cuttings for about 4 weeks."

Tissue culture is another method of propagation. The method is very valuable as it ensures rapid growth and propagation of the cuttings, and the growth and distribution of non-virus cuttings. It would be even more effective if the characteristics of the varieties could be maintained hereditarily.

7. Breeding

The collection of breeding materials and the scientific study and estimation of them is important for improving cassava varieties. Although little attention has been paid to such genetical or cytological studies, certain studies have been made and reported, particularly by Dempsey (1971), and Magoon (1967, 1970, 1973) in the Tropical Root Crops Symposia.

In addition to studies being made on hydrocyanic acid content and resistance to damage by disease and insects increase in the yield of cassava is at present the main goal of studies on breeding being carried out by CIAT, CTCRI (Central Tuber Crop Research Institute), IITA (International Institute of Tropical Agriculture, Ibadam, Nigeria), etc. Studies on induced mutation have been conducted in Costa Rica, Madagascar, and India. Improvement of protein content by the breeding of tetraploids is also under study. Experiments by Magoon and his group (1969) and Iman (1972), however, seem to have failed in attaining favorable results in increasing yield from tetraploids obtained by colchicin treatment.

Further, for the purpose of breeding varieties that will be highly resistant to insects and disease, etc., inter-specific hybrids have been developed. Studies on this subject have attracted keen attention and strong interest.

Reports have come from Java, Indonesia, on the experiments of increasing the root yield per plant (to 100 kg in 24 months) the grafting of *M. glaziovii* on the stock of *M. esculenta* (Photo 8). Whether or not this technique has a potential beyond "back yard" production has not yet been confirmed, according to Nestel whom the authors met in Lampung. The authors found the graft crop in farmers field of Lampung, but were not present at harvest time.

There is certainly a growing interest in the improvement of each kind of varieties in the prevailing boom for cassava. Breeders are engaged in experimental studies mainly in Brazil, Columbia, Costa Rica, India, Nigeria and Madagascar.

According to Irikura (1975), who has been cooperating with the breeding program of CIAT, the latter has completed observations on agricultural characteristics, and resistance to insect and pest damage of more than 2,500 species it had collected from Latin American countries, the original home of cassava. The experiments are said to have elucidated an ideal ecological type of cassava variety that would promise high yield; the first crossing of this took place in 1973. Progeny tests of crossing are being conducted actively. Tests to determine the adaptability of breeding lines have been carried out in three areas with different environmental conditions: Carimagua with acid soild and a long dry season; Caribia enjoying rapid vegetative growth and high temperature; and Popayan, a cool region where growth is delayed. The aim of the experiments is to breed varieties adaptable for any part of the world.

CIAT sets its goal, with 1978 as a target year, at varieties with higher yields: for instance, varieties ensuring a 50 ton/ha yield, (with low hydrocyanic acid content and sufficient tolerance to pests and diseases) in the CIAT breeding field, a 20 ton/ha yield in Carimagua and a 30 ton/ha yield in Caribia. The second of CIAT's goals, with 1980 as a target year, is varieties having a 60 ton/ha yield in the CIAT breeding field, a 25 ton/ha yield in Carimague, and a 40 ton/ha yield in Caribia. Such varieties should have strong tolerance to pest and disease damage, high starch content, low HCN content and be easily harvested, as well as having tuberous roots that can be stored for a long time after harvest.

8. Damage by Pests and Insects

Except for cassava almost all upland crops suffer much damage from pests and insects.

As for insects injurious to cassava, Harper (1973) has reported on damage by red spider mites in a couple of regions in Thailand, which caused a 15 % decrease in yield. There has been some damage by mites in Indonesia as well (Photo 9), but no detailed information is available on this. Damage by *Saissetia nigra* has also been reported (Photo 10), but does not seem to have been serious.

The following are some of the insects that are harmful to cassava in Malaysia. The damage from these is not so serious (Chan Seak Khen 1969):

Cricket (*Brachytrypes achatinus*)

Larva of *Tiracola plagiata*

Tachinid fly parasite ((*Blepharipoda ophirica* Walk, *Sturmia inconspicua* Mg)

Grasshopper (*Valanga nigricornis* Burn)

Scale insect (*Saissetia nigra*)

Bugs (*Megymenum brevicorne F.*)

Red spider mites (*Tetranychus telarius F.*)

In addition to these, CIAT and IITA have drawn attention to the following:

Thrips (*Frankliniella* sp., *Coliothrips masculimus*, *C. stenopterus*)

Spider mites (*Mononychus tanajoa*)

Shoot flies (*Silba pendula*, *S.* sp, *Anastrepha pickli*)

Cassava hornworm (*Erinnys ello*)

Scale insects (*Aonidomytilus albus*)

Cutworm, Centipedes

Vatiga manihotae

Root-knot nematode (*Meloidogyne* sp.)

As for damage by disease, reference is made to *Cercospora cassavae* in Thailand, which causes leaf falls before the crop becomes mature and results in a decrease yield. There is no reliable data on the decrease, however, Indonesia also experiences damage by *Cercospora cassavae* (Photo 11). Besides the above, there is data on the damage by the socalled white root disease or *Fomes lignosus* KL., which also causes a decline in yield. In Ghana, for instance, this disease reduced the yield by 20 %.

Lampung, Indonesia, saw the outbreak of bacterial wilt in large-sized cultivation fields, caused by *Pseudomonas solanacearum*. The colour of the stem vessels becomes brown, and the top part withers and dies rapidly. Experiments conducted on Japanese farms found some differences according to variety. This will be solved by breeding a resistant variety in the future.

Leaf spots caused by *Cercospora cassavae* and white root disease by *Fomes lignosus* have been reported from Malaysia by Chan Seak Khen (1969), although the damage was not so serious.

The so-called Mosaic disease has become an issue these days. Although reliable data is still lacking. IITA (1972) reported on the following in this category:

(1) A mechanically transmitted disease found in Brazil whose causal agent is virus of the potato virus X group;

(2) A whitefly-transmitted disease found in Africa and India whose causal agent is unknown;

(3) A mycoplasma-induced disease of which at least three occur in Brazil and one in the Ivory Coast.

bacterial blight having symptoms similar to those of *Xanthomonas manihotis* is considered as a serious disease in Latin America, particularly in Brazil. Stem vessels are closed with the causative organism and to begin with and lower leaves wither first of all. To prevent this, the eradication of infected plant or stems is recommendable. CIAT is now conducting experiments on the screening of varieties with high resistance.

In addition to the above, the following diseases are being studied by CIAT and IITA:

Phytophthora root rot (*Phytophthora* spp.)
Phyllosticta leaf spot
Gloeosporium disease

Superelongation disease (virus is not yet confirmed)

So far cassava is believed to be more or less free from disease or damage by insects. This is attributable to its cultivation in infertile land in the past. The trend for cultivation in larger areas with richer fertilizers may be the cause for increased damage by insects and pests, as evidenced by the appearance of bacterial wilt in Lampung, which had never been experienced there before.

Attention should be paid particularly to the question of how to prevent the outbreak and spread of virus diseased such as cassava Mosaic, by, for instance, giving strict care in transplanting stem cuttings to areas unaffected by them.

9. Harvesting and Processing

The harvest time of cassava varies according to the conditions concerned. As already mentioned, cassava is intercropped with upland rice or corn in Indonesia. The planting of cassava, therefore, ranges from October to December (Fig. 10), with harvesting from August to November--the dry season

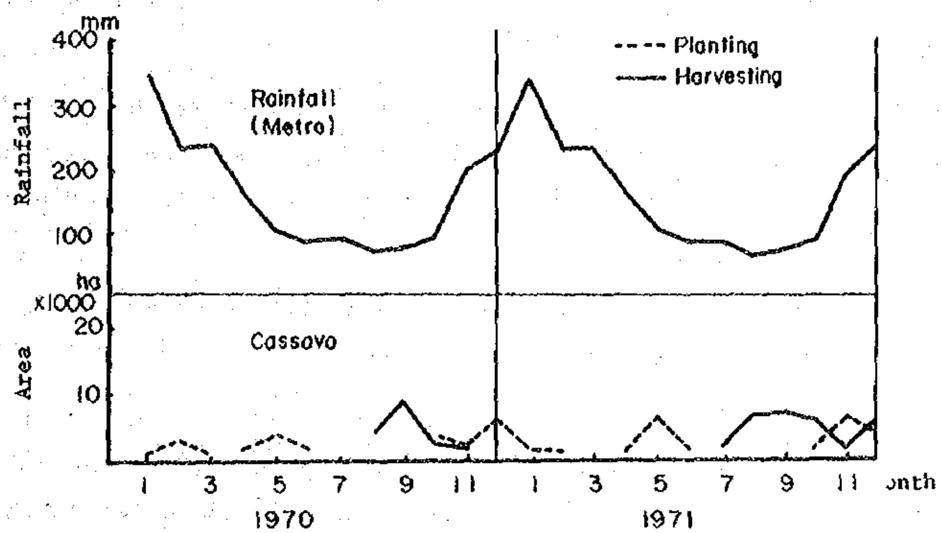


Fig. 10. Relations between Rainfall and Planting and Harvesting Seasons of Cassava in Lampung, Indonesia

Source : Agricultural Statistic on Crops in Lampung, Indonesia

to the beginning of the rainy season. Early maturing varieties which are harvested from June to July are planted in the February-March period as a crop following upland-rice or corn.

The best harvest period is when the crop contains maximum starch content; this will depend on the variety. The majority of varieties seem to reach the peak of their yield and starch content at 10 to 12 months age, after which lignin content increases, causing pithiness in many of them. Genjah putih grown in Lampung is said to be an early maturing variety that can be harvested at six to seven months age. However as shown in Fig. 5, its curve shows a slow increase in yield eighth months after planting. Thus it is not an early maturing variety in the strict sense of the word.

In harvesting, stems stretching on the ground surface are cut down (topping), and the roots are grubbed with hands and collected in one place (Photo 12). Roots left in the ground are dug out by grub hoes and gathered. When the soil is hard or/roots have grown deeply in the ground, as in the case of certain varieties, a great deal of labor is needed for harvesting. When stem cuttings are planted horizontally at around 5 cm below the ground surface, the roots grow close to the surface, resulting in little damage at the time of harvesting.

When grubbing is not easy, rope is tied around the lower part of the stems which are pulled up with the help of bamboo or wooden sticks. The grubbed roots are then cut from the stems, and treated according to use. As mentioned before, ridge culture limits the area of growth, making grubbing easier.

In places close to tapioca cassava starch factories, the roots are peeled after harvest and brought over directly by the cassava growers. In farm villages in Indonesia, they are taken to factories by oxcart (Photo 13).

To avoid the risks of changes in starch quality, factories usually take in the roots within 48 hours after harvesting.

When cassava is preserved as food, the roots are peeled, cut into two or four vertically, and exposed to the sun on the ground (Photo 14), or on hedges in front yards. They are then shredded and dried in the sun--cassava chips. The chips are processed into pellets and exported. Women are frequently seen engaged in the peeling of roots with a peeler called a paret (Photo 15).

As the quality of wet tuberous roots changes immediately after harvesting, it is not easy to store them raw. To avoid rotting, farmers usually leave the roots in the ground until the time of consumption, or immediately before they sow the seeds of the next crops. They dry them as soon as the roots are grubbed out of the ground. Leaving them in the ground too long, however, invites an increase in lignin and reduces starch content.

Generally, cropping is so arranged in tropical regions that cassava is harvested in a dry season. Although it is believed that cassava can be planted at any time of the year, except in an extremely dry season, cropping patterns seem to be decided in consideration of harvest time. The same is the practice in Lampung. Although planting can be done at any time throughout the year, harvesting in a rainy season poses problems. If, however, there is a large starch-producting factory nearby, it would make both planting and harvesting possible the year round, which is quite favorable from the standpoint of labor distribution. Studies are being made towards this direction.

Drying rate after harvesting diffuse according to variety. The rate by skin-peeling is 70 - 85 %. The ratio of obtaining chips from peeled wet cassava is shown in Table 27 in relation to Indonesian cassava (the

Table 27. Peeling & Drying Ratio of Varieties in Lampung

Variety	Plant Height	No. of Root/Plant	Weight of Wet Root/Plant (A)	Weight of Peeled Wet Root/Plant (B)	Weight of Top Stem/Plant	Dry Weight %	B/A %
SPP	309 cm	9.3	4,050 g	3,330 g	2,580 g	34.5 %	82
Un-named	247	4.4	1,430	1,080	1,190	49.0	75
Metik Urang	255	6.1	1,850	1,490	1,680	47.0	81
Mentega	218	8.2	1,400	1,180	1,570	50.0	84
Tahun	369	11.0	2,250	1,570	2,980	46.0	70
Genjah Putih	292	14.6	3,200	2,260	3,400	51.0	71
	347	12.1	3,630	2,690	2,820	47.0	74

Source : Hirose (1976)

ratos differ according to variety). 3 - 4 days (5 - 6 hours of exposure to the sun daily) are needed for drying; 6 - 7 days when the chips are larger. This means that the resultant moisture content should be 12 - 14 %.

In "Development Manual on Cassava," Yamada (1976) explained drying methods by quoting Manurung (1974) and Mathot (1974). Drying tests by Ishida in Lampung (1976) (unpublished) are quoted below:

The experiments were carried out on the concrete drying floor in Tegineneng Center from 1st to 3rd July, 1976. Ganjah Lampung, an early maturing variety, was used as a sample for the experiments. Table 28 shows the hours used for the peeling and cutting of 10 kg of wet tuberous roots and

Table 28. Time Spent for Peeling and Slicing

Type of Sample No.	Weight of Wet Root	Weight of Wet Root after Peeling	Time Spent for Peeling	Time Spent for Slicing
I. Cut in small chips: Less than 1 x 1 x 1 cm	10,000 g	8,330 g	22 min 00 sec.	6 min 15 sec.
II. Cut in 2-4 along stem, 2-3 along diameter	10,000 g	8,315 g	21 min 00 sec.	6 min 20 sec.
III. Sliced 2 cm in width	10,000 g	8,285 g	16 min 00 sec.	6 min 35 sec.

Soutce : Ishida (1975)

the weight of the peeled roots. The figures show a difference of 16 - 22 minutes in the peeling of Materials I to III, which was probably caused by the difference in the number of tuberous roots involved in 10 kg. Peeling 10 kg of roots took 20 minutes or so. It took 16 hours and 30 minutes for peeling 500 kg by women as is the usual practice in Lampung, Indonesia.

It was supposed that there would be a difference in cutting hours according to variety. The result of the experiments, however, showed only a slight differences--some 6 minutes. The rate of peeling is 16 - 17 % as shown in Table 28, which is the maximum of 29 - 16 % obtained in research made by the authors (Table 27). Fig. 11 shows the relation between drying hours and weight of roots.

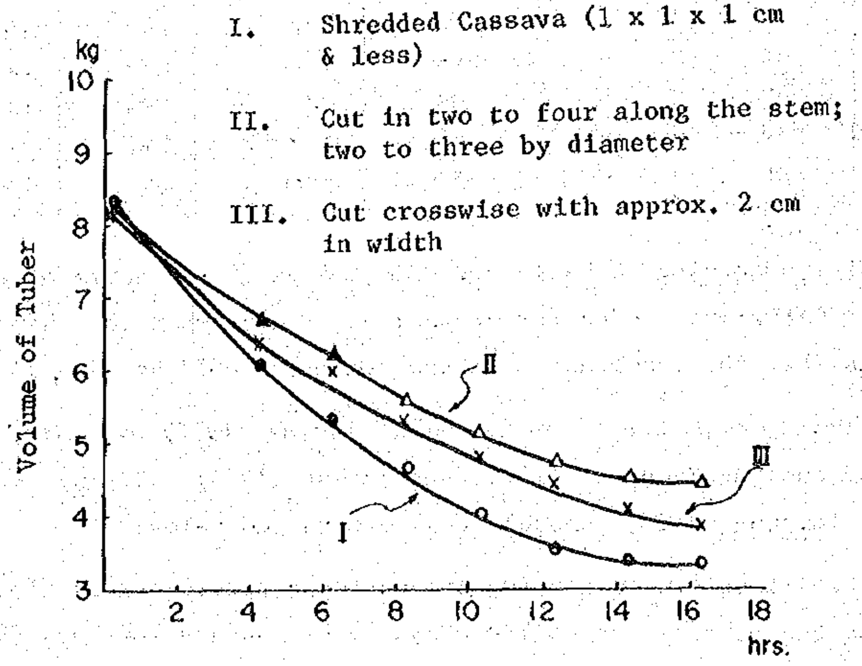


Fig. 11. Relations between Hours of Exposure to the Sun and Loss in Weight of Cassava

Source : Ishida's Experiment in Lampung, Indonesia (1975)

Materials were selected from those cut by three different methods. They were spread over a floor space of 1 m^2. The experiments revealed that roots cut into one cubic centimetre pieces dried soonest, followed by those cut in round slices of some 2 cm in thickness, and then by big slices of Glondongan cut in two to four lengthwise and 2 - 3 breadthwide. The thinner the slices, the earlier they dried, although such a definite assertion can not really be made because moisture content was not measured at the beginning. People in Lampung say that chips sold there are as dry as those dried for 12 hours and 15 minutes or for 14 hours and 15 minutes as indicated in Material II. The weights of these were 56.8 % and 54.5 % respectively at the time when drying was started. When compared with moisture content before the roots were peeled, the ratio was 47.3 % and 45.3 %, respectively. This must be considered as the finishing ratio.

The weight of the materials after they were dried for 16 hours and 15 minutes was 40 - 54 % of the weight at the time they were peeled.

This result coincides with the dryness of ordinary sliced samples attained after their exposure to the sun for 3 - 4 days (5 - 6 hours a day) and that of largely cut chips after their exposure for 6 - 7 days.

In Lampung, slicers are leased to farmers by pellet factories (Photo 16) to produce chips. The machine is operated for 6 hours a day, slicing 12 - 15 tons of cassava roots a day. If a drying floor is constructed with the machine, drying after harvesting would be easier and high-quality chips would be produced. There is a tendency to cut wet roots into small cubes, dry them and export them to Europe as chips. Cubing machines have been developed for this purpose. Roa (1975), for instance, has developed a machine to cut roots into bars of 10 x 10 x 5 mm, and based on information from a catalog, Yamada (1976) has described a Dutch machine, the Legro manioc cubing unit. If machines are further developed and improved, and bars can be substituted for pellets, the process of pelletization will be eliminated. However many more studies on the capacity of such machines must be made. As Nestel (1974) has pointed out, studies should be carried out as soon as possible on the new technology from the standpoint of drying technic, size and shapes of chips cut by cubing machines, etc., in order to determine its economic efficiency.

10. Storage

Wet tuberous roots deteriorate immediately after harvest (Photo 2).

That long-term storage is impossible for cassava has posed problems for farmers as well as for those who are engaged in processing. Under these circumstances, various methods are being examined in addition to the traditional methods of cutting into chips or storing underground by delaying the harvest period, etc.

Studies being promoted by Ingram and Humphries (1972) can be summarized as follows: One of the questions is how to store wet root tubers. The flesh turns dark blue in several days after harvesting--that is, the quality deteriorates by rottening (softening) due to the entry of pathogenic micro-organisums into the root tubers after harvesting. Majumder (1955) said that there were two types of deterioration: dry rotteness by *Rhizopus* sp. under aerobic conditions, and soft rotteness by *Bacillus* sp. under aerophobic conditions.

As deterioration of the roots by fungi progresses, acidity rises rapidly and results in a worsening of taste.

The other factor is the activity of enzymes. Blue stripes (vascular streaking) appear along the vascular bundles, in close relation with the entry of fungi. These two factors combined worsen the quality.

Burton (1970) has reported that, on the basis of this studies on cassava transported to America from Puerto Rico, *Diplodia manihoti* (Sacc.) would be the most important fungus that deteriorates the quality and changes the colour together with various other fungi (Table 29). Rotteness of wet

Table 29. Fungi Isolated from Root after Transportation

America (imported from Puerto Rico)	England (imported from West Africa)
Fusarium "Iiscola"	*Aspergillus fumigatus*
(? = *F. moniliforme* Sheldox)	Tresenius
F. solani (Mart.) Appel et Wr.	*A. flavus* Link
Fusarium sp.	*A. niger* Van Tieghem
Geotrichum canadium ink ex pers	*Penicillium* spp.
Penicillium gladioli Machacek	*Circinella* sp.
Mucor sp.	*Syncephalastrum* sp.
Phomopsis sp.	
Rhizopus sp.	
Trichoderma sp.	

Source : Burton (1970) and Ingram & Humphries (1972)

root tubers is thus caused by the presence of various fungi in them.

Various methods have been tried for storing wet root tubers in natural conditions. For instance, people in Ghana pile wet roots in heaps, sprinkle water or put clay over them to keep them safe and fresh for 4 to 6 days (Hiranandani et al. 1955, Rao 1951). In Mauritius, east of Madagascar, people used to store wet cassava roots in trenches for 12 months as potatos were stored in Europe (Anon, 1944). Anon also reported that cassava roots were stored in tightly closed rooms for about a month, by covering them with earth and straw. Baybay (1922) tested storage methods in the Philippines, he stored wet root tubers in various buildings, and continued storage for 25 days by taking out the rotten ones every six days. However, this resulted in a tremendous loss of weight (Table 30). He reached the conclusion that

Table 30. Cassava Wet Root Loss after 25-day Storage

Type of Storage Structure	Weight Loss by Decay and Shrinkage %
Permanent building	98.7 %
Dark room in Wooden building	86.8 "
Local building	92.2
Cellar	91.1
Trench	64.0

Source : Baybag (1922) and Ingram & Humphries (1972)

storage was not successful under the conditions mentioned above.

Czyhrinciw et al. (1951) reported in Venezuela that they stored wet root tubers in rooms of 25°C for two weeks, and that the weight reduced by some 75 %.

Averre (1967) covered wet roots with damp sawdust, but they became rotten. Tracy (1903) reported that wet roots could be stored for 1 - 2 months in a warm dry room. He suggested that the roots should not be put in heaps, but thinly covered with straw, as low temperature and excess humidity would accelerate deterioration. He also suggested harvesting cassava in the dry season and taking strict care never to injure the roots. According to him, harvesting time must be rigidly observed so that the roots can be rubbed at the right time; they should never be washed.

These reports show that it is very difficult to store roots in normal conditions, and that various methods have been used to suit local conditions. Parallel with these traditional methods, experiments have been made with chemical treatments. Majumder et al. (1956) compared a method of fumigating wet roots with ethylene dibromide and a mixture of ethylene dibromide and ethyl bromide, with treatment by formaldehyde. He found that the fumigation method was most effective, because the roots stayed edible as no bromide remained after fumigation. He said that formaldehyde should be used for producing starch.

Further methods involve the coating of wet root tubers with fungicidal wax; or soaking them in paraffin wax at 90 - 95°C for 45 seconds, cassava was successfully stored for 1 - 2 months, in Colombia by the latter method (Yound et al. 1971). An attempt was made to import fresh cassava to America but it cost too much and proved unpracticable for cassava, which is low in price.

Next we turn to methods of storage at low temperature: one by Czyhrinciw et al. (1951) and the other by Singh et al. (1953). Table 31 shows the result of an experiment by Singh. The figures show that the most

Table 31. Losses in Cassava Root Tubers Stored at Various Temperatures

Storage Temperature (°F)	Relative Humidity	Weight Loss %							
		1st Week	2nd Week	3rd Week	4th Week	5th Week	6th Week	7th Week	8th Week
32 - 35	80 - 90	5.6	11.0	15.0	19.2	21.7	34.1	37.5	38.1
35 - 58	80 - 90	5.1	11.0	15.0	18.0	21.7	34.1	40.3	41.1
39 - 42	85 - 91	3.7	8.3	-	-	-	-	-	
42 - 45	85 - 92	3.4	6.6	-	-	-	-	-	
47 - 50	82 - 90	5.0	9.2	-	-	-	-	-	
52 - 55	82 - 90	6.7	13.3	-	-	-	-	-	
67 - 70	67 - 72	12.1	25.0	-	-	-	-	-	
72 - 85	75 - 80	11.7	22.5	-	-	-	-	-	

Source : Singh & Mathum (1953)

favorable temperature for storage is 0 - 2°C and a relative humidity of 80 - 90 %, in opposition to Tracy who observed that low temperature and high humidity accelerate deterioration of roots. The question of storage at low temperatures should undergo further studies.

Averre (1967) suggested that cassava, if taken as food, should be immediately removed from the field, moistened, packed, and placed where it is cool. This method is advisable if cassava is sold on the market as a vegetable but unpracticable for people in the tropics.

Dry chips are frequently damaged during storage. However, scarcely any data is available on this. Properly dried cassava chips are good in quality but they are likely to be damaged by fungi and insect pests if stored for long.

Harmful insects as compiled by Ingram and Humphries (1972) are shown in Table 32. Clark et al (1968) and Ramnsley (1969) reported on fungi such as genus *Aspergillus*, *Mucor*, *Penicillium* and *Rhizopus*. *Aspergillus* sp. was seen even in sundries chips 3 months after storage (Doku 1969). Some researchers such as Kuppuswary (1961) wrote that chips of bitter type cassava were able to withstand long-term storage.

Containers used for storing cassava chips by farming people vary according to region and country. In Zaire, for instance, people store them in ordinary buckets or pails and hang them on top of the hearth. Chips are taken out when they are consumed as food. Hanging over the hearth prevents the cassava from being damaged by insects (Buyckx et al. 1957, Jones 1959).

Various insecticides have been used to keep chips from being damaged. At the same time, fumigation by methyl bromide, ethylene dibromide or a mixture of ethylene dichloride and carbon tetrachloride was effective, leaving no residuals (Anon. 1962, Pingale et al. 1956).

Cassava chips absorb moisture rapidly from humid atmospheres to reach equilibrium moisture content. At 30°C a moisture content of 15.1 % was found to be in equilibrium with an atmospheric relative humidity of 70 %, which is the accepted upper limit for safe storage (Anon 1965). Chips are stabilized in quality when moisture content is 12 %. Therefore, the international standard for the maximum moisture content of cassava chips to be exported or imported is set at 13 % (Anon 1968). In Thailand, 13 % moisture content is the maximum for special grade chips and 14 % moisture content is considered acceptable for first grade chips.

Table 32. Insect Pests Infesting Cassava Products in Storage

Species	Common Name	Cassava Chip	Cassava Flower	Cassava Starch (Tapioca)
Ahasverus advena(Wall)	Foreign grain beetle	++	+	+
Alphitobius spp.	Lesser meal worm beetle Black fungus beetles			+
Araecerus fasciculatus (Deg.)	Coffee bean weevil, Cacao weevil	++		+
Bostrychoplites cornutus (Oliv.)	-	+		
Carpophilus spp.	Dried fruit beetles			+
Cathartus quadricollis (Guer.)	Squarenecked grain beetle	+		+
Coninomus constrictus (Gyll.)	-			
Cryptolestes spp.	Rust red grain beetles, Flat grain beetles	+	+	
Dermestes spp.	Hide beetles			+
Dinoderus spp.	Powder post beetles	+	+	
Ephestia cautella(Wlk.)	Tropical warehouse moth	+	+	+
Gnathocerus cornutus(F.)	Broadhorned flour beetle	+	+	
Heterobostrychus brunneus (Murr.)	-	+		
Lasioderma serricorne(F.)	Cigarette beetle	+	+	+
Lepidoptera spp.	Moths			+
Necrobia rufipes (Deg.)	Red-legged ham beetle, Copra beetle		+	+
Oryzaephilus mercator (Fauv.)	Merchant grain beetle		+	+
O. surinamensis(L.)	Saw-toothed grain beetle			+
Palorus ratzeburgi (Wissm.)	Small-eyed flour beetle		+	+
Plodia interpunctella (Hubn.)	Indian meal moth		+	
Pyralis manihotalis (Guen.)	-		+	
Rhizopertha dominica (F.)	Lesser grain borer	++	+	+
Sitophilus oryzae (L.)	Lesser rice weevil	++	+	+
Stegobium paniceum(L.)	Biscuit beetle, Drug store beetle	++		+
Tenebroides mauritanicus (L.)	Cadelle	+	+	+
Thaneroclerus buqueti (Lef.)	-		+	
Tribolium castaneum (Herbst)	Rust red flour beetle	++	++	++

Source : Ingram & Humphries (1972)

11. Usage

Cassava contributes to the world food supply in the following three ways:

(1) Roots are consumed as food

(2) Utilized as feedstuff

(3) As starch, used for processing foodstuff

Besides its used for processing food, it is used in the paper, paper box and textile industries, as starch. Its usage can be broadened in the fermentation industry for the manufacture of alcohol, glucose or for the synthesizing of protein as a fermentation material.

As detailed information on the use of cassava has already been given by Yamada (1976) in reference to reports by Holleman and his group (1956) and Grace (1971), only a general explanation will be made in this booklet.

As has been repeatedly explained, approximately 95 % of total cassava production is directly used as a staple or subsidiary food (David 1971).

(1) Food Preparations

Cousey (1973) classified methods of food processing generally and traditionally applied in various parts of the world. He noted that classification is a matter of difficulty due to the broadness and diversity of foodstuffs in which cassava is used. Accordingly, his classification is still incomplete and tentative.
It includes the following:

1. No special detoxication techniques applied

    1.1 Totally unprocessed (i.e. eaten raw)

    1.2 Simple cooking techniques only (as used for nontoxic starchy staples)

        1.2.1 Boiling, stewing, etc.

        1.2.2 Roasting, baking

        1.2.3. Frying

    1.3 Sundrying

        1.3.1 Sundrying without subsequent processing

        1.3.2 Sundrying with subsequent processing

            1.3.2.1 etc. Different types of milling, grinding, etc.

    1.4 Kiln or Hot-air drying
    (Subdivide as for 1.3)

2. Special detoxication techniques applied

2.1 Detoxication by solution

2.1.1 Soaking of whole roots or large pieces

2.1.1.1 Soaking in static water

2.1.1.2 Soaking in running water

2.1.1.3 Soaking in walt water

2.1.2 Soaking after comminution
(Subdivide as for 2.1.1)

2.1.3 Boiling

2.1.3.1 Simple boiling

2.1.3.2 Repeated boiling, in changes of water

2.1.4 Wet extraction processes for starch

2.1.4.1 Starch extraction without subsequent gelatinization

2.1.4.2 Starch extraction with subsequent gelatinization

2.2 Detoxication by fermentation

2.2.1 Spontaneous fermentation

2.2.1.1 Fermentation followed only by washing

2.2.1.2 Fermentation followed by washing and heat treatment

2.2.1.2.1 Roasting

2.2.1.2.2 Steaming

2.2.1.2.3 Drying in hot air

2.2.2 Fermentation with use of inoculum from earlier preparations
(Subdivide as 2.2.1)

The classification above shows a great deal of duplication in the preparations under Groups 1 and 2. In this respect, Coursey (1973) explained that methods in Group 1 are applicable for varieties having less cyanide.

The boiling, heating, and drying mentioned as processes in Group 2 are undertaken to reduce HCN content in cassava roots. He wrote that the above-mentioned distinction into Groups 1 and 2 was grounded more or less on philosophical factors, rather than on scientific ones. Taking all these factors into consideration, it can be said that methods under Group 1 are for cooking sweet type cassava (Innoxious varieties), while those under Group 2 are for varieties that are moderately poisonous (in their raw state), including pretreatments such as autolytic hydrolysis of cyanide, removal of hydrocyanic acid and processing as food.

Group 2 processes place emphasis upon the removal of HCN to serve cassava roots safely. As mentioned before, varieties consumed as food are those with low HCN content, and are therefore processed and cooked by Group 1 methods. There are also other methods somewhat different from the ones above. For instance, in Indonesia and other countries in Southeast Asia, cassava chips (Gaplak) are prepared by upland farmers in the following way: they are soaked in water for 3 days and nights (during which the water is changed from time to time) exposed to the sun and dried, then pounded in hand mills to the size of rice grains. After water is added to remove dust, they are washed by hand and dried again to be stored (Photo 17), boiled or steamed as rice.

Gari in Western Africa and Farinha da Mandioca in Brazil are made of cassava in the following way: cassava roots are peeled, grated and allowed to ferment spontaneously, dewatered by squeezing and partially gelatinised; then are dried and ground into flour. Fermentation in the above method reduces pH, enhances enzyne activity, and works on substrate to form HCN, which is removed by water. By reducing the hydrocyanic acid, cassava can be consumed as food. As for various other preparations, Yamada's report (1976) compiled from various sources is highly recommendable.

(2) Nutritional Enrichment of Cassava

Cassava is lacking in protein, fat and inorganic matter. Therefore, special attention has been paid to enriching its nutritive value as food. One of the methods is to add soybean protein (separated matter) or soybean grits to cassava flour, and in other cases, fungal protein is produced by culturing fungi (*Aspergillus* sp.) on the substrate of cassava (Gray et al. 1966, Stanton et al. 1969, Strassner et al. 1970). These methods aim at producting protein through the indirect utilization of cassava.

Needless to say, it is very important to increase the protein content of cassava itself. Reports have already been made of varieties with high protein content such as Colombia cultivar with 6.0 % of protein content and Panamanian cultivar with 6.5 % protein (Rogers. 1971).

Further, attempts are being made to consume cassava as a substitute for wheat by mixing cassava and wheat flour. Deny et al. (1970) have studied the effectiveness of the flour as bread.

(3) Cassava Starch, Flour and Tapioca

In many places in Southeast Asia, traditonal methods are still used to produce cassava starch. In Lampung, cassava roots are washed in running water after the exoderm is peeled, grounded by shredder and then screened by sifter (Photo 18). Water used for this purpose is very important; it must be pure and colourless. When sifted starch milk is settled after soaking for a day and a night (Photo 19), the supernatant liquid is removed. The process is repeated again to attain good quality starch. It is then exposed to the sun for about 2 days (Photo 20). The quality is deteriorated when it gets yellowish and smelly due to prolonged drying as a result of cloudy weather, etc. Cassava varieties from which starch is produced must have clear white flesh.

The extraction rate of starch differs according to varieties, harvest period, weather conditions during the period of growth, and efficiency of the machines used. In the traditional method, 17 - 20 kg of starch is extracted on average from 100 kg of wet peeled roots. It is not so effective as some 5 - 10 % of the starch remains un-extracted and is thrown away.

Cassava flour or meal is ground into powder by hammer mill, stone grinding mill, cylindrical mill or hand mill. Grocery tapioca is made from wet starch (which is taken out in the process of starch production). It is heated, made into starch cakes and then pounded into rough lumps. When used as food, the lumps are made into flakes, pearl or seed tapioca in the shape of grains.

Cassava starch is called tapioca (including related products) and is used in the production of confectionaries, sauces, gravy, soup, baby foods, desserts, biscuits, pies, cake fillings, salad dressings, and mustard powder, etc.

The authors recommend the work done by Yamada (1976) to study cassava starch and its usages in food and industrial spheres, as information by Holleman and his group (1959) and Grace (1971) is widely quoted in it.

(4) Manufacture of Cassava Pellets

Cassava pellets for feedstuff are made from dried cassava chips. In Lampung, chips brought to the factories are grouped according to variety, and No. 1 and No. 2 pellets are manufactured according to the above groupings. First of all, chips are ground and mixed, softened by steam and compressed into cylinders which are made in a fixed size. Chips thus compressed are cooled to form pellets. Photo 21 shows pellets produced in Lampung. They look dark, because they contain some sand and earth.

The colour of the roots, moisture content and how much their exoderm is peeled (which influences the sand and earth content) determines the quality of the product (pellet). Hydrocyanic acid is detoxicated in the process of grinding and steaming, resulting in virtually no problems for its use as feedstuff.

The advantages of producting pellets are as follows:

(1) Total volume is reduced by 25 % compared with chips, making transportation easier (in export), and guaranteeing longer storage.

(2) Loading and unloading can be mechanized.

(3) Uniformity of the product in quality, moisture content and shape is advantageous for producing feedstuff.

Lampung presently has more than five pelletizing factories, most of which have West German machines. The other factories have Thai machines, but pellets produced by them are not hard enough and produce many wastes.

The purchase price of chips fluctuates according to factory, season and quality (including sand, earth and moisture content 14 % as standard) etc.

Although Thailand has been enjoying a rapid increase in production and export of pellets in recent years, monopolizing exports to Europe, the product has posed some problems from the quality point of view. These have been dealt with by Mathot (1974) and Manurung (1974).

Some of the pellet factories in Thailand are owned by West German shippers, and others by Thais. Pellets produced in the former are known as "Brand" pellets in EEC countries, while those produced by Thai factories are known as "Native" pellets. Merits and demerits of

Brand and Native pellets described in material handed over to the author (Hirose) by Mr. Itoh of UNICOOP JAPAN (Bangkok, Branch), when the former visited the country, included the following:

Brand pellets:

1. Material is carefully selected and sand, earth and other foreign matters by and large are not mixed in with it.
2. Material is steamed before it is formed into pellets (not practiced these days).
3. Dies for making pellets are made of superior material and are therefore solid.
4. Powdered tapioca out of deformed pellets are returned to pelletizers to be re-produced. No meal in products.
5. Pellets are sufficiently cooled by a special cooling device after they come out of compressors.

After going through the abovementioned processes, the pellets are solidified, have little moisture content, and can withstand long storage.

Native pellets:

1. Compared with Brand pellets, material is carelessly selected and wastes, corn cob meal, rice bran, etc. are intentionally mixed into it.
2. Due to inferiority of the material, Thai-made dies are not solid enough and are unsuitable for making pellets. Dies wear easily.
3. No device is installed to return meal to re-form them into pellets again. The waste ratio is very high.
4. Poor cooling. The majority of factories never cool the products after they come out of compressors.

Pellets made by Thai factories are soft, crumble easily and grow moldy due to high moisture content. The meal ratio reaches up to 50 % in some factories. Solid dies are capable of producing 2,000 to 3,000 tons of pellets, but poor dies have a capacity of 1,500 tons or less (supposing they are able to work for 500 hours producing 3 tons per hour). Native pellets contain moisture, and, earth and fibrous matters, lowering starch content accordingly.

There is also the question of damage caused during transportation, particularly in ship hatches and at ports, causing much trouble at the port of destination.

Out of the 82 pelletizing factories in Thailand, 65 are in Cholburi Prefecture, 8 in Rayon Prefecture, and 1 to 3 factories are in Bangkok, Nakornsawan, Karnchanaburi, Phetouri, Suphanburi and Samutprakan. Table 33 shows a list of Brand pellet factories.

Table 33. List of Brand Pellet Factories in Thailand

Name	Location	Establishment	Pelletizer	Brand	No. of Pelletizer	Daily Production
Peter Cremer Ltd.	Bang Prakong	1967	Buhler	VITAP	3	200 M/T
"	Poon Phiphat, Bangkok	1970	"	"	4	250
Krohn & Co.	Bang Prakong	1968	Buhler	KROHWEN	4	250
"	United Flour Mill, Bangkok	1970	"	"	4	250
"	Chol Buri	1972/73	Local Made		8	300
Thai Bamrung Thai Ltd.	Bang Prakong	1968	Kahl	DARIO	7	350
Trakulkam Co.,	Bang Prakong	1971	California Pellet Machine	TKK	3	350
Tradex	Poon Phiphat, Bangkok	1973	Buhler	TRADAX	3	200
TOTAL					36	2,150 M/T

Source : UNICOOP JAPAN (Bangkok)

12. Circulation of the Products--Relation with Japan

As already described, cassava can used for many purposes, but the most promising one will probably be as feedstuff. Cassava chips and pellets are imported as feedstuff by Shingapore, Taiwan, South Korea, Malaysia, HongKong and Japan in Asia, and Holland, West Germany, Belgium, France and Spain, etc. in Europe. Major exporting countries are Brazil, Nigeria, Thailand and Indonesia.

The volume of imports by European countries increased from some 400,000 tons in 1962 to 1,400,000 tons in 1970 (See Table 34), and further

Table 34. Volume of Imported Dry Cassava Products in EEC
(1,000 ton)

	1962	1963	1964	1965	1966	1967	1968	1969	1970
W. Germany	366	387	462	520	702	?	481	548	491
Holland	1	5	17	76	96	?	237	444	502
Belgium	23	72	105	100	70	?	127	212	268
France	23	20	18	17	16	?	?	?	35
Italy	0	0	0	1	0	?	?	?	14
TOTAL	413	484	602	714	884		845	1,204	1,410

Source : International Trade Center GATT, Nestel (1973)

to 1,900,000 tons in 1973. One of the main reasons for the recent increase in imports by European countries is that EEC countries have raised grain and feedstuff prices to a considerable extent. Treatment somewhat similar to preferential treatment granted towards primary products of newly independent countries has been granted to Southeast Asian countries. This has opened up opportunities for increasing imports of pellets from these countries.

Thailand leads other countries in Southeast Asia in her export of cassava products to Europe, accounting for approximately two-thirds of total European imports (Harper 1973). Table 35 shows Thai exports in recent years by destination countries, according to which she exported 1,820,000 tons of pellets in 1974, and 2,030,000 tons in 1975, mostly to Holland.

Table 35. Export Volume of Cassava Product from Thailand (1973-75)

Unit : Metric ton

Destination Country		1973				1974				1975			
	Meal	Pellets	Chips	Waste	Meal	Pellets	Chips	Waste	Meal	Pellets	Chips	Waste	Meal
Australia	-	-	-	-	-	-	-	-	-	-	2	-	-
Belgium	-	12,561	-	-	-	13,419	-	-	-	2,032	-	-	-
Canada	-	59	-	-	-	-	-	-	-	20	-	-	-
France	-	109,243	-	-	-	90,938	-	-	-	54,167	-	-	-
Italy	-	-	-	-	-	-	-	-	-	30	-	-	-
Japan	-	4,178	3,405	995	-	36,272	2,966	-	-	41,526	110	-	-
Malaysia	-	259	-	64	-	2,251	-	276	-	-	296	80	-
Netherland	-	1,274,728	-	-	-	1,531,827	-	-	-	1,849,629	-	-	-
Penang	-	-	-	913	-	-	-	702	-	-	-	-	-
Portugal	-	-	-	-	-	-	-	-	-	2,021	-	-	-
Singapore	-	6,534	1,246	407	-	855	5,327	31	-	-	-	-	-
Spain	-	5,376	-	-	-	4,444	-	-	-	-	-	-	-
S. Korea	-	1,020	-	-	-	15,192	66,648	-	-	3,733	55,511	-	-
Saudi Arabia	-	-	-	-	-	227	204	-	-	-	-	-	-
Taiwan	-	-	16,630	200	-	20,464	27,189	-	-	9,605	4,180	-	-
W. Germany	-	93,220	-	-	-	102,135	2,371	-	-	72,580	4,493	-	-
Others	-	1,021	-	-	-	-	-	-	-	-	-	-	-
TOTAL	-	1,508,199	21,281	2,479	-	1,818,024	104,705	1,009	-	2,035,748	67,907	80	-

Source : Board of Trade of Thailand Office of Commodity Standard

Indonesia exports only about 300,000 tons, or 10 %, out of the total of 3 million tons she produces. Recently, however, Indonesia has shown greater interest in the export of cassava products, and has established a joint cooperative body with Thailand: The Thailand-Indonesia Joint Coordinating Board of Maize and Tapioca Products Marketing.

The Joint Coordinating Board discussed the following matters in 1974:

1. Standardization of quality
2. Improvement of business contracts
3. Questions concerning ship transportation

Japan imports only some 50,000 tons of cassava products as feedstuff, mostly from Thailand, and a very small quantity from Indonesia (Table 36).

Table 36. Import Volume (Metric ton) in Japan

Period	Thailand	Indonesia	Total
Jan. - Dec. 1974	25,015.425	961.768	25,977.193
Jan. - Dec. 1975	47,595.943	100.000	47,695.943
Jan. - July, 1976	8.047.188	-	8,047.188

Source : Custom Clearance Figures, Ministry of Finance, Japan

The unpopularity of cassava products in Japan is attributable to the following reasons:

1. Problems concerning competition within the starth industry: for instance, competition and/or difficult relations between potato

growers and producers using imported starch, etc.

2. Questions related to import, loading and unloading, transportation and storage, etc.

3. Questions of quarantine

4. Form of feedstuff

5. Quality, nutritive value, blending, HCN content, etc.

6. Volume and stability in supply

7. Risky problems that may arise from lack of experience

As the authors are not familiar with the problems of Point 1, they will not be discussed here.

Point 2: Port facilities at loading ports, loading capacity, and the form in which cassava products are exported (whether they are packed in bags, or stored in siloes, etc.) influence prices.

Point 3: The import of cassava chips will result in an invasion of diseases and harmful insects into Japan. Noxious insects have been found in European countries among imported cassava products. Studies should be made as to the types of insects (whether they are likely to spread throughout the country), the question of disinfection in producing regions, ships, and the unloading ports in Japan. If pellets are imported, they are heated in the process of production and probably disinfected. The question is whether the heat treatment in the production process is effective enough. Information is to hand that European countries, particularly West Germany, are switching their imports from chips to pellets, probably taking the disinfection question into consideration. Needless to say, the import of pellets would economize freight space also.

Another question is the type of freight. Cassava products are now shipped in bags, but packing would be eliminated and the cost reduced if siloes were built at loading ports. Present chips as well as pellets, however, are soft and easily crumble or powder. If the powder was to scatter in the air, it would bring about serious problems for the health of dock-workers engaged in loading and unloading.

In Japan, unloading from shipside to siloes has already been mechanized. Whether or not unloading of cassava chips or pellets in the traditional method poses troubles at mechanized Japanese ports is another question that needs study.

Point 3: Considering the fact that cassava is a "new face" to Japanese ports, careful planning is needed. Complete studies on noxious insects and diseases that might be introduced into Japan must be made before anything else. Studies must be made on disinfection, particularly in relation to the method and insecticide to be used, as well as types to be imported.

Point 4: Research is necessary to determine types or shapes of cassava as well as the demands or interests of farmers and dealers of feedstuff.

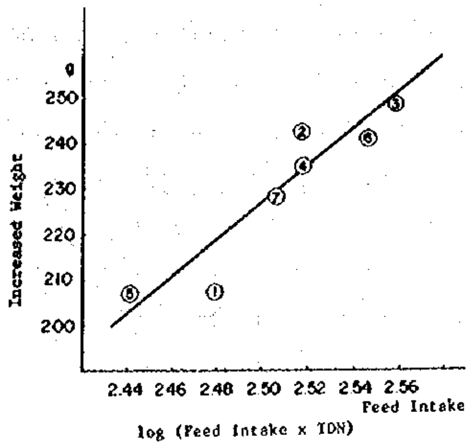
Point 5: The quality must be improved, including the uniformity of quality at the time of import. From a nutritive point of view, cassava is not an ideal feedstuff due to its lack of protein content. It may be improved in the future, but for the time being, consideration must be given to the question of adding high protein substances. In West Germany, cassava seems to be used mostly for pigs.

The next important question is that of the hydrocyanic acid contained in cassava. Japanese people are quite sensitive to toxicity of food or feedstuff. How poisonous is HCN? Why do we have to worry about the toxicity of cassava while it is consumed as feedstuff in Europe? These are simple questions, but they are questions that must be studied and answered.

Yoshida, M. (1970, JARQ, Vol. 5, No. 4, 44 - 47) wrote that cassava with 7.2 mg/kg HCN content proved poisonous to chickens and reduced their growth rate. This data should be interpreted as follows to clarify some of the points that are uncertain.

Growth of chickens (as in the case of other animals) is in proportion to the logarithm of the total volume of TDN supplied. If the days of growth are the same (Nojima--unpublished). Fig. 12 shows the volume of growth calculated from formulae according to the hypothesis mentioned above in correlation to the volume of growth after three weeks.

Fig. 12 Relations between Feed Intake and Increase in Fowl's Weight



Outline of Treatment

1. SO - 0 ; Soybean oil, 0 %
2. SO - 5 ; Soybean oil, 5 %
3. SO - 10 ; Soybean oil, 10 %
4. C - 10 (Hydrocyanic Acid 3.6 ppm) ; Cassava meal 10 %
5. C - 20 (" " 7.2 ppm) ; Cassava meal 20 %
6. C - 32 (Water soaked) ; Cassava meal 32 %
7. C - 32 (Autoclaved) ; Cassava meal 32 %

Note : Standard Carbohydrate is taken from yellow corn. Percentage shows the portion substituted by yellow corn.

Source : Yoshida, M. (1970)

The observed value should form a straight line according to the hypothesis. However this is not so in Fig. 12. Chickens in C-20 (HCN 7.2 mg/kg) show a lower level of growth. The reasons for their low growth rate are that (1) the intake of feedstuff was less for some reason; (2) the average TDN was lower than the other plots and (3) therefore, the volume of intake x TDN was less. From these figures alone, it is impossible to judge whether or not chickens in C-20 suffered from toxicity of hydrocyanic acid. Rather, attention should be given to the chickens in SO-0 Chickens in this plots took standardized feedstuff. It is quite strange that the volume of growth of these chickens is more or less similar to that of chickens in C-20 while the intake volume x TDN was more than that of C-20. The present authors take the view that this is due to experimental error and it should be marked correctly on the upper straight line.

This is but one example. Reference should be made to more examples, if these are available. The point in question is that we should not overreact to the presence of HCN alone. Efforts should be made to collect more data on hydrocyanic acid, such as the degree of toxicity, the limitation of toxicity and detoxication, etc.

Point 6: The question of feedstuff in Japan should be judged comprehensively in relation to various other feedstuffs. It is not appropriate to discuss cassava in this way alone. Further, the question under Point 6 is an important one which is beyond the scope of this booklet.

However, in case cassava is imported in Japan, it can be considered from the point of view of the period and stabilization of supply. Any estimation or prediction as to supply is difficult because supply volumes change with fluctuations in the world market situation.

Limiting the question to the supply of cassava from Southeast Asia, the only suppliers at present are Thailand and Indonesia. Thailand produces more rice than it actually needs, and is able to export large portion of its total cassava production. Indonesia produces in good quantity, but is unable to export so much because cassava ranks third among its staple foods, serving as an important calorific source together with rice and corn. Export of cassava from Indonesia would create some sort of concurrence with the domestic food situation. At the same time, however, Indonesia has set a clear distinction between cassava for food consumption (sweet type) and that for export (bitter type). Although it is not correct to say that there will be no concurrence whatsoever, there is certainly room for further consideration in this respect. (For instance, the Government of Indonesia banned the export of cassava in 1972 during drought conditions, but the cassava stocked as a result could not be consumed, and there was a heavy fall in domestic prices.)

Indonesia has vast areas which are suitable for cassava production, with huge production potential. Exports naturally require the presence of ports nearby. Favorable conditions are already preserved in this regard. If one-fourth of the 400,000 ha of barren land in Lampung, Indonesia, which is completely neglected today is reclaimed for cultivating cassava for export purposes, it would guarantee approximately 300,000 tons of cassava chips. The place in question has a port for the incoming and outgoing of 10,000 ton oceangoing vessels nearby.

Then, what about the possibility of stabilized supply? So far as Lampung is concerned, the cassava withstands drought conditions well and promises a stabilized supply even under unfavorable weather conditions. Another advantage is that it is free from serious diseases and insects that might cause serious damage to other crops. In Lampung, the harvest period extends from September to December, while in Thailand, they begin harvesting in November (the beginning of the dry season). If imports from Indonesia were combined with those from Thailand, long term supplies could be ensured to a considerable extent. The importation of several million tons of cassava might be possible (presently some 50,000 tons) from the two countries.

Import of cassava from the two countries would contribute towards solving the present unbalanced trade between Japan and these countries. What is more important is that it would give opportunities of work to cassava growers there.

At present, developing countries export their primary products to advanced countries. Some people take the view that export of semiprocessed products from developing countries should be further promoted in order to help them.

Today when various hindrances exist to check the normal development of rural industry, the export of cassava as a cash crop, if materialized, could help to meet the needs of farming people for the following reasons:

(1) At present, cassava is suitable for labor-intensive cultivation by

small-sized farmers, rather than cultivation on large farms,

(2) Cassava is good as a dry seasons crop and increases the work load such as harvesting, slicing, drying, etc. which leads further to an increase in income,

(3) At present, cassava chips vary in quality as they are produced by individual farmers. The prospect of the improvement of simple manufacturing methods is relatively certain, and the quality of chips can be improved in the future.

Needless to say, much improvement must be sought in relation to cargo booking, transportation, and marketing, etc. if production and export in large quantities are expected.

The questions confronted by those concerned with the production of cassava are (1) that a good harvest of corn and sorghum is expected worldwide for the 1976 crop year, and (2) the kind of reception that cassava chips and pellets would receive in such a situation when prices of these materials for feedstuff are lowered while that of cassava remains more or less the same.

13. International Institutes of Research

Studies on cassava are carried out at the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria and the Centro Internacional de Agricultura Tropical (CIAT) in Cali, Colombia, whose activities are financially supported by the Ford, Rockfeller and Kellog Foundations as well as the governments of advanced countries of the world. The Government of Canada is offering its financial support through the International Development Research Center (IDRC), which has been working on the summarization (with a key work index) of important theses related to cassava in close cooperation with CIAT. It has completed work on some 2,000 theses, and will continue its work on the remaining 1,500 theses.

Readers who need further information are advised to contact Dr. Fernando Monge of CIAT, who will be happy to answer requests immediately.

The following is a list of publications published by IDRC:

IDRC-017f Durabilité naturelle et préservation de cent bois tropicaux africains. Yves Fortin et Jean Poliquin. 143 p., 1974.

IDRC-018f Education sexuelle en Afrique tropicale, 124 p., 1973.

IDRC-019s Administración Universitaria: Aspectos Fundamentales sobre la Administración Académica Universitaria, Henrique Tono T., 25 p., 1973.

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IDRC-024e Triticale: proceedings of an international symposium, El Batan, Mexico, 1 - 3 October 1973, Reginald MacIntyre/Marilyn Campbell, ed., 250 p., 1974.

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IDRC-032e The first 200 projects, Claire Veinotte, ed., 38 p., 1974.

IDRC-032f Les premiers 200 projets, Claire Veinotte, ed., 39 p., 1974.

IDRC-034e Test control: the role of pathogens, parasites, and predators: report of a scientific advisory group convened at the Memorial University of Newfoundland, St. John's, Canada, 25 - 29 March 1974, 22 p., 1974.

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